The Socioecology, and the Effects of Human Activity on It, of the Annamese Silvered Langur (*Trachypithecus margarita*) in Northeastern Cambodia

Álvaro González Monge

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Statement of originality

The work presented in this thesis is, to the best of my knowledge and belief, original and my own work, except where acknowledged. This material has not been submitted either in whole or in part, for a degree at this or other university

Álvaro González Monge

In memoriam:

GANG HU

JOAQUIM JOSEP VEÀ BARÓ

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Abstract

The Annamese silvered langur (*Trachypithecus margarita*) is a colobine species recently recognized as a separate species and considered Endangered by the IUCN. It lives in Indochina, east of the Mekong River. There are some studies on its morphology, distribution and diet. Information on the species' ranging, social behavior and organization, habitat use and reproduction is scarce. The effects of human disturbance on langurs are unknown, a reason for concern given the current biodiversity crisis in the region. Information on the habitats where the species is found in the wild is scarce, with some sources conflicting. I aim to expand our current knowledge on the socioecology of *T. margarita* and the effects of human activities on it.

Research was done at Veun Sai Siem Pang Conservation Area, Ratanakiri Province, Cambodia, from April 2013 until May 2014. An unhabituated group was followed for five days every week. Group size was estimated and their geographical position was marked every 30 minutes until the end of the day or the group was lost. Canopy layer and forest type were noted every time an individual was seen. When eating, plant part and species were identified to species level. Eight botanical transects of 5x200 meters were set up, classified by forest type and anthropic disturbance. Plants with a DBH of 12 cm or over were identified to species level. Biodiversity and Evenness indices were calculated for the habitat and each transect and compared. Langur visits to a mineral lick were recorded using camera traps. Group size, sex and age classes were counted, and morphological characters analysed for individual variability. Chainsaw numbers, length of logging in hours and distance from logging spots to the group were calculated daily.

Mixed evergreen forest is more heterogeneous than mixed deciduous forest and presents more canopy layers and smaller stems. Logging tracks affect habitat structure but not diversity, while intensive logging strongly affects structure and diversity. Vertebrate populations at VSSPCA are resilient to small scale logging.

T. margarita at VSSPCA are morphologically uniform. Group size is at least 61 individuals and the social organization is multi-male multi-female. Langurs associate with other sympatric species of primates at the site, especially *M. leonina* and *P. nemaeus*. Langurs fed mainly on seeds, (69% of their diet), but also ate other fruit parts; leaf consumption was low. Focus on plant parts, food species and families varied between seasons. Dipterocarps were highly consumed, but *Willughbeia* and oak trees were highly selected.

Home range size reached 256 ha, being larger in the dry season than in the rainy season, likely because of different food availability. The high canopy was most frequently used, although juveniles used the mid canopy more frequently. Langurs preferred mixed deciduous forest during the rainy season but avoided it during the dry season, probably for a lack of canopy to hide and feed. Langurs were strongly affected by logging, moving higher in the canopy as intensity increased, and abandoned areas of their home range where it was most destructive. While *T. margarita* tolerates human disturbance, loggers target key tree groups and law enforcement must be maintained.

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CHAPTER 1

Introduction

1.1 Project background

While Cambodia is undergoing a high rate of deforestation, low human population densities, smaller access to remote areas and cultural differences with neighbouring countries (such as a much smaller cultural relevance of hunting and less dependency on traditional medicine from wildlife parts) have helped maintain high populations of megafaunal species that are already extinct, or nearly so, in the region. This state of affairs has recently begun to change due to easier access to remote areas and the increasing economic influence of neighbouring countries with a large demand for local wood and wildlife. There has been a trend towards the loss of local biodiversity, mainly driven by habitat loss, but also by poaching of wildlife destined for human consumption in Vietnam, Laos and even China. If steps are not urgently taken by the authorities and agencies to curb deforestation and habitat loss, what is one of the besieged last arks of biodiversity in the region could very quickly disappear, leading to a loss of biodiversity as well as income for local communities, creating an ecological and economic crisis in the country.

While there has been an increase in the amount of research on Asian colobines over the last 20 years, much crucial information is still lacking regarding many species within the group. Due to recent historical political instability and violence, this is particularly the case for primate research in Indochina, which has lagged behind until recent times. Even though primatology studies have been carried out in increasing numbers in the last decades in Vietnam (Agmen, 2014; Ha *et al.,* 2010; Hoang, 2007; Hoang *et al.,* 2009; Kenyon *et al.,* 2010; Le *et al.,* 2007; Nguyen *et al.,* 2012; Schneider *et al.,* 2010; Streicher, 2004, 2009; Tran, 2013; Tsuji *et al.,* 2013; Workman, 2010; Workman & Le, 2009, 2010; Workman & Schmitt, 2012), information on the ecology and behavior of primates (as well as most other living organisms) found in Laos and Cambodia remains scarce with only a handful of long-term studies beyond distribution assessments and censuses (Coudrat & Nekaris, 2013; Frechette, 2014; Rawson, 2009; Rawson & Luu, 2011; Rodgers & Nekaris, 2011; Starr, 2011), possibly because there are fewer funds, institutions and personnel available within the countries for such a task.

Some of these studies (Frechette, 2014; Hon, not published) have been carried out in Veun Sai Siem Pang Conservation Area (VSSPCA), an area gazetted for the preservation of Annamitic biodiversity, run by Conservation International and the Cambodian Forestry Administration. This area, together with other protected areas in the country like Virachey National Park and Siem Pang Protected Forest, is vital for the conservation of biodiversity and the livelihood of the local people.

The Annamese silvered langur has only been recognized as a separate species in the last decade (Groves, 2007; Osterholz *et al.,* 2008; Roos *et al.,* 2007, 2008), and although there is a study on its diet at Ta Kou Nature Reserve in Vietnam (Tran, 2013), other research on the species consists mostly of distribution assessments (Moody *et al.,* 2011; Rawson, 2010) and preliminary censuses (Hoang *et al.,* 2010). This species is considered Endangered but currently merged under *T. germaini* in the same taxon in the IUCN Red List (Nadler *et al.,* 2008), which means the actual population numbers will be smaller as there are two species involved. The actual conservation status of *T. margarita*, however, would be data deficient, as there is no information on its population numbers. As populations in Laos and Vietnam present reduced numbers and are under a great deal of pressure from human activities (Nadler *et al.,* 2007; Nadler & Brockman, 2014; Timmins *et al.,* 2013), it is highly likely that Cambodia is the global stronghold for the species (Moody *et al.,* 2011). Thus, populations found within the country should be included as a priority for conservation, along with other more studied and charismatic species found in the Annamitic region in particular and the Indo-Burma Biodiversity spot as a whole. Given that Annamese silvered langurs have historically been understudied, research on the species would not only improve our understanding of the species, but also shed more light on the ecology and behavior of the genus *Trachypithecus* and the ecosystems of the region.

1.2 Research aims

The objectives of this dissertation are to study the socio-ecology of the Annamese silvered langur (*Trachypithecus margarita*) in VSSPCA, northeastern Cambodia, to try to gather as much information on its behavior and ecology as possible, as well as observe any changes caused by logging activities carried out in the area. The particular research questions tackled in the different chapters are as follows:

1. What are the habitat preferences of *T. margarita*?

- What forest types and habitats are used by the Annamese silvered langur?
- What species of plants and vertebrates are associated with these forest formations?

2. What are the morphological characteristics of the *T. margarita* populations in VSSPCA? What can this tell us about the taxonomy of the species?
   - What color are the fur and body parts?
   - Do these characters show evidence of sexual dimorphism?
   - How do these features fit with previous descriptions of the species in the literature?
3. What are the demographic features of *T. margarita* groups at this site?
   - How many individuals comprise the study group?
   - What is the composition of this groups?
   - Do Annamese silvered langurs associate with other species? And if so, what are these species?
4. What is the diet of *T. margarita* in VSSPCA?
   - What species form the diet of the Annamese silvered langurs?
   - What parts of the plant are consumed?
   - Does the diet vary during the different seasons?
   - How does the diet of *T. margarita* at the site compare to the results obtained on other studies of the same species?
   - How does the diet of Annamese langurs compare to that of other *Trachypithecus* species?
   - On what type of plant growth form and at which heights do Annamese silvered langurs feed more frequently?
   - To what extent do Annamese silvered langurs engage in geophagy? How often do they visit mineral licks? For how long?
5. How large is the home range of *T. margarita*, and what factors can possibly influence the ranging behavior of the species?
   - What is the size of the study group's home range? How does it compare to those presented by other *Trachypithecus* species as well as other Asian colobine genera?
   - Which areas within the home range are most commonly used?
   - What kind of forest are Annamese silvered langurs more commonly found?

    - Does home range use vary seasonally?
    - In which levels of the canopy are langurs most commonly found?
    - What tree species are used as sleeping trees?
6. In what way, if at all, do logging activities in the study site affect the ecology and behavior of *T. margarita*?
    - What species of tree are the most sought after by loggers in the langur home range? In what quantities are they logged?
    - Are species of tree that are important to the langurs targeted?
    - What impact do logging activities have on the ranging and habitat use of the Annamese silvered langur? What response does the species have to these impacts?

1.3 Research significance

This is the first study of the species in Cambodia and one of the first long term on the species in general. Results will thus be very helpful for our understanding of the ecology of the species, the ecosystems of Northeastern Cambodia and the impacts of human activity on local wildlife. Data gathered on the habitat of the Annamese silvered langurs can help understand the different forest formations that occur in Indochina. Knowing how different forest formations differ in their species composition, tree quantities and biodiversity indices can help categorize local forests for conservation and economic purposes. These results, as well as an inventory of the local vertebrate biodiversity, will also help us to improve our knowledge of the biodiversity of the region and know its significance and value in relation to biodiversity and conservation in Cambodia, and help in the management plans on the current protected areas of Cambodia and even unprotected forest areas of importance to biodiversity conservation, as well as in the development of further plans for eco-tourism.

One way in which information gathered by this study will be helpful is to increase our knowledge of the characters that differentiate *T. germaini* from *T. margarita*. It is now generally considered that they are different species, but the debate on this has not yet been settled, mainly because of the massive lack of information on both species. Not many groups of either of these species are found in captivity (those that are in captivity are mainly in wildlife rescue centers), and studies in the wild have been scarce, with most information coming from censuses. Thus, detailed information that could support either side of the discussion is still lacking. The information on the behavior, diet, social structure, vocalizations and calls, as well as the morphological characters, will be able to better characterize the Annamese silvered langur and be used to compare with other populations of the species, as well as those of *T. germaini*, which will help establish further differences that can tell the species apart. This information will also be helpful to better understand the variability within the silvered langur species group, the genus *Trachypithecus* as a whole, and even the colobines and Old world monkeys. These data will also be helpful in order to manage langur groups in captive conditions, or to be released in the wild from captive individuals.

Data obtained on the effects of logging on the langurs will be of utmost importance for drafting conservation plans. If the effect of human activity impacts on the species can be known, sustainable uses of natural resources in non-protected areas where the species is still found can be managed so that both the monkeys and the local community will benefit, thus enriching the area. It will also help with drafting conservation plans of protected areas, as well as conservation plans for the species itself.

1.4 Research limitations

Several issues should be addressed on the subject of the number of days that the animals were followed. First of all, the study group had not been habituated prior to the commencement of the study; habituation of Southeast Asian colobines in general has been found to be hard, and it can take up to a year, and sometimes even more, to do so (R. Delgado, pers.comm.; Koenig & Borries, 2012). Furthermore, even if some species seem to tolerate human presence and can be found on a more or less regular basis as happened with my study group, their predator avoidance tactics by hiding and staying still in the forest canopy for long amounts of time hinders data collection, and, as in the case of this study, most behaviours in which the animals are visible are whenever they are moving around; this prevented organized behavioral data collection using focal scans, and behaviors were recorded *ad libitum*. The fact that the study species was found in areas where the ground was relatively flat prevented the researcher from finding a vantage point from which to improve the visibility of the group and also proved a further hindrance towards data collection. These issues were previously raised by Furuya during his study of *T. selangorensis* in Malaysia (1962), as well as in other studies on Asian colobines such as *R. bieti* (Cui *et al.,* 2006), *P. nigripes* (Rawson, 2009), *S. vetulus* (Rudran *et al.,* 2013), *S. johnii* (Umapathy & Kumar, 2003) *P. rubicunda* (Supriatna *et al.,* 1986), *P. comata* (Ruhiyat, 1983), *P. potenziani* (Fuentes, 1996), *T. leucocephalus* (Li & Rogers, 2005) and *T. obscurus* (Curtin, 1980).

As outings into the forest were always done in the company of one of the local guides or the local research assistants employed by Conservation International and the Cambodian Forestry Administration for security purposes, it was not possible always to go out whenever I might see fit. Sometimes, local research assistants needed to be out of the site for a day or more due to family related issues or for community gatherings, so it was impossible to go on to collect data. Other disruptions were the celebrations for Khmer New Year in 2014 and the Cambodian national elections of 2013.

A further issue to bear in mind was the impact of human activity on the home range. During the whole duration of the study, but most often during the early and mid rainy season of 2013, a considerable amount of illegal logging activity was carried out in the area, with a lot of logging hotspots right in the middle of the langur home range. While this issue will be tackled in further chapters, it is important to note that people engaging in illegal activities in the area hindered data collection in several ways, by scaring langurs so that the group abandoned areas while logging was carried out, or their presence in the vicinity could be masked by the loud noise resulting from such activities.

Also of importance to data collection was the rain regime. The late rainy season of 2013, namely late August, September and early October, involved a large discharge of water, which provoked a large rise of the water levels of the streams in the study area, all but isolating the ranger station from both outside access and the study site. It was impossible to access the study site during the whole of September and early October 2013 due to waterways spilling over their usual course. Further disruptions to data collection happened if during most of the early morning rain was heavy or it was coupled with strong winds. In days where this was the case, it was decided not to venture into the forest for security reasons, due to the dangers posed by falling trees.

Lastly, I was ill with dengue fever from mid-November until early December 2013, which coupled with recovering time made a dent in data collection for the last couple of months of 2013.

1.5 Thesis overview

The present thesis consists of nine chapters. The first chapter is an introduction to the thesis, outlining the general background information on primate research in Indochina and the reasons behind the undertaking of this project, the aims of the research involved and the limitations I encountered during the study. The second chapter extends the background information on the topics that are treated in the thesis: it gives an overview of the information known about the characteristics that define the subfamily Colobinae, particularly focusing on those taxa that form part of the Asian branch of the group, and the current taxonomic consensus on the different genera of Asian colobines. Further information on the genus *Trachypithecus* is outlined afterwards, looking at the different species groups that form part of it, and the diagnostic features of the genus as well as the ecology and behavior of the species within it. It also delves into current knowledge on the silvered langur species group within that particular genus, especially on the taxonomic status of the different species, their geographical distribution and general concepts on their ecology and behavior.

The third chapter details the characteristics and history of the study site, with special focus on the historical background in the area and the current state of conservation as well as the traditional activities of resource extraction done by human populations found in centers adjacent to the study site and their impacts on the local ecosystems. Afterwards, it is explained in detail what methodologies were used to gather the data recorded during the course of the project and what equipment and materials were employed: these include how the botanical transects were set up, how canopy use, feeding and geophagy behaviors were collected and how data were analyzed.

The fourth chapter deals with the composition of the ecosystem where the langurs are found: this includes forest types and structure as well as the plant species diversity in the areas that were regularly used by the langur group throughout the study, and what species and families are dominant among the plants in the area. Differences between different forest type patches are addressed, and a detailed inventory on the vertebrate fauna observed within the study group's home range is laid out, along with the implications the obtained data have for conservation.

Chapter five describes the phenotypic characters presented by *T. margarita* individuals at the study site and looks at how it compares with phenotypic observations noted by previous works. Also described is the demography of the study group, with the number of individuals observed to form part of it as well as the proportions in which the different age and sex classes appeared. Observations in which langurs were found to be in close association with other sympatric primate species are described and the possible reasons behind these associations posited.

The sixth chapter shows the diet composition of the study group: the different species and plant parts that were consumed by langurs, and the different proportions in which they figured throughout the whole study as well as in the different seasons; the selectivity for particular species or plant parts and the possible reasons behind them are also treated briefly. A comparison between the obtained data and the information on other conspecific groups and other langur species is done to look at the feeding strategy and preferences of *T. margarita* at the site. Data on mineral consumption is presented afterwards, looking at how often and for how long did langurs visit mineral licks at the study site, as well as the differences between the seasons and the possible causes for these.

Chapter seven presents the dimensions of the study group's home range both cumulatively for the whole length of the study and for each of the different seasons during the year. The way langurs use the different canopy layers of their habitat is shown, and the way they select a particular kind of habitat and the differences in this selectivity between seasons are also indicated. Lastly, the characteristics of the trees that were used by the study group as sleeping sites are presented, and the possible driving factors between this selection are discussed.

The eighth chapter looks into the intensity of the illegal logging activities that were carried out during the project, the particular plant species that were sought after, and the quantities in which these were targeted, as well as the changes on these during the course of the study. The effects that these activities had on the way the langurs moved about their home range and the ways in which they reacted to them were explained. The implications for the conservation of the species in Cambodia and its geographical range and the objectives and perspectives for the future were outlined.

The ninth and last chapter summarized the results obtained during the course of the project, the findings and the conclusions that were reached after the analysis of such data, and their significance in the light of the knowledge on the species as well as the current conservation challenges posed in the region. Suggestions for further avenues of research are also outlined and justified.

CHAPTER 2

Background information

2.1 Overview of the subfamily Colobinae

The Annamese silvered langur is a member of the primate family Cercopithecidae, the Old World Monkeys. The cercopithecids are one of the largest and most diverse families in the whole primate order: The family is divided into two subfamilies: Cercopithecinae and Colobinae, the latter being the one that includes langurs. The subfamilies are differentiated by certain morphological characters. Colobines have a broad interorbital region (although this is not the case in neither *Nasalis* nor *Simias* (Groves, pers. comm.)), deeper jaws with narrow incisors, molar and premolar teeth with high and sharp cusps and large salivary glands; as well as the most defining morphological trait for the group, a specialized sacculated, three- or four-part stomach. All these are adaptations for their specialized diet (Delson, 1975; Fleagle, 1998; Zinner *et al.,* 2013). Other characters that are not defining for the group but are commonly present are long tails, short or absent thumbs, and alloparenting behaviors, where female group members will look after and engage with babies even though they may not be related to them (Fleagle, 1998; Zinner et al., 2013). Males of most studied species, bar some exceptions in African red colobus species (Sterck, 2012), disperse outside of their natal groups; in the case of females, while there is also variability, their dispersal has been recorded in several species as well; there are differences between species in regards to the reproductive state of dispersing females and the way in which they depart their natal groups (Sterck, 2012). Female dispersing behavior is not shared by other cercopithecid species (Yeager & Kool, 2000).

Table 2.1 *Summary of the particular morphological and behavioral characters that are characteristic of the subfamily Colobinae and differentiate them from other Cercopithecines*

Defining characters	**Not defining but prevalent**
Specialized sacculated stomach	Long tails
Deep jaws with narrow incisors	Short or absent thumbs
Higher and sharper teeth cusps	Alloparenting
Larger salivary glands	Bisexual dispersion out of natal groups
	Broad interorbital region

Langurs are a part of the Asian branch of the colobines, the group with the highest diversity and number of species within the Old World monkeys (above 50 species, to 26 of guenons and 23 of macaques) (Fleagle, 1998; Zinner *et al.,* 2013). Asian colobines are found from Pakistan eastwards to the Indonesian islands of Lombok and Borneo, and are found in a huge diversity of habitats: alpine and temperate forest, karst formations, evergreen and deciduous forest, savannah and semidesert formations, coastal mangrove forest, even some species have adapted to living in urban environments. This habitat diversity has led to different adaptations, with some species even having semi-terrestrial habits, a feature not seen in African colobines (Zinner *et al.,* 2013) (Figure 2.1).

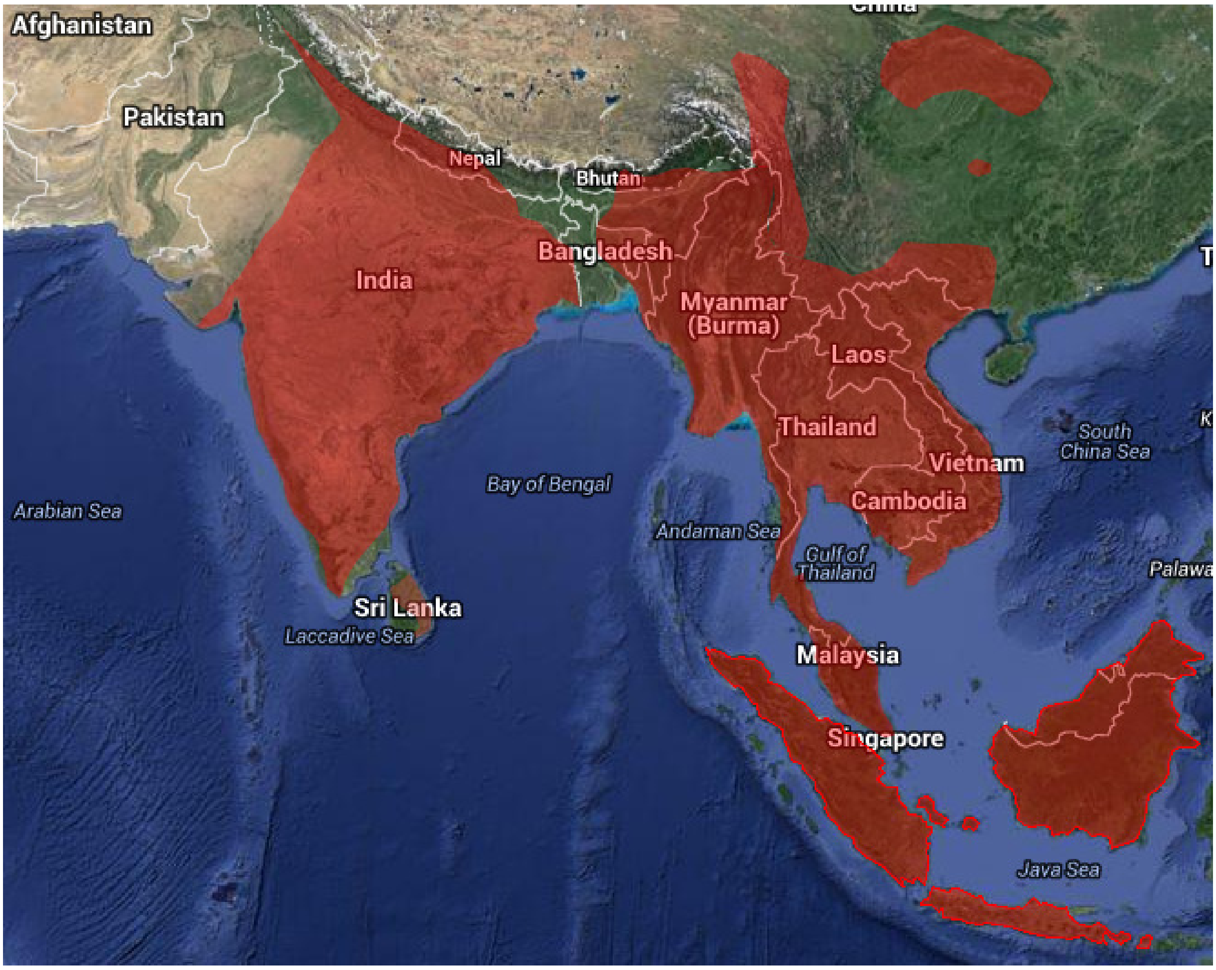

Fig. 2.1 *Approximate historical distribution of the Asian colobines*

The phylogeny and taxonomy of colobines, and especially the Asian branch of species, has been a historically contested issue, with the debate still ongoing to this day (Brandon-Jones, 2004; Brandon-Jones *et al.,* 2004 Karanth, 2010; Karanth *et al.,* 2008; Osterholz *et al.,* 2008; Sterner *et al.,* 2006; Zhang & Ryder, 1998). While in the past some lines of study did not consider the group monophyletic, nowadays it is agreed that they indeed form one tribe: Presbytini (Sterner *et al.,* 2006; Zinner *et al.,* 2013). The tribe consists of six or seven genera divided into two different lineages: the monophyletic odd-nosed monkeys, consisting of three or four genera (*Nasalis*, *Pygathrix*, *Rhinopithecus* and *Simias*, (this last probably a synonym of *Nasalis*: Roos *et al.,* 2014), and the langurs, consisting of three genera (*Presbytis*, *Semnopithecus* and *Trachypithecus*) (Roos *et al.,* 2014; Zinner *et al.,* 2013). This last genus is the one to which the study species belongs. In the past most langur species were pooled together under the genus *Presbytis* (Baldwin *et al.,* 1975; Chivers, 1985; Delson, 1975; Fleagle, 1977, 1998; Nisbett & Ciochon, 1993; Zinner *et al.,* 2013); other researchers, however, considered that *Trachypithecus* should be included within *Semnopithecus* (Brandon-Jones, 2004); However, after genetic, ecological, behavioural and morphological analyses, the consensus is that there is good evidence that the group should be split into three genera (Nowak, 1999; Roos *et al.,* 2013, 2014; Zinner *et al.,* 2013). The phylogenetic relationships between these three genera remains a topic under discussion: while some studies pointed to *Presbytis* and *Trachypithecus* being sister taxa, leaving the place of *Semnopithecus* in the phylogeny unclear (Sterner *et al.,* 2006), other studies placed *Semnopithecus* and *Trachypithecus* as sister genera (Osterholz *et al.,* 2008), though there was evidently a complex history of hybridization between them in the early stages of their separation (Roos *et al.,* 2011).

Table 2.2 *Summary of the Asian colobine groups with their genera, number of species and geographic distribution*

Group	Genus	species number	Distribution
Odd nosed colobines	*Rhinopithecus*	5	China, N Vietnam, E Burma
	Nasalis	1	Borneo
	Simias	1	Mentawai Archipelago
	Pygathrix	3	Indochina (east of the Mekong)
Langurs	*Semnopithecus*	9	South Asia
	Presbytis	11	Sundaland
	Trachypithecus	20	northeastern South Asia, Sundaland, Indochina

2.2 Overview of the genus Trachypithecus

Trachypithecus contains the largest number of species of all Asian colobine genera, about 20. These 20 species are divided into four main groups, according to morphological, geographic, ecological and genetic similarities:

1. The karst langur (*T. francoisi*) group (or "limestone langurs"), with 7 species: François' langur (*T. francoisi*), Delacour's langur (*T. delacouri*), white-headed langur (*T. leucocephalus*), golden-headed langur (*T. poliocephalus*), Hatinh langur (*T. hatinhensis*), Laos langur (*T. laotum*) and the controversial black langur (*T. ebenus*);
2. The dusky langur (*T. obscurus*) group, with 4 species: dusky langur (*T. obscurus*), Phayre's langur (*T. phayrei*), Tenasserim langur (*T. barbei*) and

Indochinese grey langur (*T. crepusculus*), which some studies suggest should form a different species group by itself (Liedigk *et al.,* 2009);

3. The pileated langur (*T. pileatus*) group, with 3 species: capped langur (*T. pileatus*), golden langur (*T. geei*) and Shortridge's langur (*T. shortridgei*), although some studies do not consider this group to form part of the genus *Trachypithecus* (Karanth, 2010); and
4. The silvered langur (*T. cristatus*) group, which includes seven species: Sunda silvered langur (*T. cristatus*), Selangor silvered langur (*T. selangorensis*), East Javan langur (*T. auratus*), West Javan langur (*T. mauritius*), Indochinese silvered langur (*T. germaini*) and our study species, the Annamese silvered langur (*T. margarita*) (Roos *et al.,* 2014; Wangchuk et al., 2008; Zinner *et al.,* 2013).

Other species of langur that are found in South Asia used to be included in this genus as well, but are nowadays included within the genus *Semnopithecus*: the Nilgiri langur (*S. johnii*) and the purple-faced langur (*S. vetulus*) (Brandon-Jones *et al.,* 2004; Karanth, 2010; Karanth *et al.,* 2008; Osterholz *et al.,* 2008).

Trachypithecus is probably the genus with the largest geographical distribution of all Asian colobines. It extends east and southeast from Bangladesh, Bhutan and the eastern Indian states in the Himalayas, into southern China, and south throughout the Southeast Asian mainland to eastern Borneo and Lombok (Figure 2.2), making it the only colobine group found east of Wallace's line, although there are doubts on whether the species found in that particular island (*T. auratus*) was introduced in Lombok or the island is an actual part of the species' natural range, as suggested by Harrison *et al.* (2006) by referencing other authors. Species within the genus share several traits: the bright orange fur color of the newborn babies, heavier body weights and slightly more marked sexual dimorphism than *Presbytis* but less than *Semnopithecus* (Harding, 2010; Raemaekers & Chivers, 1980; Zinner *et al.,* 2006), with females presenting whitish patches in the groin (in most species) that can be used to identify individuals (Agmen, 2014; Furuya, 1962; Nadler, 2010; Tsuji *et al.,* 2013), a character absent in males; the brow ridges are also more prominent than in other langur genera (Ankel-Simons, 2007; Nowak, 1999). Their habitats are mainly arboreal, with a preference for quadrupedal walking and running in order to move through the canopy, and less reliance on leaping than the genus *Presbytis*, as they have relatively shorter hindlimbs (Ankel-Simons, 2007; Fleagle, 1977; Harding, 2010). Thumbs are generally shorter than in *Presbytis* as well (Furuya, 1962; Nowak, 1999).

Fig.2.2 *Approximate historical distribution of the genus Trachypithecus*

Information on the ecology and demography (group size, sex ratios, breeding seasonality) of the species that form the genus *Trachypithecus* has been scarce up until very recently. Most information on group size and composition, ranging and even dietary composition of species within the genus has been derived from generalizations from data in studies on the better known species (Nowak, 1999). It has been observed that, as a general rule, *Trachypithecus* species have a higher degree of folivory, particularly mature leaves, and a lesser amount of fruit in their diet than *Presbytis* species, as referenced by Yeager & Kool (2000), something that earned the genus its moniker of "leaf monkeys".

It has generally been thought that most langurs were found in small groups with between 6 and 30 individuals living in small home ranges, in which there tends to be only one adult male within the group (Chivers, 1985; Nowak, 1999; Rowe, 1996; Zinner et al., 2013), and with breeding occurring throughout the year but experiencing peaks at certain times (Jin *et al.,* 2009a). Some species (e.g. *T. crepusculus*) are territorial (Gibson & Koenig, 2012), while others alternate between displays of territoriality and tolerance of other groups in close proximity (Bernstein, 1968), so there is not enough available information to confirm whether this is a common behavior within the genus. It is also stated that generally, in undisturbed areas, home ranges of colobines usually overlap and groups of most species will be tolerant to adjacent groups (Yeager & Kool, 2000). While infanticide commonly happens in groups of *Semnopithecus* (Borries, 1997; Hrdy, 1974) and is also present in *Presbytis* (Steenbeek *et al.,* 1999), it has been observed in only a few species of *Trachypithecus*, particularly some populations of white-headed langurs (*T. leucocephalus*) (Wolf & Fleagle, 1977; Yin *et al.,* 2013; Zhao *et al.,* 2011), and it is unknown to what extent this behavior happens within the genus.

2.3 The silvered langur group

2.3.1 Morphology

Silvered langurs are generally of a gray to black colour, with the hairs having grey or white tips, thus giving the animals a silvery hue (Furuya, 1962; Rowe, 1996), although different species will have distinctly lighter or darker coats and limbs. Exceptionally, there is a population of *T. auratus* that has an orange coat (Nijman & Supriatna, 2008; Zinner *et al.,* 2013), and individuals of *T. cristatus* sporting a red coat have been observed in the Malaysian state of Sabah in Borneo (Harding, 2011). The different species have different facial hair and crests. Males are larger than females.

2.3.2 Habitats and geographic distribution

All species are preferentially found in lowland areas and habitats close to water (Bernstein, 1968; Campbell *et al.,* 2006; Coudrat *et al.,* 2011; Furuya, 1962; Harding, 2010; MacKinnon, 1985; Matsuda *et al.,* 2011; Moody *et al.,* 2011; Nadler *et al.,* 2007; Rowe, 1996; Royan, 2010; Ruggeri & Timmins, 1996; Starr *et al.,* 2010; Timmins *et al.,* 2013), although both the East and West Javan species can be found in mountainous areas (Nijman, 2000, 2014; Nijman & Supriatna, 2008; Zinner *et al.,* 2013), as well as some exceptional groups of the other species (Hoang *et al.,* 2010; Nadler *et al.,* 2007; Tran, 2013). The geographic distribution of the silvered langur group is one of the largest within the genus. Silvered langurs are found as far west as Myanmar and as far southeast as the Indonesian island of Lombok (Harrison et al., 2006; Rowe, 1996): *T. germaini* is found in the mainland, west of the Mekong River (southern Myanmar and Thailand, western Cambodia, southern Vietnam) (Nadler, 2007; Roos *et al.,* 2007, 2008, 2013, 2014; Zinner *et al.,* 2013); *T. margarita* is found east of the Mekong (eastern Cambodia, south-central Vietnam, southern Laos) (Nadler, 2007; Roos *et al.,* 2007, 2008, 2013, 2014; Timmins *et al.,* 2013; Zinner *et al.,* 2013); *T. selangorensis* is found in Peninsular Malaysia, along the west coast (Zinner *et al.,* 2013); *T. cristatus* is found in Sumatra and Borneo (Zinner *et al.,* 2013); *T. auratus*, the largest species (Zinner *et al.,* 2013), is found in central and eastern Java, Bali and Lombok (Harrison *et al.,* 2006; Nijman, 2000; Nijman & Supriatna, 2008; Roos *et al.,* 2008; Zinner *et al.,* 2013); *T. mauritius* is restricted to a portion of western Java (Nijman & Supriatna, 2008; Roos *et al.,* 2008; Zinner *et al.,* 2013).

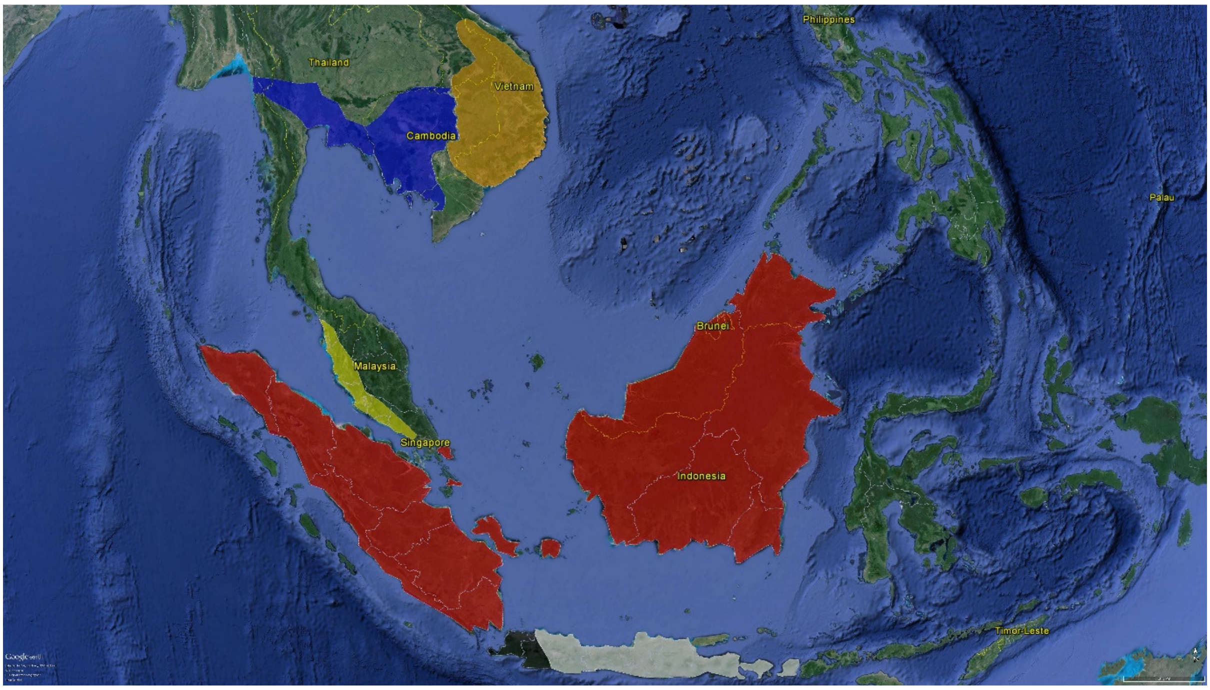

***Fig.2.2** Approximate historical distribution of the species that form the Silvered Langur group: T. auratus (white); T. mauritius (black); T. cristatus (red); T. selangorensis (yellow); T. germaini (dark blue); T. margarita (orange). Areas where there are no species are in green color*

The seven species that form the silvered langur group used to be pooled together as a single species *Trachypithecus cristatus*, while in other studies *Trachypithecus villosus* was used as the binomial species name instead of *T. cristatus* (Ankel-Simons, 2007; Brandon-Jones *et al.,* 2004). Although for a time many studies considered *T.*

auratus as the only other separate species in the group (Fooden, 1996; Nowak, 1999; Rowe, 1996; Weitzel & Groves, 1985), other studies expressed doubts that *T. auratus* would be a species at all (Denise *et al.,* 2008, Ingicco *et al.,* 2011). Morphological and genetic data eventually led to the group being split into several species (Roos *et al.,* 2008). Three lineages are identified: mainland Southeast Asian lineage (north of the Isthmus of Kra), Javan lineage, and Borneo, Sumatra and Malaya lineage (Zinner *et al.,* 2013). While the silvered langur group is considered a monophyletic group (Denise *et al.,* 2008; Osterholz *et al.,* 2008; Roos *et al.,* 2007), phylogenetic relationships between the lineages are still unclear (Harding, 2010; Roos *et al.,* 2007, 2008). Some studies suggest that *T. selangorensis* is descended from *T. auratus* that expanded their range into the Malayan Peninsula when sea levels were lower (Harrison *et al.,* 2006; Rosenblum *et al.,* 1997; Roos *et al.,* 2008). Until very recently, the two mainland Southeast Asian species of silvered langur (*T. germaini* and *T. margarita*) were lumped together either into *T. germaini*, a practice still held by IUCN criteria (Nadler *et al.,* 2008), or lumped together with all other silvered langur species under the name *T. villosus* (Ankel-Simons, 2007; Brandon-Jones *et al.*, 2004). Lately, however, genetic analyses have shown differences between them and thus both Indochinese species have generally been accepted (Groves, 2007; Hoang *et al.,* 2012; Osterholz *et al.,* 2008; Rawson, 2010; Roos *et al.,* 2007, 2008, 2013, 2014), although this still remains a topic of discussion (Moody *et al.,* 2011).

It has been considered that the Mekong River is the geographical barrier that led to an allopatric speciation of *T. germaini* and *T. margarita* (Roos *et al.,* 2007). Given that both species still use riparian environments as preferred habitats, it is still unclear whether the Mekong is indeed the driving force behind this differentiation (Moody *et al.,* 2011); it has also been observed that some other primate and mammal species are found on both sides of it, so in those cases it would not act as an efficient barrier that would prevent the dispersion of these species either (Blair *et al.,* 2011; Fooden, 1996; Meijaard & Groves, 2006). It has been observed, however, that there is more species diversity, particularly among primates, on the eastern side of the river. This can be attributed to several changes in the course of the Mekong due to climatic and seismic changes in recent geological ages (Blair *et al.,* 2011; Groves, 2007; Meijaard & Groves, 2006). Another possibility is that there were allopatric speciation processes that affected populations of the same ancestor species which were isolated from each other in different Pleisthocene refugia (Hassel-Finnegan *et al.,* 2013).

Although there have been some studies of silvered langur species in captive conditions (Amarasinghe *et al.,* 2009; Eakins, 2010; Nijboer *et al.,* 2006, 2007; Shelmidine *et al.,* 2007, 2009, 2013; Witte, 2011), the number of studies on them in the wild is very scarce, particularly on any species other than *T. auratus* and *T. selangorensis* (Nijman & Meijaard, 2008; Shelmidine *et al.,* 2009; Zinner *et al.,* 2013), so a lot of information on their ecology and behavior has been inferred from related species either in the group or in the genus as a whole.

2.3.3 Diet

As with all colobines, silvered langurs have a mainly folivorous diet, but flowers, fruit, seeds, shoots and invertebrates can also figure in the diet (Medway, 1970; Rowe, 1996; Zinner *et al.,* 2013). Not a lot is known about the diet of many silvered langur species, and the best information on diet comes from studies on *T. auratus* (Kool, 1992, 1993). There is some very general information on *T. selangorensis* (Bernstein, 1968), which was observed to feed mainly on leaves, particularly buds and young leaves; seeds and flowers were also important, but no numbers were given in the study, and fruit was also eaten. A study mentioned by Harding (2010) stated that *T. selangorensis* had a mostly folivorous diet, up to 91% of it being leaves, the rest being mainly fruit. A recent study was carried out on the composition of the diet of a population of Annamese silvered langur (*T. margarita*), at the Ta Kou Nature Reserve, in Vietnam (Tran, 2013). In that particular case, leaves were found to be the most consumed plant part with proportions over half the total, although the percentages of fruit and flowers were not insignificant, both being consumed in higher quantities than mature leaves.

2.3.4 Ranging and habitat use

Generally found to be much smaller than those for other Asian colobine genera, home range sizes for species of *Trachypithecus* vary widely. The largest recorded home range in the genus was that of *T. crepusculus*, with 446 ha (Fan *et al.,* 2015. Many other species have been found to have home range sizes between 30 and 50 ha, like *T. leucocephalus*, *T. francoisi* and *T. obscurus* (Curtin, 1980; Li & Rogers, 2005; Zhou *et al.,* 2011a, 2011b). The only known home range size of any species of silvered langur is that of *T. selangorensis*, where Furuya (1962) estimated it as 20 ha, a home range size that falls below the average for the genus.

Canopy use of silvered langurs has not been addressed in studies about their habitat use. It is known that other langur species, such as *Presbytis potenziani* (Fuentes, 1996) and *Trachypithecus obscurus* (Curtin, 1980) are known to use mostly the upper medium and high layers of the canopy. *T. crepusculus* were observed to be present at heights as high as 50 meters and as low as 5 meters (Koenig & Borries, 2012).

2.3.5 Reproduction

Studies of *T. selangorensis* in the wild show that breeding occurs all year round (Medway, 1970), as it does in captivity (Shelmidine *et al.,* 2009). Medway did warn that this yearlong breeding might be because of the lack of seasonality in Kuala Selangor; thus, silvered langur species that are found in areas with a more marked seasonality, such as the study species, could actually undergo seasonal breeding peaks; however, *T. crepusculus* is also found in habitats with a marked seasonality and still breeds throughout the year with peaks in some months (Lu *et al.,* 2010). Females do not appear to show any external signs of oestrus, and although sometimes females do have swollen genitals, it seems they are not only not related to oestrus, but they also do not attract males (Shelmidine *et al.,* 2007). Females do use soliciting behavior towards adult males when in oestrus in order to mate (Bernstein, 1968).

Trachypithecus gestation periods range from 184 days on average for *T. francoisi*, as in a study referenced by Borries *et al.* (2011) to 205 days on average (Lu *et al.,* 2010): The gestation period of *T. selangorensis* lasts for 195 days on average (Shelmidine *et al.,* 2009), but it might be different in the study species; also, species of *Trachypithecus* in seasonal habitats have longer gestation periods (Lu *et al.,* 2010). Females inside the genus found in the wild tend to have their firstborn at about five years of age (Borries *et al.,* 2011), although in captive populations of *T. selangorensis* it has been observed to be as young as three years and a half (Shelmidine *et al.,* 2009). Interbirth intervals for *T. selangorensis* are an average of 15 and a half (Shelmidine *et al.,* 2009), but wild females of other *Trachypithecus* species have been observed to present periods over 20 months on average (Borries *et al.,* 2011).

While infants get the dark adult skin color early on, the orange fur coat will change only after up to 5 months (Bernstein, 1968; Borries et al., 2008), although a study on *T. crepusculus* shows that infants in larger groups take more than a further month to change to adult coat color than their counterparts in smaller groups (Borries et al., 2008).

Weaning ends when infants are 18 months old as mentioned by Harding (2010), citing earlier studies.

2.3.6 Social organization

Most *Trachypithecus* species have maximum group sizes between 15 and 20 individuals: *T. obscurus* (Md. Zain & Ch'ng, 2011), *T. delacouri* (Wojciechowski & Nguyen, 2013, Workman, 2010), *T. francoisi* (Hu, 2011; Zhou *et al.,* 2007, 2011a), *T. geei* (Chetry *et al.,* 2010). Some species can however have maximum group sizes below 15, such as *T. pileatus* or *T. poliocephalus* (Kumar & Solanki, 2008; Schneider *et al.,* 2010), while others can be more than 80, like *T. crepusculus* (Fan *et al.,* 2015). The number of males in a group varies not only between different species (Yeager & Kool, 2000), but also between different groups of the same species (Koenig & Borries, 2012). Silvered langur species, while differing in their group size, generally have group sizes larger than the average for the genus. The lowest maximum group size of all the silvered langur species is that of *T. germaini*, with 19 individuals (Le *et al.,* 2010). Maximum known group size for *T. auratus* is 28 individuals (Leca *et al.,* 2013). *T. margarita* groups can be as large as 35 individuals in Vietnam (Hoang *et al.,* 2010), but the largest silvered langur group recorded belongs to *T. selangorensis*, with 51 individuals (Bernstein, 1968). Group composition is also variable: *T. auratus* was observed to have only groups with one male in them; *T. selangorensis* could have groups with a single adult male as well as groups where there were several adult males, while *T. margarita* groups were always seen with more than one adult male (Hoang *et al.,* 2010). To my knowledge, information on the number of males in *T. germaini* groups is nonexistent.

2.3.7 Social behavior

While a clear hierarchy has been observed in some species of *Trachypithecus* (*T. crepusculus* (Koenig *et al.,* 2004b; Lu *et al.,* 2016)), information regarding group structure and relations in most species of the genus is absent. Adult males of *T. selangorensis* engage in social behaviours with infants and juveniles, although it seems they are always initiated by the latter (Bernstein, 1968; Harding, 2010). Affiliative behaviours have been observed between all members of a group (Bernstein, 1968; Furuya, 1962). A certain but not very strong social hierarchy in wild groups of *T. selangorensis* was observed by Furuya (1962), in which there was displacement of subordinate individuals. There are also studies that show a hierarchy between the female members of a group of the same species found in captivity (Amarasinghe *et al.,* 2009), although these results do not prove to what extent female hierarchies exist in the wild: confounding factors brought by captive conditions could also be at play and more research needs to be done in this regard. Bernstein (1968) observed *T. selangorensis* to be territorial, but studies mentioned by Harding (2010), as well as one by van Schaik *et al.* (1992) did not have definite answers as to the question of territoriality: it is mentioned that there was conflict sometimes, while at other times different groups tolerated each other. There are observations in *T. selangorensis* of a violent albeit non-lethal takeover of a one-male unit by an adult male that ousted the previous adult male as well as the subadult males within the group, as well as indirect evidence of infanticidal behavior on the new male's part (Wolf & Fleagle, 1977). Yeager & Kool (2000), however, noted that this particular case happened in a group living in a highly disturbed environment, within an area with a high population density, factors which could also have had an impact. In any case, agonistic behavior seems to be low in the species, and whenever it happens, it rarely involves very high levels of aggression (e.g. biting) (Bernstein, 1968).

2.3.8 Conservation

Although all the species in this group have an extended geographical distribution and are protected by law in their countries of distribution, population trends in all of them are diminishing, with the loss of habitat being the main threat, closely followed by hunting, whether it is for bushmeat, medicinal purposes or for the pet trade (Harding, 2010; Lippold & Thanh, 1998; Malone *et al.,* 2003; Nadler *et al.,* 2008; Nijman & Meijaard, 2008; Nijman & Supriatna, 2008; Rawson, 2010; Workman, 2004; Yeager & Kool, 2000; Zinner *et al.,* 2013). Although in some areas *T. germaini* and *T. margarita* are of religious importance to local populations and thus spared from local poachers (Hoang, 2003; Timmins *et al.,* 2013), hunters from outside the community or loss of habitat due to economic development can still be an important threat to the survival of these populations.

The particular case of the conservation of *T. margarita* has been difficult to assess. At this moment, its conservation status is listed as endangered by the IUCN Red List (Nadler *et al.,* 2008), but as it is not considered a species on its own and is included under *T. germaini* it is likely that the actual numbers of both species will be much smaller than assessed by the Red List. No proper censuses of Annamese silvered langurs have been carried out in the region, so it is unclear how many animals are out there; population densities of *T. margarita* are considered to be very low in Vietnam, being present at only a handful of locations, and the species is now considered rare (Nadler *et al.,* 2007; Nadler & Brockman, 2014). Hunting pressure has taken a big toll on populations in Laos as well (Timmins *et al.,* 2013). Given the low population densities in Vietnam and the pressure on populations in Laos, the size of protected areas in Cambodia, coupled with a much lesser hunting pressure, probably means that eastern Cambodia is a key area for the conservation of the species, and efforts should be made to carry out a census on populations within the country, as well as develop conservation plans to keep populations healthy.

CHAPTER 3

Study Site and Methods

3.1 Study site

The study site where the research was carried out is Veun Sai Siem Pang Conservation Area, sited on the Northeast of the country. The Area has a size of 55,000 hectares and spans through two provinces, namely Stung Treng and Ratanakiri, and it's under the management of the Cambodian Forestry Administration, helped by Conservation International and the Japan International Cooperation Agency. The area has historically been very sparsely populated, with the main ethnicities being Lao, Chinese and Kavet.

Veun Sai Siem Pang Conservation Area (VSSPCA) borders both with Western Siem Pang Protected Forest (150,000 ha) and Virachey National Park (320,000 ha), which also border on the Xe Pian National Protected Area in Laos (240,000 ha), making it one of the biggest tracts of wild habitat left in Indochina (765,000 ha). It holds a mosaic of semi-evergreen, mixed deciduous and dry deciduous forest and grasslands in the southern flatlands, while evergreen forest appears in the northern hills (Hon *et al.,* 2010; Iseborn *et al.,* 2012; Neang *et al.,* 2011).

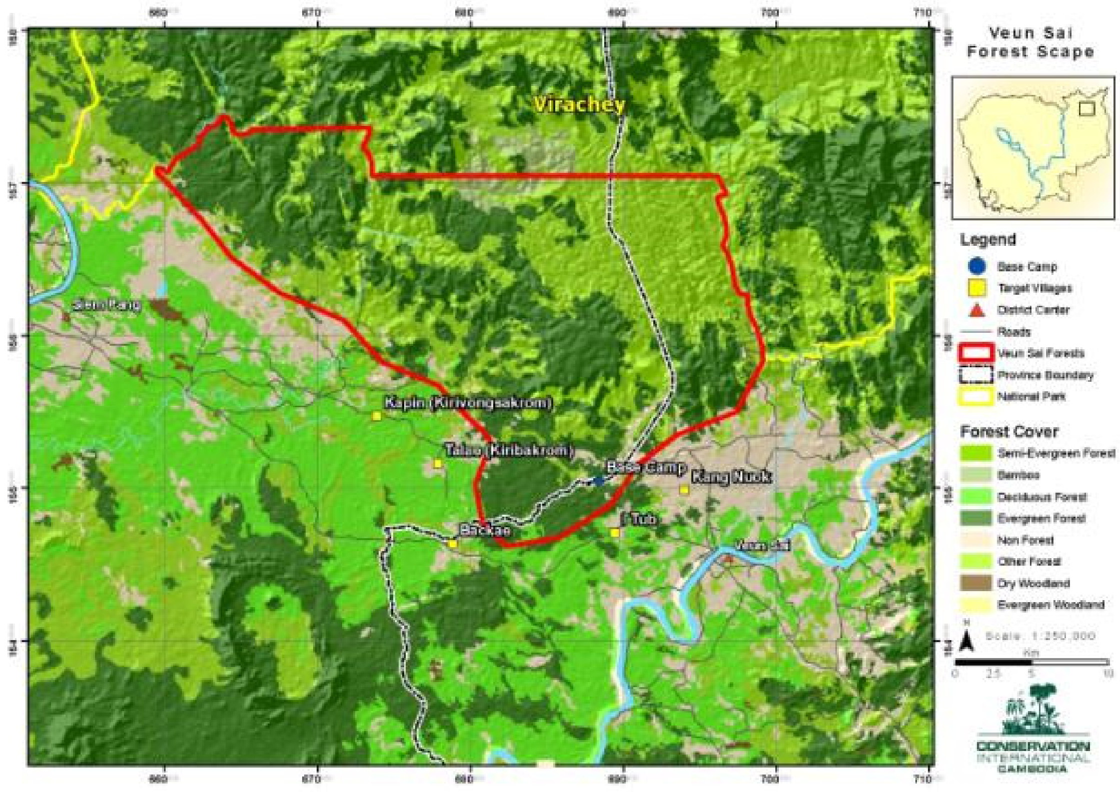

Fig. 3.1 *Map of Veun Sai Siem Pang Conservation Area. Obtained from the archives of Conservation International, Greater Mekong Program, with their permission.*

Not many biodiversity studies have been carried out in VSSPCA. Historical obstacles for studies in the region are related to the country's unstable past, for example, the area was used by the North Vietnam Army and Viet Cong as part of the Ho Chi Minh Trail to send supplies to the south of Vietnam for the war against the United States. As such, the area was bombed by the latter country's air force, with bomb craters still present in the study site. Not much later, the area became a hotbed of the Khmer Rouge insurgence, who were active until the time of the Vietnamese invasion in 1978 (Baird & Dearden, 2003). Furthermore, it is known that Vietnamese nationals were executed by Khmer Rouge troops in the study site.

3.1.1 Human activities in VSSPCA and their impacts on the local wildlife

People living in villages around the fringe of VSSPCA use the forest in order to get a variety of resources. They pick up branches and logs for firewood, cut down certain species of tree in order to get materials to build their houses, collect edible fruits and berries from forest plants and cut palms of the genus *Calamus* in order to eat the hearts.

One very important economic activity in which local inhabitants engage in the Area is to obtain resin from *Dipterocarpus alatus*. In order to do so, locals cut an opening in the tree at around 1.20 m height, then proceed to burn material in the carved hole to stimulate resin flow, that will be collected and then used or sold. This resin is seemingly used for many different purposes, such as burning oil, medicine, boat waterproofing and furniture and floor lacquering (Baird & Dearden, 2003). These trees are owned by different families and there are trails in the forest that lead to some of them.

The impact of human activities in VSSPCA was very low up until around 15 years ago. Previously, it is reported that the area hosted species that have been all but exterminated by hunting, including the Asian Elephant (*Elephas maximus*), Indochinese Tiger (*Panthera tigris*), Burmese Hare *(Lepus peguensis*) or Sunda Pangolin (*Manis javanica*). Other animals, while still present, have seen their numbers seriously depleted, like the Long-Tailed Macaque (*Macaca fascicularis*), which has lost most of its population due to the capture of live individuals in order to be sold and taken to Vietnam to be used in the medical research industry. Some animal extractive activities that are commonly engaged in VSSPCA are the collection of honey, harvesting of East Asian Bullfrogs (*Hoplobatrachus rugulosus*) and fishing, but the main one is still hunting (Khem & Chou, 2013).

Although hunting is illegal inside the Area, locals still engage in it more or less openly. Main target species, all hunted in different ways, are the Red Junglefowl (*Gallus gallus*), Wild Boar (*Sus scrofa*), Indian Muntjak (*Muntiacus vaginalis*), Water Monitor (*Varanus salvator*) and Clouded Monitor (*Varanus nebulosus*). While the Monitors are hunted with the help of dogs, traps are deployed to target Junglefowl and Boar. People are not above killing bigger quarry, and crossbows and makeshift pellet rifles are also made in order to kill boar, muntjak and even gaur or banteng; the use of these artefacts is prohibited and, whenever people are caught using them, they are confiscated. During the length of this study, over a long period of time law enforcement could not be carried out, and gunshots were commonplace. Given the fact that gun ownership is controlled by the state, this means that people involved in shooting forays either were army or police personnel living close to the area, or somehow managed to obtain a firearm from such individuals (Khem & Chou, 2013). While boar and muntjak are the main quarry, monkeys could be slain opportunistically, and at least one individual from the study group was killed for food by a group of illegal loggers targeting Burma Padauk (*Pterocarpus macrocarpus*), locally known as Thnong.

Fig.3.2 *Trap for birds and small mammals found in VSSPCA*

Fig.3.3 *Trap for ground birds such as red junglefowl found in VSSPCA*

Further illegal activities in relation to fishing also occur somewhat commonly: While women fish the traditional way by use of nets, young men of Lao ethnicity will use a car battery to electrocute fishes (Baird & Dearden, 2003), killing most living things affected and eventually wiping out the whole community; this method of fishing is banned in the country and there have been many campaigns and even signs against it have been erected, but it is still carried out. In regards to the use of plant resources, the last decade has sadly seen an increase in illegal logging activities in the area.

A further issue is the starting of fires. During the dry season, villagers in many parts of the country take to burning not only grass formations, but also stands of dry deciduous and mixed deciduous forest. Fires started in this manner do not spread too far and there is not a great deal of habitat destroyed, but this activity is done regularly in many areas of open habitat in VSSPCA, especially those close to population centres. The reasons for this activity are obscure, and different people have given differing reasons for it, but the fact remains that the burning of open areas in some sectors of VSSPCA that have no economic value to locals keeps being a common practice.

Fig.3.4 *Dry deciduous forest patch affected by an intentional fire*

3.2 Data Collection

3.2.1 Weather measurements

Maximum and minimum monthly temperatures were recorded at the study site, from the 25th of July 2013 until the 17th of May 2014. Every day at 19:30 hours the temperature from a Sper Scientific thermometer set up at base camp was taken. Precipitation was measured in inches using a Rain Gauge from Alternative Solutions inc. at the same time daily.

3.2.2 Forest types

As it was stated in the introduction, there has not been a consensus on definitions used to describe forest formations in Southeast Asia, and categories that have been proposed tend to be too vague or restrictive to accommodate certain forest formations found in VSSPCA. Thus, the approach taken follows that of Rawson (2009) and Rundel (1999), where different forest types were defined according to the observed composition and structure of the forests studied. There are further comparisons with other previous works below so that the approach taken in this work is justified with further background. This resulted in the main forest types in this area being classified as:

1. Savanna Woodland: The dominant species in this habitat are grasses and annual plants. Wooden stems are sparse and isolated from each other, not forming a canopy. The dominant family of trees is Dipterocarpaceae (in VSSPCA, mainly *Shorea* species), forming a not very tall top canopy layer. Saplings and shrubs form an intermediate canopy tier. Langurs are seldom found in this habitat, but they are occasionally seen here moving between forest fragments.

2. Mixed Evergreen Forest (depending on the source also called mixed deciduous forest (Sterling *et al.,* 2006; Phuong, 2007), evergreen forest (Averyanov *et al.,* 2003; Eang, 2015; Hiramatsu *et al.,* 2007)), while other studies refer to it as dry evergreen forest (Bunyavejchewin, 1999; Rawson, 2009; Tani *et al.,* 2007)): In this forest type, most species keep the leaf cover all year round despite a significant dry season of five months, but there are still many deciduous species present in the habitat. There is a large amount of shrubs and small trees forming an intermediate canopy tier, and wooden stems are found much closer together than in grassland and mixed deciduous forest; the canopy is closed and consists of several tiers. Dipterocarpaceae, *Cinnamomum*, *Baccaurea* are

important taxa. The understorey is very dense, presenting high numbers of vines and *Calamus* palms.

3. Mixed Deciduous Forest (completely different in structure from the mixed deciduous concept mentioned above, and called mixed evergreen forest by some authors (Eang, 2015; Goes, 2013; Hayes *et al.,* 2013)): Arguably the hardest to define. Some works mention dry deciduous forest formations in Indochina and Burma, but then it is stated that the dominant species are Dipterocarps (Sterling *et al.,* 2006), which would actually be dry deciduous dipterocarp forest. These forest formations indeed appear in Siem Pang Province, but further East in Ratanakiri and Mondulkiri, there are forest formations not dominated by Dipterocarps where most species are deciduous, losing their leaves for several months during the dry season, but where also other trees and shrubs are perennial. These formations are dominated by *Lagerstroemia* and Fabaceae species, with the understorey very open and almost no ground cover, although there are numerous small trees, shrubs and small bushes and the occasional vine. There are far more species present than in dry deciduous dipterocarp formations, and the space between wooden stems is larger than that in mixed evergreen forest, but a close canopy is still formed, which clearly separates it from dry deciduous woodlands; it also reaches higher than that of mixed evergreen forest. They are also closely associated with bodies of water. Sometimes these forests are considered as products of human disturbance and in the particular case of VSSPCA, while there has been selective logging and there were bomb raids during the Vietnam War, none of this activities were carried out with such an intensity that would cause such a change in forest structure. Furthermore, mixed deciduous and mixed evergreen are tightly interspersed in mosaic. These forests have been lumped with deciduous dipterocarp forest in some works (Averyanov *et al.,* 2003; Blasco *et al.,* 1996), but in other, they've been classified as mixed deciduous forests (Baker *et al.,* 2005; Marod *et al.,* 1999; Rabinowitz & Walker, 1991; Rawson, 2009; Rundel, 1999; Williams, 1965). In this case, given that it has been found to be the most adequate, the latter one will also be the definition used for this forest formation.

3.2.3 Botanical transects

Eight transects measuring 5x200 m (1000 m^2) were established inside the known langur home range. The transects were chosen so that they were representative of all habitat types and degrees of human disturbance within the langur home range. Three transects were in unlogged mixed evergreen forest (2,3,7), three on mixed deciduous forest (5, 6, 8) one along a logging road in mixed evergreen forest (1) and one in a highly logged tract of mixed evergreen forest that eventually ends with a gallery forest (4) (Figure 3.5).

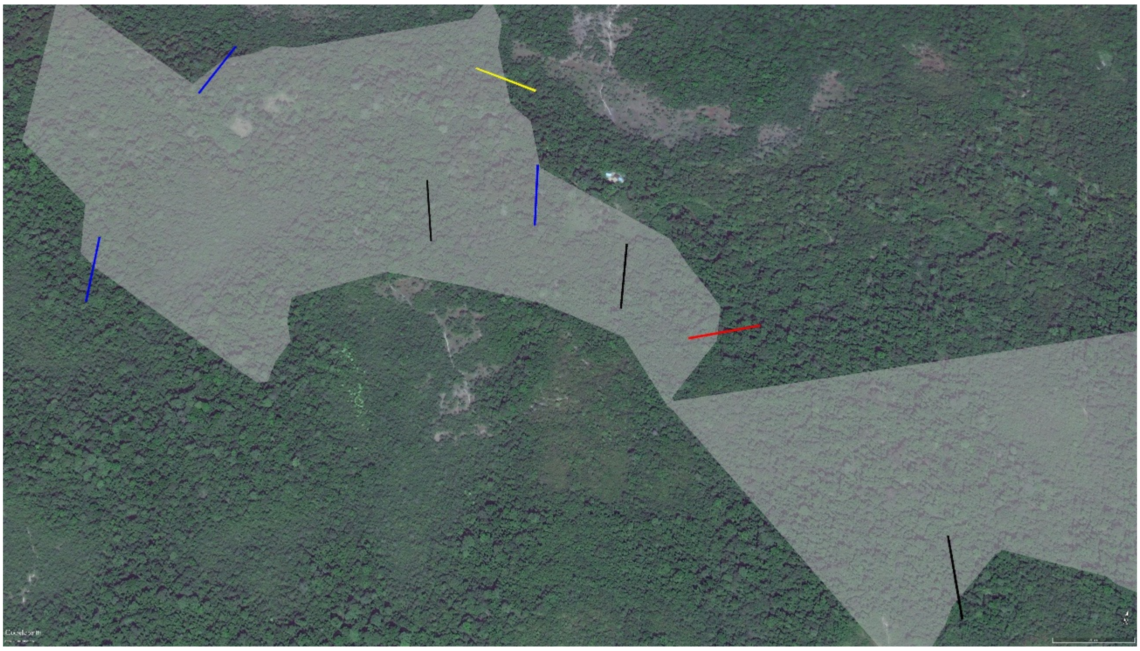

Fig.3.5 *Map of the different botanical transects imposed on the langur home range. The transect on a logging track (1) is red, the heavily logged transect (4) is yellow, unlogged mixed evergreen forest transects (2,3,7) are black, mixed deciduous forest transects (5,6,8) are blue*

From February 2013 to May 2013, tree composition in each transect was determined. GPS reference points were noted for the starting point, and at every 100 m along the trail, measured with a Sterling measuring tape. The transect was flagged every 10 m with biodegradable paper tags. The Diameter at Breast Height (DBH) of every stem inside the transect was measured with the aid of a Richter 5m Diameter Tape, and those equal or bigger than 12 cm were considered for further analysis: this was due to the lower dimensions deemed to pertain to plant species too small to be considered as relevant to langur ecology and to a difficulty in ascertaining the identification of the stem. If a plant presented several stems surging from the same point on the ground, DBH for each stem was measured and then added for total plant DBH. With the assistance of a local guide and guide books an effort was made to identify each stem to the species level. Scientific names were obtained from Khmer names given by the guides by using the Dictionary authored by Dy Phon (2000). When names were given in Lao, the work authored by Inthakoun and Delang (2008) was used. Height for each stem was measured in meters with the help of a Haglöf Clinometer. Lastly, coverage for each stem was measured in the percentage of canopy each particular stem occupied when looking up from its base by using the naked eye.

Cut stems that were obviously a result of logging (it was truncated evenly, as from the result of the use of a chainsaw, and rests of the tree were found processed adjacently), were identified and included as long as it had a DBH higher than 30 (trees that would be sought after for luxury woods). These felled trees, however, were not taken into account for analysis of trees used by the monkeys.

3.2.4 Biodiversity Indexes

In order to estimate the biodiversity values of the different parts of the home range, the Shannon-Wiener Diversity Index (*H*) (Peet, 1974) and Equitability Index (*E*) (DeJong, 1975) were calculated for each transect separately and as a whole. An Importance Value Index (IVi) was then calculated both for each species and each family. The following equations were used for each index:

- Shannon-Wiener Index (H) = $-\sum_{i=1}^{S} pi \ln pi$

- Shannon's Equitability Index (E) = $\frac{H}{\ln S}$

Where S is the number of species present and pi is the proportion of each species relative to the total number of stems. E values oscillate between 0 (most even species composition, lowest diversity) and 1 (least even species composition, highest diversity).

- Importance Value Index (IVi) = Rd+Rf+RD

Where Rd is relative density, the number of individuals of each species per ha as a percentage of the total densities for all species; Rf or relative frequency, the occurrence of each species in the transects as a percentage of the total frequencies for all species; RD is relative dominance, calculated by the basal area in m^2 for each species or family as a percentage. In order to obtain these, we followed the methodology outlined in Cottam and Curtis (1956):

- $\mathrm{Rd} = \frac{di}{dS} \times 100$

- $\mathrm{Rf} = \frac{fi}{fS} \times 100$

- $\mathrm{RD} = \frac{BAi}{BAS} \times 100$, where $\mathrm{BA}i = (\mathrm{DBH}i)^2$ (cm) x 0.00007854

When using the biodiversity indexes, only the stems identified as far as genus were factored.

3.2.5 Terrestrial vertebrate inventory

Every day, either while looking for the langurs in the forest or while gathering data, any terrestrial vertebrate species that was seen, heard or signs of their activity observed (tracks and scats) was noted along with the type of forest in which I was and the numbers in which they were found. Animals were identified to the species, and no effort in census was undertaken, given that, as we usually followed certain tracks in the langur home range to try and locate them, some species which resided adjacent to these would be registered far more constantly than other species, and their abundance might thus be overestimated.

3.2.6 Finding and following the study group

The study group was an unhabituated group of silvered langurs that was found in the study area. Low encounter rates and a lack of connection of the home range with further forest areas on all sides but the western area point to langurs observed in this range always being the same group. The study group was tracked in the area 5 days a week, starting from 5:30 am. Whenever the group was encountered, and from the encounter time onwards until the end of the day or the animals had not been lost, the group position was recorded every 30 minutes as a GPS point in UTM coordinates using a Garmin 62s GPS unit. In order to considered the group lost, we waited for an hour and 30 minutes to pass without any signs of presence whatsoever from the group. This is because the group went very quiet after being aware of the presence of humans in the vicinity or during the middle of the day.

3.2.7 Group size and composition

Group counts were attempted every time the group was found on the move, usually during early morning or evening periods, when the group moved out or into sleeping tree areas. The distance from the observer to the subjects varied, but it ranged from 20 to 100 meters. If individuals were close or the path they used was devoid of any foliage, no material was used to observe the langurs and they were just observed with the naked eye. If distance reached 40 meters or longer, binoculars were used to observe the subjects. Any individual that was observed was categorized in base to its age (adult, subadult, juvenile, infant) and sex class (male, female). The age and sex class categories were not developmental milestones as used in other works as the non-habituation prevented close observation, and are divided as follows:

- Adult male: Largest size of all categories. Pink, pendulous genitals could be observed; generally observant and defensive behaviors.

***Fig.3.6** Adult male. Some of the phenotypical features characteristic of the species can be seen in the image, like the lack of a crest of erect hair or the presence of rings of light skin around the eyes*

- Adult female: Smaller size than the previous category, but clearly larger than any other category, with the same proportion of limb length to body constitution than males. White patch of skin and fur in the groin, the best diagnosing character. Pendulous nipples could be observed if the individuals faced the researcher. Genitals not obvious. Very often with some smaller sized category attached or in tow. Behavior was seen to be more skittish and cautious.

Fig.3.7 *Adult female carrying an infant. The orange fur of the latter can be seen in the image*

- Subadult: Medium sized individuals, clearly smaller than the previous categories, very slender constitution with longer limbs in proportion to the body than any other category. The distance from the observer, their speed, and small size made it impossible for the researcher to be able to distinguish their sex.

Fig.3.8 *Subadult female. The white patch in the groin that characterizes females is clearly visible in the image*

- Juvenile: Small sized individual, presenting the grey coloration that is characteristic of the species. Limbs and tail were short. The distance from the observer, their speed, small size and erratical behavior made it impossible for the researcher to be able to distinguish their sex.

Fig.3.9 *Three juvenile individuals*

- Infant: Small sized individual, presenting a characteristic orange coloration, almost every time they were observed were in physical contact with an adult animal.

Pictures of silvered langurs during full day follows were taken with a Canon EOS650D camera during the length of the study, always when an animal could be well observed and foliage interference was small, either during movement or when the animal was resting or observant, and preferably whenever their face could be visible. Key phenotypic characters for the species were looked for, such as the shape of the head hair, body and limb fur color or facial markings and color. Given the fact that Annamese silvered langurs, as it happens with most colobines, were shy in the presence of human observers and tried to avoid making their presence known, the distance from the observers to the study subjects most of the time was further than 30 meters away, preventing a proper identification of the different individuals conforming the study group and a high degree of detail in all the animal parts in each of the images obtained , but the resulting images were more than enough for the aims of the study. Due to a lack of proper identification, it is also quite likely that some members of the group will appear more than once in the recorded images.

If the group was found in contact with any other wildlife, the date, GPS position, general group behavior and any interaction or lack of it of the langurs with the other species was registered.

3.2.8 Morphological characters

Every recorded image of silvered langur obtained from full day follows was studied and, whenever each phenotypic character attributed to the species in the literature was visible in any of the photographs, they were noted by their presence or absence. In the former case, the prevalence of the character within the study group was calculated by obtaining the percentage of individual instances in which animals presented each phenotypic character. These characters were tabulated as the following categories:

- Hand color: Black or lighter colors, like grey and its different tones.
- Feet color: Black or lighter colors, like grey and its different tones.

- Absence of crest: While *T. germaini* presents a conspicuous conical crest of hair on top of the head, *T. margarita* has been described to lack this, having a markedly flatter top of the head than the former species.
- Presence of hood: Long hairs joining at the occipital region of the head are a phenotypic character of *T. margarita*. This and the high, stiff forehead hairs give the animals the appearance of sporting a hood.
- Whiskers: Long white hairs on the sides of the head have been reported for both Indochinese silvered langur species.
- Presence of eye rings: One key phenotypic character of *T. margarita* is the presence of uniform clear patches of skin of light pink color around the eyes. Studies have differed on how prevalent this character is in populations of the species.
- Coat color: The color the animal presents in the dorsum and flanks of the body trunk. Three main categories were established, and a particular fourth one was also present. The three main categories were different tones of grey: light grey (close to white), medium grey (grey color with an intermediate intensity between the other two main categories), dark grey (close to black). The fourth category was the neonatal orange coloration, absent once an animal is a few months old.
- Leg color: The color the animal presents in the leg, from the thigh to the beginning of the ankle. Three main categories were established, and a particular fourth one was also present. The three main categories were different tones of grey: light grey (close to white), medium grey (grey color with an intermediate intensity between the other two main categories), dark grey (close to black). The fourth category was the neonatal orange coloration, absent once an animal is a few months old.
- Arm color: The color the animal presents in the forearm, from above the elbow to up until the beginning of the wrist. Three main categories were established, and a particular fourth one was also present. The three main categories were different tones of grey: light grey (close to white), medium grey (grey color with an intermediate intensity between the other two main categories), dark grey (close to black). The fourth category was the neonatal orange coloration, absent once an animal is a few months old.

- Tail color: The color the animal presents in the leg, from the thigh to the beginning of the ankle. Three main categories were established, and a particular fourth one was also present. The three main categories were different tones of grey: light grey (close to white), medium grey (grey color with an intermediate intensity between the other two main categories), dark grey (close to black). The fourth category was the neonatal orange coloration, absent once an animal is a few months old.
- Underparts: The color the animal presents in the belly and abdomen. Four main categories were established. These were: white, light grey (close to white), medium grey (grey color with an intermediate intensity between the other two categories of grey), dark grey (close to black).

3.2.9 Canopy and forest type use

Animals were sometimes directly observed with the naked eye, but for small details such as food items, binoculars or a 70-135mm lens on an EOS 650D Canon camera were used. Every time an animal was observed, its age (adult, juvenile, infant) and sex class was noted, as well as the canopy level in which it was found. Canopy levels were established as follows: low (0 to 10m), medium (10 to 20m), high (21m and over). The type of forest in which the animal was found was also noted (mixed evergreen forest, mixed deciduous forest, dry deciduous forest).

3.2.10 Feeding

When individuals were directly observed eating some items, the plant species on which they were feeding was identified as closely as possible to species level with the help of local guides who knew plant names in Khmer or Lao language, then translated with the help of documents referencing local vernacular names (Dy Phon, 2003; Inthakoun & Delang, 2008); the particular plant part that langurs were eating was identified in addition. In the case that the food plant could not be identified in the field, a sample of the fruit, leaves or flowers or a photograph was taken to the field station in order to ask other guides that worked there and could be able to properly identify the local vernacular name of the species. Also, when plant parts were dropped from trees in which animals were known to be, and they showed clear signs of being fed on (pieces abruptly cut, bite marks, particular plant parts missing from dropped items), the plant from which the parts had fallen was also taken into consideration as a feeding tree.

Plant parts were categorized as following:

- Fruit: Animals ate both the seeds and pulp of the fruit, or it was not possible to ascertain whether they were focusing on a particular part of the fruit.
- Seed: Langurs selectively ate only the seeds found inside of fleshy fruits, the winged dry fruit or samaras of dipterocarps, legume seed pods, or the interior of the acorns presented by the Fagaceae.
- Leaf: While in a few cases it was possible to tell if a langur was feeding on young leaves, most of the time it was not possible to distinguish between leaf ages, and it was decided that age categories had to be merged.
- Flower: Subjects would be observed plucking flowers out of the plant and eating them.
- Other: This category included epiphytic ferns that foraging langurs browsed through.

3.2.11 Food trees

Growth type of any food tree was determined by observation of the structure:

- Tree: Plant structure with a height above 5 meters, with one single woody stem that projects from the ground upwards and presents branches mostly at its terminal end.
- Shrub: Plant structure with a height of 5 meters or less, with several woody stems that project in a parallel manner from the ground upwards, presenting branches at almost any part of its height.
- Vine: Plant structure that consists of a thin stem, which can be woody or green, which extends itself towards a larger parallel surface, in this particular case almost always a tree, and attaches itself to its branches, several meters above the forest floor. Its surface can be smooth or thorny, and it does not necessarily go straight up, but some species present growth in a winding direction before they eventually head upwards.

The geographical position of a food tree was marked in UTM coordinates by the use of a Garmin 62s GPS unit, and its height measured in meters with the help of a Haglöf Clinometer. The Diameter at Breast Height (DBH) of all food plants was measured in centimeters by using a Richter 5m Diameter Tape. Approximate crown area was measured by assuming the crown would present a somewhat elliptical shape, then measuring the two axes of said ellipse by using a 100 m Sterling measuring tape and standing right below the fringe of the crown at the end of each axis. Food trees were labeled by nailing aluminum tags to the plant. In a few cases, along tracks or heavily trodden areas the tags were removed by locals who had spotted them as many are hostile to conservation efforts in the area.

3.2.12 Sleeping trees

If the researchers were able to follow and stay with the group until the end of the day and langurs were observed settling on the branches of a particular tree without any signs that the group intended to further move, the particular tree where langurs were observed was recorded as a sleeping tree. The geographical position of such a sleeping tree was marked in UTM coordinates by the use of a Garmin 62s GPS unit and its height measured in meters using a Haglöf Clinometer. The Diameter at Breast Height (DBH) of sleeping trees was measured in centimeters using a Richter 5m Diameter Tape. An approximate crown area was measured by assuming the crown would present a somewhat elliptical shape, then measuring the two axes of said ellipse by using a 100 m Sterling measuring tape and standing right below the fringe of the crown at the end of each axis. Sleeping trees were labeled by nailing aluminum tags to the plant, but along tracks or heavily trodden areas, some of the tags were removed by locals who had spotted them, as many local inhabitants are hostile to conservation efforts in the area.

3.2.13 Mineral lick visits data collection

Several mineral licks were monitored by use of Bushnell Trophy camera traps set up in order to register the wildlife visiting the licks from April 2013 until May 2014. Two such licks a fair distance outside the study group's home range were frequented by Annamese silvered langurs, whose visits were registered from June and July 2013 respectively until November 2013 by images, and from then on to May 2014 by videos. For each visit, the approximate number of animals in the group was calculated, and the number of individuals in each age and sex class was registered, and phenotypical characters that could be observed were also recorded. Cameras recorded the date and time every time a picture or video was taken.

Several camera traps were affected by the humidity brought on by the rains and had to be substituted by new cameras. Two camera traps were stolen by locals. One camera was set up at the beginning of the dry season in mid-November 2013 to record any images at an exposed mineral outcrop in an open grassland area, but it was stolen in less than 15 days after being installed, and no information was ever obtained from it. A second camera trap, overlooking a mineral lick which was used by red-shanked langurs, was used for much of 2013 and 2014, but was eventually stolen in February 2014. It is known that locals used to get into the forest area surrounding this and a nearby, more hidden lick, most likely looking for ground birds, Burmese hare or mouse-deer, because photographs of them with dogs were recorded in both of the camera traps, so it is likely that the stolen camera was taken by a disgruntled hunter. After consultation with the Conservation International Field Site Manager, it was decided that the stolen camera would not be substituted for the time being, which lasted until the end of this study.

3.2.14 Logged trees and logging intensity variables

Trees that had been felled by loggers in the area were located once the loggers had left, their position registered by use of a Garmin 62s GPS unit, their species identified with help of different local guides, and the approximate date of felling noted. Location and data collection of logged trees was done after loggers had left because, in the early days of the study, when illegal loggers were approached, I and the local guides accompanying me were not well received and we were forced to leave the area immediately. To prevent a further hostile reaction, I decided to avoid directly confronting loggers. The kind of habitat where the trees had been felled was also recorded.

Each day that any logging activity in the area was detected, the number of chainsaws that were working was recorded. The length of each daily logging episode was measured in hours by noting the hour in which it started and the hour in which it finished, then pooled in different categories depending on each daily length: 0; any minutes up to 2 hours; over 2 hours until 4 hours; over 4 hours up to 6 hours; over 6 hours up to 8 hours; over 8 hours up to 10 hours.

The distance between each ranging point and any logging hotspot where logging activity was carried out in the particular day was also plotted using Google Earth Pro version 7.1.2.2041. Distances obtained were pooled in three different broad categories: 1 to 1000 meters (close distance), over 1000 to 2000 meters (mid distance) and over 2000 meters (far distance). The reasoning behind this was that the noise and disturbance from chainsaws can be noticed very strongly even from a kilometer away, and the fact that langur group spread is considerable, with more than a hundred meters between individuals in the fringes of the group.

3.3 Data Analysis

3.3.1 Habitat diversity and structure

Mann-Whitney U tests were carried out to compare the H and E values, number of stems and number of species obtained for mixed deciduous and mixed evergreen forests. Chi-squared tests were also used to look at any significant relationship between the type of forest and the proportion in which different DBH and height values appeared. Statistical analysis was done by using SPSS Statistics 23

3.3.2 Group size and composition

Group counts were analyzed and the maximum and minimum amount of individuals, both in total and for each of the age and sex categories, as well as mean group size and mean size of each of the age and sex categories.

3.3.3 Feeding

Recorded food tree GPS points were plotted on maps using Google Earth Pro version 7.1.2.2041. The geographical distribution of the known food plants for the silvered langurs could be seen, and any differences in years or seasons could be observed.

Feeding episodes were counted. Species and families that formed a part of the diet were quantified and their proportions calculated, as well as the different plant parts or other sources of food. A χ^2 -square test was undertaken in order to see if there were any significant differences between the diet compositions in plant parts and plant families in each of the seasons of the year. Spearman's rank-order correlation tests were used to look into any correlation between the proportion of species or families in the diet and the basal area proportion in the habitat.

Selection ratios (SR) for those species as well as plant families that were found in botanical transects were calculated after the methods outlined by Fashing (2001a), by dividing the percentage in which it figures in the diet of the langurs by percentage of the total basal area for the species or family in question. Thus, if the SR value for a species or family was below one, there was no selection towards it, if the value was above one but below 10 animals preferred to feed on that taxon, and if its value was above 10, it was one of the most preferred taxa in their diet. Pearson's Correlation Coefficient was carried out between both sets of data in order to detect a strong relationship.

$$\text{SR(species)}=\frac{Proportion\ of\ the\ species\ from\ the\ total\ langur\ diet}{Proportion\ of\ the\ species\ basal\ area\ from\ the\ total\ stem\ basal\ area}$$

$$\text{SR(family)}=\frac{Proportion\ of\ the\ family\ from\ the\ total\ langur\ diet}{Proportion\ of\ the\ family\ basal\ area\ from\ the\ total\ stem\ basal\ area}$$

Recorded videos and images of Annamese silvered langurs were analysed, and the date, starting time of visit, ending time of visit, visit length in minutes and mean visit length in minutes were calculated. The frequencies of mineral lick visits at the different times of the day were also calculated by separating the different hours of the day from 7 am until 7 pm in two hour long blocks: 7 to 9 am, 9:01 to 11 am, 11:01 am to 1 pm, 1:01 to 3 pm, 3:01 to 5pm, 5:01 to 7pm. In order to establish if group size had any influence on the visit length or visiting time, Spearman's rank-order correlation coefficients were calculated for both cases; times were converted into numerical form in order to be able to do the calculations.

3.3.4 Ranging and habitat use

In order to plot the graphical representation of the group home range, Google Earth Pro version 7.1.2.2041 was used. GPS data were entered and several maps were produced. The seasons were differentiated by both the results obtained after measures and the information provided by Thoeun (2015).

Home range, both total and seasonal, was established by using the Minimum Convex Polygon method (MCP) (Hayne, 1949), by linking all outer GPS locations, then calculating by means of using the Google Earth Pro tools for calculating area size. Low encounter rates and a lack of connection of the home range with further forest areas on all sides but the western area point to langurs observed in this range always being the same group.

Total and seasonal home range estimation by using the grid cell method (Adams & Davis, 1967) was also used. The map was divided in grids of 250 by 250 meters, given that the study group had a big spread, well over a hundred meters. Thus, home range size would result from multiplying the number of cells used by the group by 6.25 ha, which is the area of a single grid cell.

Home range use intensity and differences between seasons were determined by the amount of ranging GPS points present in each cell in the home range, to which end three categories of use-intensity were used: <2.0% of total use, 2.01 to 5.0% of total use, and >5.0% of total use. Only total home range, dry season range and wet range were assessed, given that the group was unhabituated, and it was not easy to find it or keep up with it for the whole day, and not many full-day follows were achieved, so the assessment of monthly home ranges was discarded. The average number of ranging points per month was 36.08.

Habitat selection and any differences between seasons were calculated by using the preference index (P_i) equation established by Jacobs (1974), which has previously been used in other studies when looking at habitat preference by herbivorous mammals (Barnes *et al.,* 1983; Newton, 1992),

$$P_i = \frac{Ri-Qi}{Ri+Qi}$$

Where R_i is the proportion of ranging points out of the total for habitat i, and Qi is the proportion of occupied cells out of the total for habitat i. If P_i is positive, there will be a positive preference of the species towards that habitat, a negative value will mean a negative preference towards that particular habitat, and a value of 0 will show that the species has no preference towards that habitat.

In order to establish the relationship between age/sex classes and canopy layer use and any differences between them, χ^2 tests were used. Statistical analysis was performed using Microsoft Excel 2007 and IBM SPSS Statistics 23.

3.3.5 Logging impacts

Registered tree GPS points were plotted on maps using Google Earth Pro version 7.1.2.2041. Thus, logging spots and ranging points were represented and the evolution of both variables over the year could be studied, in order to ascertain any possible influences by logging over the langur's ranging.

In order to establish any influence over the canopy layer use by the whole group and the different sex/age classes by the daily number of chainsaws, daily length of logging activities, and the distance between the closest logging hotspot and the ranging points recorded for the group, χ^2 tests were used. Statistical analysis was performed by using Microsoft Excel 2007 and IBM SPSS Statistics 23.

CHAPTER 4

Habitat diversity, structure and composition

4.1 Introduction

The Kingdom of Cambodia is a country sited in mainland Southeast Asia, between 11º and 14º latitude, bordering on Thailand to the West, Laos to the North and Vietnam to the East. To the south, it opens to the South China Sea through the Gulf of Thailand. Most of the country is quite flat, being the bed of the Mekong River and the Tonle Sap, some of the biggest waterbodies in the region. There are also the Cardamom and Elephant Mountains in the Southwest, the Dangkrek Mountains in the North, and the first hills of the Annamite Range in the Northeast. Biodiversity wise, the country falls in the Indochinese floral region (in the Indo-Pacific floral Kingdom) (Cox, 2001), and the Indo-Malayan zoogeographical region (Corlett, 2004). While also part of the Indo-Burma Biodiversity Hotspot (Mittermeier *et al.,* 2011; Myers *et al.,* 2000), the biodiversity of the country itself has been historically understudied due to several possible factors including: the difficulty in accessing many areas, an endemic problem of banditry and the political violence during most of last century.

Probably due to the historical and political instability of many of the countries in Indochina, research on forest structure and species composition has been quite scarce until nowadays. Due to a lesser amount of historical conflict as well as a historical exploitation of particular wood species found local forest formations by a logging industry and large plantation surfaces, both present since colonial times, most research on forest ecology in Southeast Asia was undertaken in Malaysia (Adam *et al.,* 2007; Aiba & Kitayama, 1999; Appanah, 1993; Appanah *et al.,* 1993; Ashton & Macintosh, 2002; Ghollasimood *et al.,* 2012; He *et al.,* 1996, 1997; Kochummen *et al.,* 1990; Medway, 1972; Newbery *et al.,* 1992) and Indonesia (Hadi *et al.,* 2009; Kessler *et al.,* 2005). Some research was started in Thailand in the 1960's to aid the United States war effort in Vietnam (Williams, 1965), but there have also been more recent studies (Baker *et al.,* 2005; Bunyavejchewin, 1999; Bunyavejchewin *et al.,* 2003; Lamotte *et al.,* 1999; Marod *et al.,* 1999). Work on the Indochinese flora is minimal when compared to other regions, with some studies on plant diversity and forest composition carried out in Vietnam

(Averyanov *et al.,* 2003; Blanc *et al.,* 2000; Nguyen, 1997; Nguyen & Harder, 1996; Qin *et al.,* 2012; Tran *et al.,* 2013; Trang, 2011; Phuong, 2007), while work centered on the plant biodiversity and ecology in Cambodia itself is even more rare, the best and most known work being the one done by Dy Phon (2003), although there have been some surveys on the vegetation composition of protected areas (Eang, 2015; Hayes *et al.,* 2013; Maxwell, 2009; Webb, 2005) as well as some studies published on the topic of forest composition and diversity, particularly around the Mekong and Tonle Sap (Neth *et al.,* 2009; Theilade *et al.,* 2011), but with some studies also focused in the north (Kao & Iida, 2006) and northeast (Pin *et al.,* 2013) of the country. However, there are too many questions that need to be addressed. Not only species and genera that are of yet unknown or very poorly known: There is not even a consensus in the definition of forest types in Indochina: even when looking at forest types where there is a higher consensus on their structure and composition, different names are used, such as in the case of mixed evergreen forests, also called dry evergreen forests by some studies, as referred by Rundel (1999) (Tani *et al.,* 2007). This is much worse in the case of deciduous assemblages, with some works fusing together formations of different structure and floristic composition such as dry deciduous woodland and mixed-deciduous forest (Averyanov *et al.,* 2003; Blasco *et al.,* 1996), while other studies separated them as different habitats (Baker *et al.,* 2005; Birdlife International Cambodia Programme, 2012; Eang, 2015; Hayes *et al.,* 2013; Lamotte *et al.,* 1999; Marod *et al.,* 1999; Rawson, 2009; Rundel, 1999; Tani *et al.,* 2007), and this has proven problematic when classifying certain forest formations found in Northeastern Cambodia (Rawson, 2009; Birdlife International Cambodia Programme, 2012; Eang, 2015; Goes, 2013; Hayes *et al.,* 2013; Rundel, 1999).

Forests found in the area are classified as one of several categories:

1- Savanna woodland, dominated by annual grasses, with hardy deciduous species tolerant to fire sparsely dispersed in the habitat so that they do not form a canopy (Rundel, 1999) (Figure 4.1)

Figure 4.1 *Savanna woodland: grasses and dipterocarps dominate with some shrubs present. Stems are dispersed and there is no canopy. Most plants in the understorey are saplings or young stems of dipterocarps*

2- Dry deciduous forest, with an open canopy that loses leaves during the dry season, dominated by deciduous dipterocarps, mainly *Dipterocarpus* and *Shorea* species, with wide space between themselves and forming a low top canopy, saplings and small shrubs forming an intermediate canopy and annual herbaceous stems including small bamboos at ground level, and fire plays a big part in the ecology of this forest type (Birdlife International Cambodia Programme, 2012; Eang, 2015; Hayes *et al.,* 2013; Rundel, 1999; Tani *et al.,* 2007; Phuong, 2007)

3- Mixed deciduous forest, a habitat dominated by deciduous trees that are not dipterocarps with a high top canopy limit and many emergent stems, with a higher species diversity including many perennial species, an understorey that is pretty much absent and open and the presence of some vines but not in abundance (Rawson, 2009; Rundel, 1999; Tani *et al.,* 2007; Phuong, 2007; Williams, 1965), this forest is called mixed evergreen forest in some works

(Eang, 2015; Goes, 2013; Hayes *et al.,* 2013) or put together with dry deciduous forest by others (Averyanov *et al.,* 2003; Blasco *et al.,* 1996; Sterling *et al.,* 2006) (Figure 4.2)

Figure 4.2 *Mixed deciduous forest: stems are more frequent and diverse than in previous types. Lagerstroemia (blotched stems) largely dominate and there is a tall canopy; the understorey is not structurally complex*

4- Mixed evergreen forest, with an even higher species diversity than other forest types and dominated by perennial species, particularly dipterocarps, but with presence of deciduous species too, also presenting a large amount of understorey plants, vines and epiphytes, the top canopy is not as high as the previous type but it is much more closed and has many more layers, with a thicker lower canopy and a very dense understorey, this type has also been called evergreen forest (Averyanov *et al.,* 2003; Eang, 2015; Hayes *et al.,* 2013; Hiramatsu *et al.,* 2007) or dry evergreen forest (Tani *et al.,* 2007) (Figure 4.3).

Figure 4.3 *Mixed evergreen forest: Stems are numerous and close together, with different species. Canopy presents many layers. Vines are abundant, as understorey species and saplings*

As a result of the general lack of information on the ecology of the region's forests, not much is known on the effects of factors with intense and potentially destructive effects on the future of the country, such as logging and climate change. If research on the local plant communities and the species that form a part of them is not stepped up and encouraged, it will not be possible to account for and be able to counter those harmful effects, not only for maintaining the biodiversity of the country, but also to provide the local population with proper access to water and crops and livestock, as the country is in high risk of being subjected to alternating periods of drought and flood (Talbott & Brown, 1998), which present dire implications of famine and loss of life. Some studies have already addressed the effects of logging in the country (Kao & Iida, 2006), but it is important to increase these as well as those on the impacts of global warming, as logging has become uncontrolled and the rates have risen to the highest in the world (Global Witness, 2007, 2015; Hansen *et al.,* 2008, 2013) with the country eventually becoming the one with the highest deforestation rate (Petersen *et al.,* 2015). In addition to logging, uncontrolled development, particularly in coastal areas, poor planning, lack of education and the high economical value of animal and plant products in the regional trade have increasingly put a higher amount of local biomes under threat from human activities, with a sensitive approach from both authorities and law enforcement agencies as well as a bigger reach to both local and urban populations in the close future being the only chance to curb these worrying trends.

The forests in the study area are a mosaic of mainly mixed evergreen and mixed deciduous forests, with rare patches of dry deciduous or bamboo forest, and patches of savanna woodland (called *veal* in Khmer language) between masses of forest. Such a diversity of environments would support an accordingly high diversity of organisms, especially in a place such as VSSPCA, which has not been impacted by human activity as much as other areas in the country.

This study aims to record the temperature and precipitation values for VSSPCA, and categorize the diversity and structure of the langur home range, as well as look into any differences between forest types.

4.2 Methods

4.2.1 Weather measurements

Maximum and minimum monthly temperatures were recorded at the study site, from the 25th of July 2013 until the 17th of May 2014. Every day at 19:30 hours the temperature from a Sper Scientific thermometer set up at base camp was taken. Precipitation was measured in inches using a Rain Gauge from Alternative Solutions inc. at the same time daily.

4.2.2 Forest types

As it was stated in the introduction, there has not been a consensus on definitions used to describe forest formations in Southeast Asia, and categories that have been proposed tend to be too vague or restrictive to accommodate certain forest formations found in VSSPCA. Thus, the approach taken follows that of Rawson (2009) and Rundel (1999), where different forest types were defined according to the observed composition and structure of the forests studied. There are further comparisons with other previous works below so that the approach taken in this work is justified with further background.

This resulted in the main forest types in this area being classified as savanna woodland, mixed evergreen forest, mixed deciduous forest. These categories are explained in detail in the methods chapter.

4.2.3 Botanical transects

Eight transects measuring 5x200 m (1000 m^2) were established inside the known langur home range. Three transects were established in unlogged mixed evergreen forest (2,3,7), three on mixed deciduous forest (5, 6, 8) one along a logging road in mixed-evergreen forest (1) and one in a highly logged tract of mixed evergreen forest that eventually ends with a gallery forest (4).

From February 2013 to May 2013, tree composition in each transect was determined. GPS reference points were noted for the starting point, and at every 100 m along the trail, measured with a Sterling measuring tape. The transect was flagged every 10 m with biodegradable paper tags. The Diameter at Breast Height (DBH) of every stem inside the transect was measured with the aid of a Richter 5m Diameter Tape, and those equal or bigger than 12 cm were considered for further analysis due to the lower dimensions deemed to be too small to be considered as relevant to langur ecology and to a difficulty in ascertaining the identification of the stem. If a plant presented several stems surging from the same point on the ground, DBH for each stem was measured and then added for total plant DBH. With the assistance of a local guide and guide books an effort was made to identify each stem to the species level, although many stems were not identified even to family or genus. Scientific names were obtained from Khmer names given by the guides by using the Dictionary authored by Dy Phon (2000). When names were given in Lao, the work authored by Inthakoun and Delang (2008) was used. Height for each stem was measured in meters with the help of a Haglöf Clinometer. Lastly, coverage for each stem was measured in the percentage of canopy each particular stem occupied when looking up from its base by using the naked eye.

Cut stems that were obviously a result of logging (it was truncated evenly, as from the result of the use of a chainsaw, and rests of the tree were found processed adjacently), were identified and included as long as it had a DBH higher than 30 (trees that would be sought after for luxury woods). These felled trees, however, were not taken into account for analysis of trees used by the monkeys.

4.2.4 Biodiversity Indexes

In order to estimate the biodiversity values of the different parts of the home range, the Shannon-Wiener Diversity Index (*H*) and Equitability Index (*E*) were calculated for each transect separately and as a whole. An Importance Value Index (IVi) was then calculated both for each species and each family. All the following equations were used for each index, and are explained in detail in the methods chapter:

- Shannon-Wiener Index (*H*) = $- \sum_{i=1}^{S} pi \ln pi$

- Shannon's Equitability Index (*E*) = $\frac{H}{\ln S}$

- Importance Value Index (IVi) = Rd+Rf+RD

When using the biodiversity indexes, only the stems identified as far as genus were factored.

4.2.5 Data analysis

Mann-Whitney U tests were carried out to compare the *H* and *E* values, number of stems and number of species obtained for mixed deciduous and mixed evergreen forests. Ch-squared tests were also used to look at any significant relationship between the type of forest and the proportion in which different DBH and height values appeared. Statistical analysis was done by using SPSS Statistics 23.

4.2.6 Terrestrial vertebrate inventory

Every day, either while looking for the langurs in the forest or while gathering data, any terrestrial vertebrate species that was seen, heard or signs of their activity observed (tracks and scats) was noted along with the type of forest in which I was and the numbers in which they were found. Animals were identified to the species, and no effort in census was undertaken, given that, as we usually followed certain tracks in the langur home range to try and locate them, some species which resided adjacent to these would be registered far more constantly than other species, and their abundance might thus be overestimated.

4.3 Results

4.3.1 Weather

The maximum temperature registered during the study was 43 ºC in March 2014, while the lowest was 12 ºC in January 2014. Averages show that the warmest registered month was March 2014 and the coldest one, January 2014. Mean temperature in VSSPCA for the duration of the 11 months in which temperature was recorded was of 28.7 ºC (Figure 4.4).

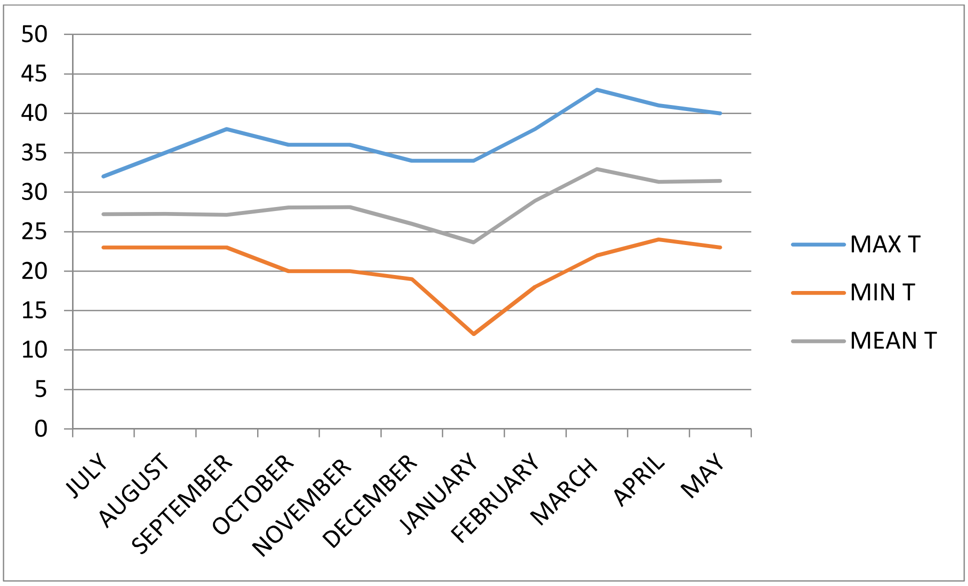

Fig.4.4 *Temperature regime at VSSPCA (in ºC) between the end of July 2013 until May 2014*

In regards to precipitation, of all the measured months, the wettest was August 2013, while January, February and March 2014 didn't see any rainfall at all. Total precipitation observed for the 11 registered months was of 850.8 mm (Figure 4.5).

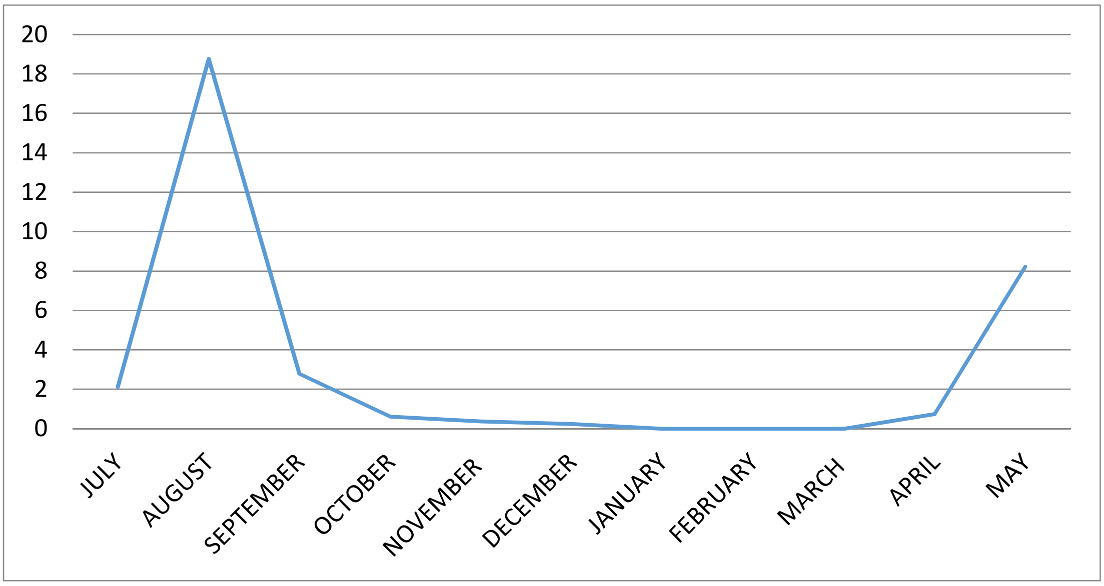

Fig.4.5 *Rainfall regime in VSSPCA (in mm) between late July 2013 and May 2014*

4.3.2 Botanical transects

There were a total of 346 stems recorded in the eight transects, of which 223 were identified at least up to genus. Twenty-nine families including 44 genera and 47 species were found, and the mean species number per transect was of 13. Overall mean height was 14 m, with a maximum of 47.3 m and a minimum of 0.5 m. Overall mean DBH was 32.60 cm, the smallest being 12.5 cm while the biggest was 194 cm. The total *H* was 3.33, and total *E*, 0.61

In regards to transect composition, the higher number of stems was found in one of the mixed deciduous forest transects (8) with 59 (0.59 stems per ha), while the lowest was in the transect that was heavily affected by logging (4) with only 26 (0.26/ha). The highest number of identified taxa was found in one transect each of mixed evergreen forest (2) and mixed deciduous forest (8), both with 18, and the lowest in the heavily logged transect (4) with 9 (Figure 4.6). The highest *H* value was 2.74, from a mixed evergreen transect (2), and the lowest was 1.80, from a mixed deciduous transect (6). The transects with the highest value for *E* were two of the mixed evergreen type (2 and 7), both with 0.80, and the lowest one was a mixed deciduous transect (6) with 0.52 (Table 4.1).

Table 4.1. *Information on heights, DBH, stem number, species number, Shannon-Wiener Index and Evenness Index for each transect. ME stands for Mixed Evergreen, MD stands for Mixed Deciduous*

Transect	**Mean height**	**Max height**	**Min height**	**Mean DBH**	**Max DBH**	**Stem number/ density (per ha)**	**Species number**	***H***	***E***
Logged Trail (T1)	12.52	47	1.5	26.77	88.9	40/0.4	16	2.58	0.77
ME1 (T2)	12.01	43.1	0.5	27.6	88.1	52/0.52	18	2.74	0.80
ME2 (T3)	11.78	25.6	1.6	28.24	112	44/0.44	10	2.04	0.63
Heavily Logged (T4)	13.2	45.9	2.3	35.31	194	26/0.26	9	2.10	0.76
MD1 (T5)	18.83	47.3	3.3	43.83	108.9	39/0.39	12	1.93	0.62
MD2 (T6)	16.37	36.4	4.7	30.25	102	41/0.41	11	1.80	0.52
ME3 (T7)	13.33	38.3	1.6	29.74	121	45/0.45	15	2.56	0.80
MD3 (T8)	14.24	45.6	3.2	39.82	154	59/0.59	18	2.43	0.66

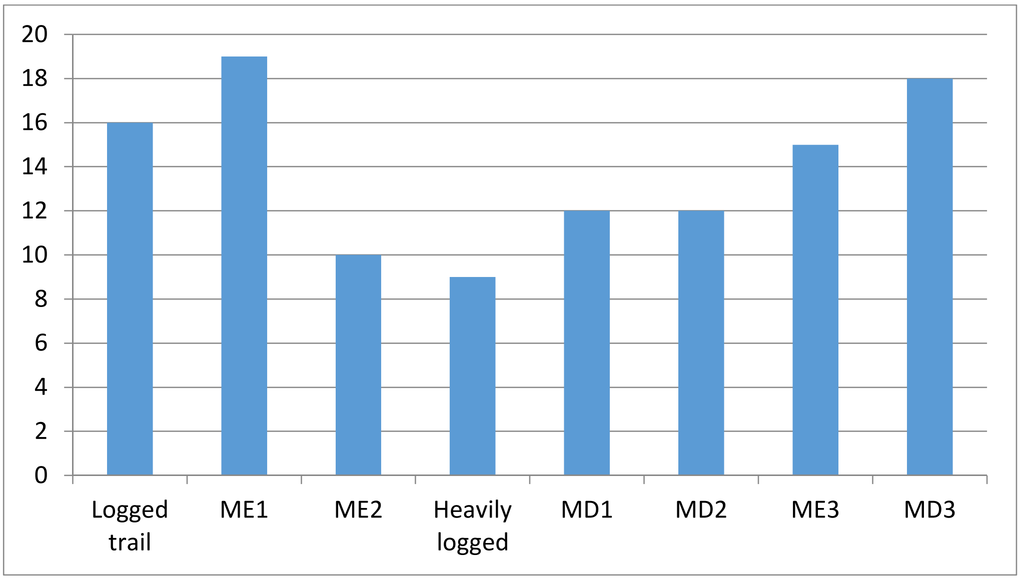

Fig.4.6 *Number of species per transect.*

As for transect structure, the tallest trees were found in a mixed deciduous transect (5) (47.3 m), as well as in the transect on a logging track (1) (47 m). Mean height was highest in a mixed deciduous transect: 5 (18.33 m) and lowest in a mixed evergreen transect (3)(11.78 m) (Figure 4.7). Most registered trees fell in the height category of 10 to 20 m (152 stems), being the most numerous category in all transects except in two mixed deciduous transects (2 and 8) and the heavily logged one (4); the second most common height category was less than 10 m. Only 8 trees surpassed the 40 m of height (Figures 4.8, 4.9).

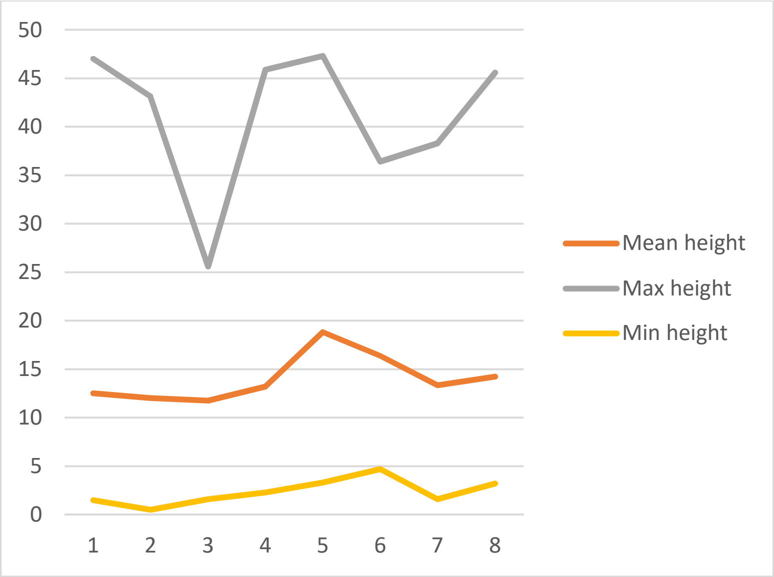

Fig.4.7 *Variation in maximum, minimum and mean height (in m) for each transect*

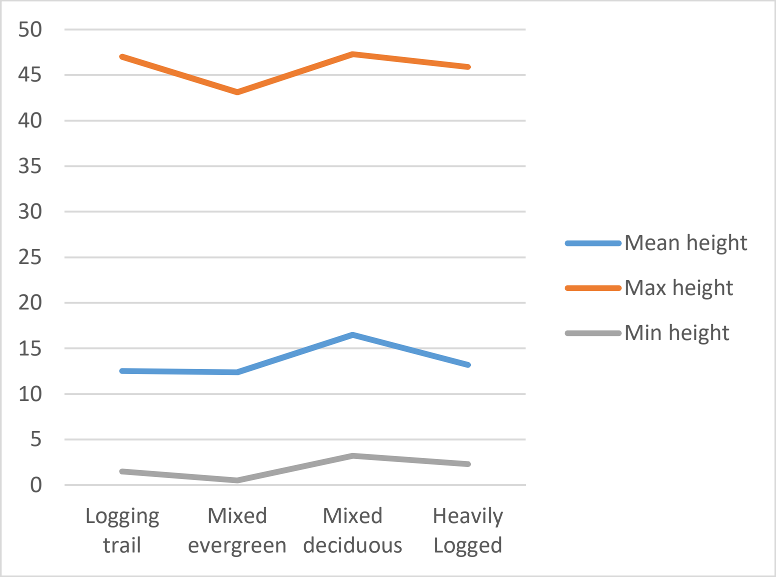

Fig.4.8 *Variation in maximum, minimum and mean height (in m) for each habitat type*

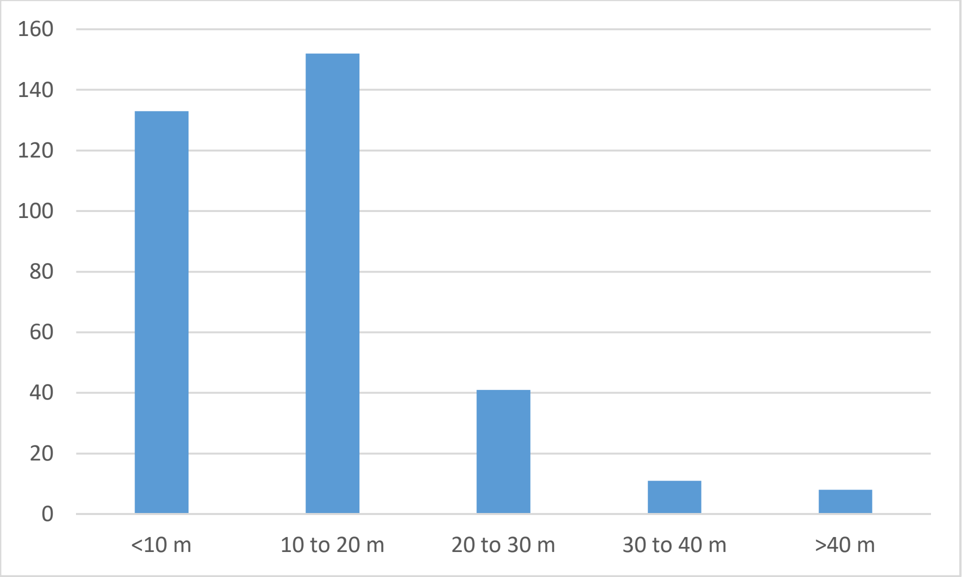

Fig.4.9 *Distribution of each height category in the langur home range*

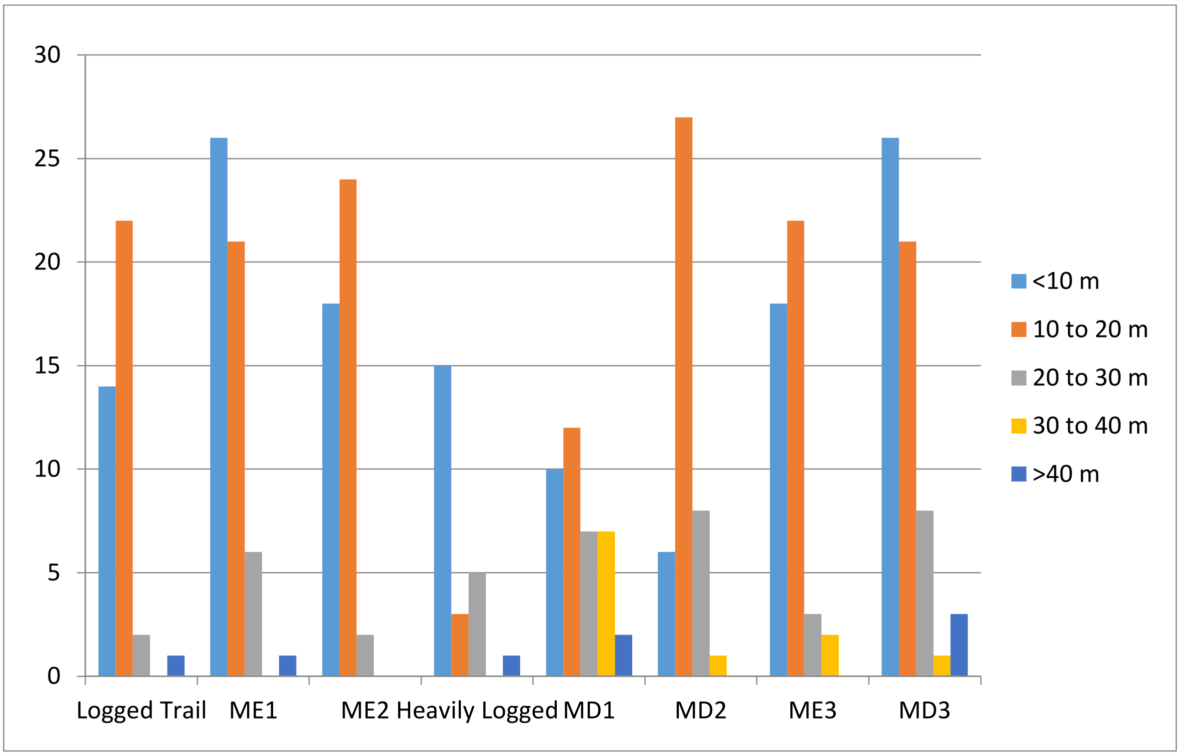

Fig.4.10 *Distribution of each height category in each transect*

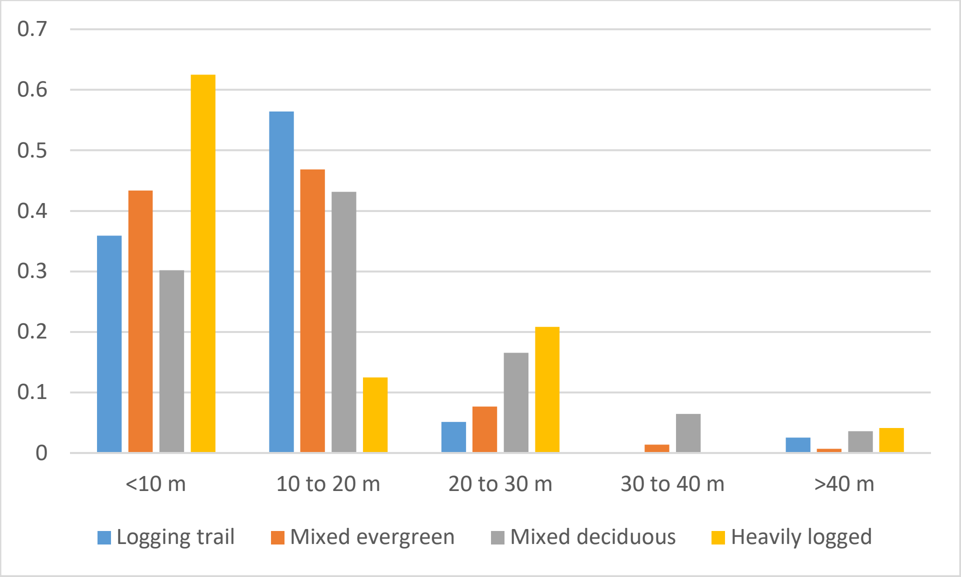

Fig.4.11 *Proportion of each height category in each habitat type*

The largest DBH was found in the heavily logged transect (4) (194 cm). Mean DBH was highest in transect 5, a mixed deciduous type (43.83 cm) and lowest in the transect on a logging track (1) (26.77 cm) (Table 2). DBH of most trees fell in the 12 to 20 cm size category (144 stems),which was the most numerous category in all transects, closely followed by the next category, 20.1 to 50 cm (143 stems); then each following category diminished, although the only category with no recorded stems was the 140 to 150 cm. (Figures 4.10, 4.11).

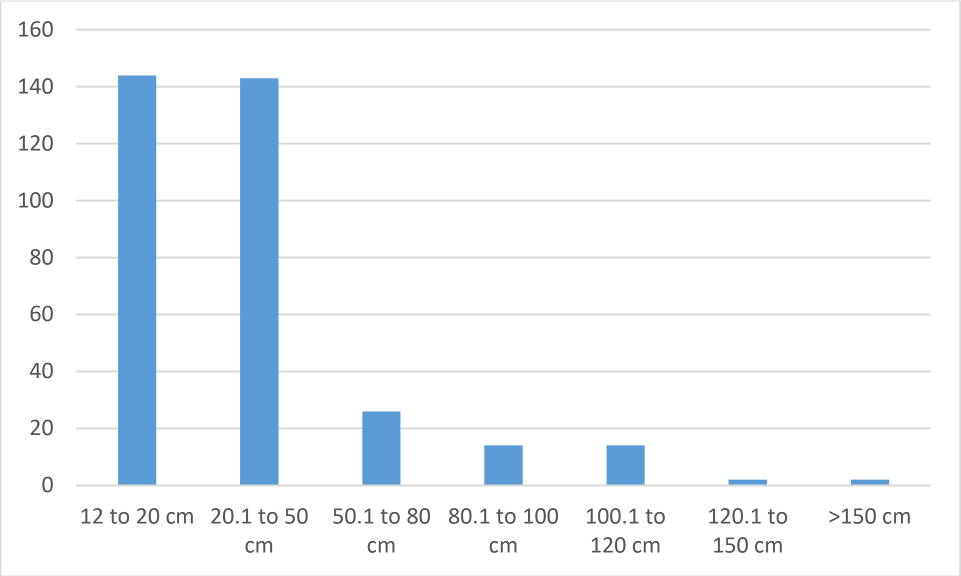

Fig.4.12 *Distribution of each DBH size category in the langur home range*

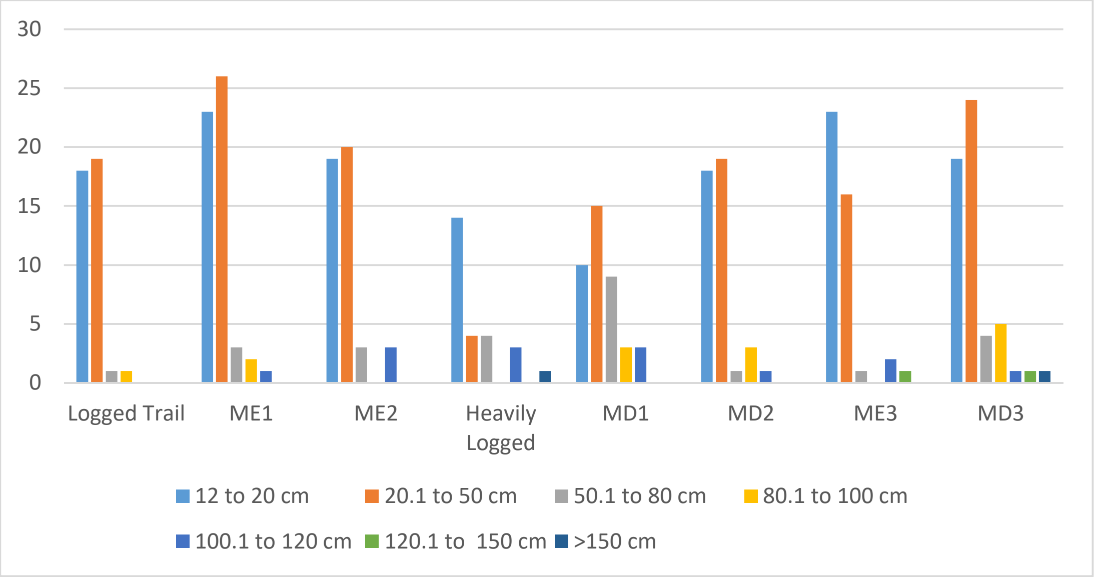

Fig.4.13 *Distribution of each DBH size category in each transect*

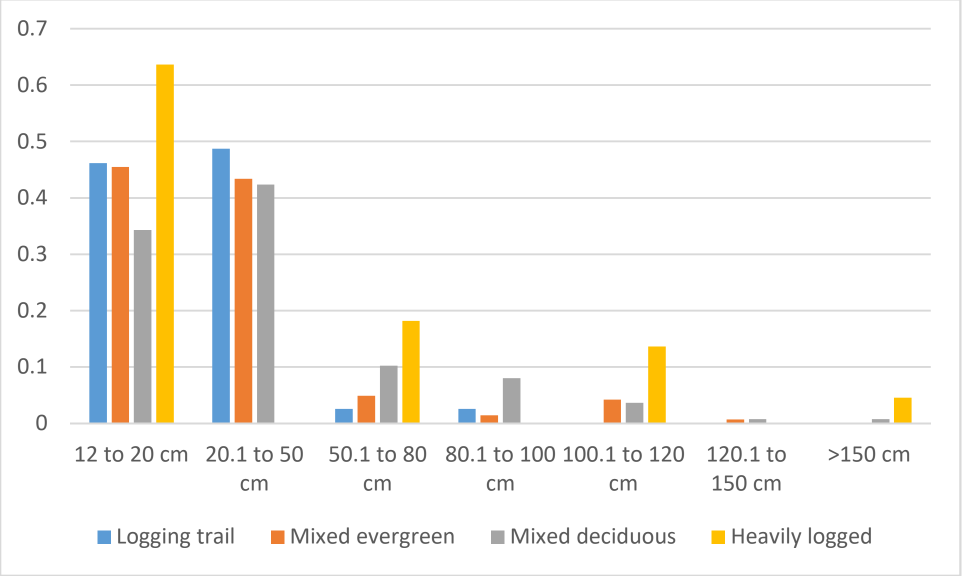

Fig.4.14 *Proportion of each DBH size category in each habitat type*

Mann-Whitney U tests showed that there was not a significant difference between the values of *H* (U=1, p= >0.05 n_{md}=3, n_{me}=4) or *E* (U=1, p= >0.05 n_{md}=3, n_{me}=4) between mixed deciduous and mixed evergreen forest transects. Interestingly, however, if transect number 3 is excluded (a mixed evergreen transect with anomalous values for number of species, *H* and *E* when compared to other mixed evergreen transects, including number 1), *E* values were observed to be significantly different between mixed evergreen and mixed deciduous transects (U=0, p= <0.05 n_{md}=3, n_{me}=3). Number of species was not significantly different between forest types (U=5.5, p= >0.05 n_{md}=3, n_{me}=4), and there neither was a significant difference in number of stems between forest types ($U=5$, $p= <0.05$ $n_{md}=3$, $n_{me}=4$).

There were significant differences in the proportion of different DBH sizes in regards to forest type ($\chi^2= 37.49$, df= 18, $p= <0.01$), and in the proportion of the different heights in regards to forest type ($\chi^2= 35.12$, df= 12, $p= <0.01$). Mixed deciduous forest presented a higher amount of stems taller than 20 meters, while mixed evergreen forest presented significantly higher numbers of stems under 10 meters tall. Regarding DBH size, mixed deciduous forest presented a significantly larger amount of stems with DBH dimensions between 50 and 100 cm, while mixed evergreen forest presented significantly more stems between 12 and 20 cm.

The most numerous species overall was *Diospyros pilosanthera* (Ebenaceae), with 30 trees. The next most numerous species was *Lagerstroemia calyculata* (Lythraceae), with 25; after these, and at a distance, the most numerous species were *Dipterocarpus alatus* (Dipterocarpaceae), *Cinnamomum cambodianum* (Lauraceae) and *Sterculia lychnophora* (Sterculiaceae), all of them with 13 stems. The only other species with 10 stems or more were *Schoutenia ovata* (Malvaceae, 11 stems) and *Irvingia malayana* (Irvingiaceae, 10 stems). The most frequent species were *Dipterocarpus alatus* and *Diospyros pilosanthera*, found in 7 out of 8 transects. Interestingly, *Sterculia lychnophora*, while being one of the most numerous species, had a very low frequency, being only present in 1 out of 8 transects. The most dominant species around O'Ksiap was *Lagerstroemia calyculata* (46.28), representing 16% of the total IVI values. All other species lag far behind, the following species being *Dipterocarpus alatus* with 26.85, *Diospyros pilosanthera* with 22.56 and *Irvingia malayana* with 16.9 (Annex 2).

Between families, the most numerous was Ebenaceae with 30 trees (although all the stems belonged to a single species, *Diospyros pilosanthera*) followed by Lythraceae with 26 trees (also monopolised by *Lagerstroemia calyculata*, with only one tree belonging to other species), following them were Dipterocarpaceae and Sterculiaceae with 19 and 18 respectively. Other numerous families were Malvaceae (14), Fabaceae (13) and Lauraceae (13, composed only by *Cinnamomum cambodianum*). In regards to family composition, Fabaceae was by far the most diverse family, with 6 different species under its belt. The only family to be present in all transects is Dipterocarpaceae. The most dominant family was Lythraceae with an IVI of 55.39, followed by Dipterocarpaceae, which presented an IVI value of 45.13. Far behind these appear Ebenaceae with 24.64 and Irvingiaceae with 18.68 (Annex 1).

When looking at forest type diversity, mixed evergreen forest transects (1, 2, 3 and 7) presented a total of 37 species, of which 13 (35.1%) were not found on mixed deciduous forest (Table 4.2), while the number of families present was 24, with 9 (37.5%) of them only found on transects of this type of forest: Annonaceae, Gentianaceae, Hypericaceae, Lecythidaceae, Meliaceae, Myrtaceae, Ochnaceae, Rubiaceae and Solanaceae. The five most dominant species for this type of forest were *Dipterocarpus alatus*, *Irvingia malayana*, *Anisoptera costata*, *Diospyros pilosanthera* and *Cinnamomum cambodianum* (Table 4.3). Regarding families, the five most dominant in mixed evergreen forest were Dipterocarpaceae, Irvingiaceae, Ebenaceae, Lauraceae and Myrtaceae (Table 4.4).

Table 4.2 *Species found only in mixed evergreen forest transects and the families they belong to*

Annonaceae	*Sphaerocoryne affinis*
	Uvaria cordata
Combretaceae	*Terminalia bellirica*
Ebenaceae	*Diospyros decandra*
Fabaceae	*Dalbergia cochinchinensis*
	Xylia xylocarpa
Gentianaceae	*Fagraea fragrans*
Hypericaceae	*Cratoxylon formosum*
Lecythidaceae	*Barringtonia macrostachya*
Lythraceae	*Lagerstroemia floribunda*
Meliaceae	*Sandoricum koetjape*
Myrtaceae	*Melaleuca leucadendra*
	Tristaniopsis burmanica
Ochnaceae	*Euthemis leucocarpa*
	Ochna harmandii
Rubiaceae	*Haldina cordifolia*
Sapindaceae	*Euphoria cambodiana*
Solanaceae	*Solanum sp.*
Sterculiaceae	*Pterospermum semisagittatum*

Table 4.3 *List of the ten species with higher IVI value from mixed evergreen forest transects, with their relative density, frequency and basal area*

Species	**Relative density**	**Relative frequency**	**Relative basal area**	**Importance Value Index**
Dipterocarpus alatus	5.83	7.14	17.68	30.64
Irvingia malayana	4.85	3.57	21.98	30.4
Anisoptera costata	3.88	1.79	23.17	28.83
Diospyros pilosanthera	13.59	7.14	4.11	24.85
Cinnamomum cambodianum	10.68	3.57	8.08	22.33
Sandoricum koetjape	3.88	3.57	4.75	12.21
Sphaerocoryne affinis	4.85	5.36	0.84	11.05
Pterospermumsemisagittatum	4.85	3.57	2.52	10.95
Nephelium melliferum	4.85	3.57	2	10.02
Croton tiglium	4.85	3.57	1.51	9.93

Table 4.4 *List of the ten families with higher IVI value from mixed evergreen forest transects, with their relative density, frequency and basal area*

Family	**Relative density**	**Relative frequency**	**Relative basal area**	**Importance Value Index**
Dipterocarpaceae	9.74	7.84	39.72	57.3
Irvingiaceae	4.87	3.92	21.37	30.16
Ebenaceae	14.6	7.84	4.14	26.59
Lauraceae	10.71	3.92	7.86	22.49
Myrtaceae	5.84	5.88	2.1	13.82
Sapindaceae	5.84	5.88	1.7	13.42
Combretaceae	5.84	3.92	2.8	12.56
Meliaceae	3.89	3.92	4.62	12.44
Sterculiaceae	4.87	3.92	2.45	11.24
Malvaceae	4.87	3.92	1.91	10.7

Mixed deciduous forest transects (5, 6 and 8) presented 29 different species, of which 12 (41.4%) were only found in this type of forest (Table 4.5). 21 different families were registered, of which five were not found in mixed evergreen forest transects: Ancystrocladaceae, Apocynaceae, Bignoniaceae, Moraceae and Theaceae. Regarding dominant taxons in the habitat, the five most dominant species were *Lagerstroemia calyculata*, *Sterculia lychnophora*, *Diospyros pilosanthera*, *Dipterocarpus alatus* and

Schoutenia ovata (Table 4.6). The five most dominant families in the habitat were Lythraceae, Sterculiaceae, Ebenaceae, Dipterocarpaceae and Malvaceae (Table 4.7).

***Table 4.5** Species found only in mixed deciduous forest transects and the families they belong to*

Anacardiaceae	*Bouea oppositifolia*
Ancistrocladaceae	*Ancistrocladus harmandii*
Apocynaceae	*Willughbeia sp.*
Bignoniaceae	*Oroxylum indicum*
Fabaceae	*Pterocarpus macrocarpus* *Sindora cochinchinensis*
Moraceae	*Ficus sp.*
Phyllanthaceae	*Aporosa octandra*
Sapindaceae	*Nephelium hypoleucum*
Sterculiaceae	*Sterculia lychnophora*
Theaceae	*Schima wallichii*

***Table 4.6** List of the ten species with higher IVI value from mixed deciduous forest transects, with their relative density, frequency and basal area*

Species	**Relative density**	**Relative frequency**	**Relative basal area**	**Importance Value Index**
Lagerstroemia calyculata	73.33	0.67	65.41	139.41
Sterculia lychnophora	43.33	0.33	5.27	48.93
Diospyros pilosanthera	43.33	0.67	3.08	47.08
Dipterocarpus alatus	20	0.67	7.98	28.64
Schoutenia ovata	20	0.67	1.51	22.18
Terminalia triptera	13.33	0.33	2.58	16.24
Polyalthia sp.	10	0.67	0.39	11.05
Anisoptera costata	6.67	0.67	3.7	11.03
Antidesma cochinchinense	10	0.67	0.34	11.01
Irvingia malayana	6.67	0.67	0.73	8.06

Table 4.7 *List of the ten families with higher IVI value from mixed deciduous forest transects, with their relative density, frequency and basal area*

Family	**Relative density**	**Relative frequency**	**Relative basal area**	**Importance Value Index**
Lythraceae	73.33	0.67	65.41	139.41
Sterculiaceae	43.33	0.33	5.27	48.93
Ebenaceae	43.33	0.67	3.08	47.08
Dipterocarpaceae	26.67	1	11.68	39.34
Malvaceae	26.67	1	2.53	30.2
Fabaceae	23.33	0.67	2.34	26.34
Combretaceae	13.33	0.33	2.58	16.24
Phyllanthaceae	13.33	0.67	0.42	14.42
Sapindaceae	10	0.67	0.25	10.92
Irvingiaceae	*6.67*	0.67	0.73	8.06

4.3.3 Terrestrial vertebrate inventory

A total of 154 terrestrial vertebrates or inequivocal signs of their activity were found in the langur home range. Of these, 32 were mammals, 87 were birds, 24 were reptiles, and 11 amphibians.

Of the mammals, the order with most species encountered was Carnivora with 11 species, with these evenly distributed between different families, including Viverridae, Herpestidae, Mustelidae, Ursidae, Canidae and Felidae. When looking at families regardless of Order, Cercopithecidae (Old world monkeys, O. Primates) and Sciuridae (Squirrels, O. Rodentia) were the dominant ones, with 4 and 5 different species respectively.

Fig 4.15 *Acuminate Horseshoe Bat (Rhinolophus acuminatus): one of the many bat species at VSSPCA*

Fig 4.16 *Northern buffed-cheeked gibbon (Nomascus annamensis): VSSPCA is key for the conservation of the species, which is used as a draw for ecotourism*

Fig. 4.17 *Red-shanked douc (Pygathrix nemaeus): the population of the species at VSSPCA appears to be healthy and under no immediate conservation risks*

In regards to birds, the order Passeriformes was, unsurprisingly, the most diverse, with 39 different species. The most diverse family, however, was the Picidae (Woodpeckers, O. Piciformes) with 6 species. The next most abundant was a group of diverse families with 4 species each: Phasianidae (Pheasants and Partridges, O. Galliformes), Columbidae (Pigeons, O. Columbiformes), Cuculidae (Cuckoos, O. Cuculiformes), Accipitridae (Buzzards and Kites, O. Accipitriformes), Pycnonotidae (Bulbuls, O. Passeriformes) and Dicruridae (Drongos, O. Passeriformes).

***Fig 4.18** Great hornbill (Buceros bicornis): Populations in Cambodia are decreasing, but they are present in large numbers at VSSPCA*

Amidst reptiles, all 24 species found in the langur home range belonged to the order Squamata (Lizards and Snakes). The most diverse family in the order was Scincidae (Skinks) with 5 species, after which Gekkonidae (Geckos), Agamidae (Dragon Lizards) and Colubridae (a group of snakes) appeared with 4 species each.

***Fig. 4.19** The two most dominant reptile groups at VSSPCA: snakes, represented by a bamboo pit viper (Cryptelytrops sp.) (left); and lizards, represented by the endemic neon blue lizard (Calotes bachae) (right), shown here in non-breeding colors*

Of the last vertebrate class, Amphibians, the most diverse group was the family Microhylidae (Narrow-Mouthed Frogs, O. Anura), with 4 species (Annex 3).

Fig. 4.20 *Two species of microhylids, the most dominant amphibian group at VSSPCA: Kalophrynus interlineatus (above) and Microhyla heymonsi (below)*

4.4 Discussion

4.4.1 Weather

From the weather data, it could be said that VSSPCA presents a rainy season from mid to late May until mid-October, followed by a dry season from November to early May. Temperatures are generally over 20 ºC, although in the rainy season there is a general trend for it to be much cooler with temperatures being relatively cold up until the end of January and gradually increasing until the end of the dry season, being the hottest time of the year. This is the same as the weather in other parts of Cambodia. These low temperatures probably cause changes in langur behavior, adjusting them to maintain body temperatures: Thermoregulatory behavioral responses have been observed on other Asian colobines living in regions with cold temperatures (Liu & Zhao, 2004; Xiang *et al.,* 2010; Zhang *et al.,* 2011), although those species had to withstand temperatures below 0° C, much lower than those at VSSPCA.

Regarding the precipitation values, the obtained measures fell short of what it would be expected in the area, and what was noted by other works (Frechette, 2014). However, it is explained by the fact that precipitation measurements were only started at the end of July 2013, which omits the months of May, June and July of the year 2013, which would have presented a high regime of precipitations, given that they form part of the wet season. The absence of said months from this account ends in an underestimation of the amount of rain during the year at VSSPCA, which will obviously be much higher than registered and closer to the values obtained in other works.

When comparing mean temperature and precipitation values to those recorded in the other study on the species (Tran, 2013), temperature was a little over a degree warmer in VSSPCA. As there is no mention to minimum or maximum temperatures at Ta Kou, no further comparisons can be made about temperature differences between sites. There was a higher volume of precipitations at Ta Kou (at least 200 mm), but in reality these values are much closer because the recorded precipitation volume for VSSPCA is an underestimation. Overall, there are no large differences in climate regimes between the two study sites.

4.4.2 Botanical transects

It is important to note that the results of this study do not include all the species that are found in the langur home range, but only a fraction of them. A key factor to have into account and that significantly hindered the results of the research in regards to the topics discussed in this chapter was an extended lack of knowledge on the flora of Cambodia, both by local and international institutions: There is no national herbarium and taxonomical experts on the region are scarce and work in institutions outside the country. In addition to this, the most important botanical reference work, authored by Dy Phon (2003), did not particularly address the flora found in the Northeast of the country and was mainly focused on plants with important human applications, which means many species present in the site would be absent. These particular issues have also been discussed in other works (Eang, 2015). 123 of the recorded stems in the botanical transects were left unidentified: It was not expected by the researchers that local researchers and rangers would be able to identify every single plant species of importance to the study, but a lack of reference works and institutions so that it was not possible to find some alternative ways to identify some of these unknown species; thus, the data and results in this theses would have been stronger. More information is needed to improve common knowledge on the ecology of the flora and forests of VSSPCA, as one of the key biodiversity regions of Cambodia in particular and of Indochina and Southeast Asia as well.

Vines were not particularly targeted for two reasons. The first one was that it was originally planned to only target stems with a DBH of 12 centimeters, and most vine stems were far below that size measure. The other was the fact that when these transects were planned, the researcher thought that plant species targeted by Annamese silvered langurs as food would mostly be larger than the mentioned size, had no idea that vines were of particular importance to the study species and that they targeted different species of them for food. At any rate, and linked to the issues already outlined in the previous paragraph, it is impossible to know if targeting vines would have made a large difference other than having information and an outlook at the amount of vines present in areas of mixed evergreen forest, which were pretty much the only formation type that presented a variety and number of vines in great quantities, because almost all vines that were actually included in the final results were not positively identified. Only one particular species was recognized by the local guide and research assistant, and the lack of further reference works made it impossible to be able to ascertain the scientific name of the vine in question. It would definitely be of importance to address this issue in further works in the study site or in the area, but further research on the Cambodian flora as well as further training for locals working as either research assistants or tourist guides would be invaluable.

Although the obtained picture regarding the vegetation found in the langur habitat in VSSPCA is only partial, given the large amount of wooden stems which it was not possible to positively identify at least until genus level (almost half of the recorded trees), it is still useful in order to establish which species and families are commonly found in the area. The most common tree species in the langur home range is *Diospyros* *pilosanthera* (Ebenaceae), while the most dominant is *Lagerstroemia calyculata* (Lythraceae). Other species with high dominance values are *Dipterocarpus alatus* (Dipterocarpaceae), *Irvingia malayana* (Irvingiaceae), *Anisoptera costata* (Dipterocarpaceae), *Schoutenia ovata* (Malvaceae), *Cinnamomum cambodianum* (Lauraceae), *Sterculia lychnophora* (Sterculiaceae), *Terminalia triptera* (Combretaceae) and *Nephelium melliferum* (Sapindaceae). The family setup is similar, with dominant families being Lythraceae, Dipterocarpaceae, Ebenaceae, Irvingiaceae, Malvaceae, Fabaceae, Sterculiaceae, Lauraceae, Combretaceae, Euphorbiaceae and Myrtaceae.

While transect 4, the most impacted by illegal logging activities, expectedly presented the lowest recorded number of stems and identified taxons, its Shannon-Wiener Index value is only marginally smaller than other mixed evergreen transects (1,2,7). The transect over a logging track (1) showed H and E values in the same proportion as other unlogged mixed evergreen forest transects. When looking at biodiversity indexes, there seems to be only a small difference separating transects belonging to different forest types, further supported by almost no significant differences being observed between *H* and *E* values, as well as the number of stems and species present. However, removal of an anomalous mixed evergreen transect (3), showed that evenness values between mixed evergreen and mixed deciduous were significantly different: Evenness values show differences between mixed evergreen transects (values over 0.75) and mixed deciduous transects (between 0.5 and 0.70), so it can be observed that mixed evergreen forests present a higher amount of species, and the habitat is less homogenous than mixed deciduous. It seems transect 3 is somehow anomalous when compared with the rest of transects: in addition to its low value for *H*, transect 3 presents an *E* value of 0.63, much closer to values presented by mixed deciduous forests than those of mixed evergreen forests, the group where it should be included due to tree composition and forest structure. Furthermore, when transect 3 was removed from the Mann Whitney U test, *E* values of mixed evergreen and mixed deciduous forest transects were observed to be significantly different.

While the amount of stems in the logged transect was the lowest, with 26, it does not mean that the forest will not recuperate its structure if logging is prevented from happening in the area in the future. The diversity and evenness number that it presents also point in the same direction. Logged areas can recover stems rapidly and the loss of diversity will be somewhat balanced by the apparition of pioneer species (Ferry Slik *et* *al.,* 2002; Verburg & van Eijk-Bos, 2003) as well as seeds carried from the adjacent forest areas where trees have not been cut down. Thus, the portion of logged forest might eventually recover in less than twenty years if there is no further logging in the transect area or neighbouring forest parts. On the other hand, it might also take the fragment much more time than 20 years to get to a similar structure and composition (Okuda *et al.,* 2003; Plumptre, 1996).

There were significant differences between the different forest types and the proportion in which they presented the different DBH sizes: The heavily logged transect (4), showed that trees of DBH sizes between 12 and 20 cm were present in the same proportions as in other unlogged transects, but trees with DBH dimensions larger than those were dramatically reduced. The transect over a logging track (1) roughly presented DBH sizes in the same proportion as other unlogged mixed evergreen forest transects, showing that logging tracks just by themselves do not dramatically affect the structure of the forest they cut through. Mixed evergreen transects were observed to present a significantly larger proportion of stems with DBH between 12 and 20 cm than mixed deciduous transects, but their proportion of stems with DBH dimensions between 50 and 100 cm as well as those over 150 cm was found to be significantly lower. The same happens when looking at the results for height, where there also were significant differences between forest types: the heavily logged transect (1) presented trees with heights of 10 meters or below in the same proportions as unlogged forest transects, but heights over that category presented significantly lower proportions than any other transect. Transect 1, the one on the logging track, presented proportions similar to those of unlogged mixed evergreen transects. These presented a significantly higher proportion of trees of 10 and below meters tall, but mixed deciduous forest transects presented significantly higher proportions of stems with heights over 20 meters. These results point to structural differences between both mixed evergreen transects presenting a larger amount of shrubs and other small canopy stems, and mixed deciduous presenting a higher canopy height.

The biodiversity of the different forest types was also different. The most dominant species of mixed evergreen forest was *Dipterocarpus alatus*, followed by *Irvingia malayana* and *Anisoptera costata*. *Lagerstroemia calyculata* was the most dominant species in mixed deciduous forest, followed by *Sterculia lychnophora* and *Diospyros pilosanthera*. In mixed evergreen forest, the dominant group was found to be the dipterocarps, far ahead of the next group, the Irvingiaceae; Lauraceae, Myrtaceae and Malvaceae were other highly important families to this forest type. On the other hand, the most important family in mixed deciduous forest were the Lythraceae with an IVI almost three times as high as the next two families, Ebenaceae and Sterculiaceae, with other important families in the habitat being the Fabaceae and Phyllanthaceae. Important families in both forest types were dipterocarps, Irvingiaceae, Malvaceae, Combretaceae, Sapindaceae and Sterculiaceae. A particular species, *Diospyros pilosanthera*, as well as its family, the Ebenaceae, were observed to be very important and prevalent in both ecosystems, presenting high numbers of stems and high IVI values in both cases

When comparing the results of this project to those obtained in another study on *T. margarita* in Vietnam (Tran, 2013), it is observed that both study areas differ in numerous ways, even if no analysis on forest type differences was done in the latter study. The forest structure at Ta Kou present a widely different structure, where hardly any trees present a DBH size over 90 cm, while these are not a rare occurrence at VSSPCA. Something similar happens with heights: tall, canopy forming trees, are rare at Ta Kou, where rarely a tree was found to be higher than 30 meters, while they were regularly present at VSSPCA. While some families are important in the habitat in both study sites, appearing among the top 10 most important based on their IVI values (Lauraceae, Ebenaceae, Myrtaceae), the remaining 70% of the list is formed by completely different families: in Ta Kou, the three most important families were the Moraceae, followed by the Euphorbiaceae and the Lauraceae. While these families are also present at VSSPCA, only the Lauraceae is found within the top 10. Meliaceae were very important at Ta Kou, as well as in mixed evergreen forest in VSSPCA. Lamiaceae, an important family at Ta Kou, were not even observed in VSSPCA, although this might be a construct of the difficulties in identifying stems. The most dominant families in VSSPCA, were the Lythraceae, the Dipterocarpaceae and the Ebenaceae, with the latter the only one present in the top 10 list at Ta Kou. Of all the important species in VSSPCA, only the two most dominant, *D. alatus* and *L. calyculata*, are present among the most dominant species at Ta Kou. This and other works on other species of the genus (Gupta & Kumar, 1994) show that langurs are very ecologically flexible and can inhabit very different areas, including those where there is a lack of large canopy forming trees, and when dominant species and families in one area of their distribution are less ecologically relevant in another area, and still succeed in adapting to the different environments. This ecological plasticity is a good sign, showing that the species is able to withstand human activities in their habitat, something that will help conservation efforts and allow a better relationship with human activities in their environment.

Some works have posited the idea that mixed deciduous forests might have been formed as a result of human activity of some sort that eradicated certain taxons of plants, ending with groups such as the Lythraceae as dominants (Blanc *et al.,* 2000). While there are indeed human activities carried out in both fragments, and logging on priced hardwoods like *Xylia xylocarpa*, *Pterocarpus macrocarpus* and *Dalbergia cochinchinensis* has been done, especially around the O'Ksiap station and areas close to farmland, there's the likely possibility that these forest formations might just be naturally occurring ecosystems associated with freshwater courses, such as suggested in previous works (Webb, 2005). However, it is still necessary to note that the logging for certain species in the area has most probably had effects on the results obtained for diversity and species composition for the different transects in the langur home range.

Other explanation for the existence of mixed deciduous formations is that these happen as a result of seasonal fires (whether of natural or human origin), and that they are an intermediate formation between mixed evergreen forest and dry deciduous forest (Lamotte *et al.,* 1999), thus explaining its intermediate position between those habitats regarding structure and species composition. While it is quite likely that some mixed deciduous forests are indeed the result of fire, the species composition, structure and dynamics within each type of forest do differ throughout their range (Bunyavejchewin, 1999). The study area shares some important species or genera noted by other studies in the same type of habitat (Lamotte *et al.,* 1999) but dipterocarps, while present, are not the dominant species in mixed deciduous fragments at VSSPCA. In previous studies, it has also been remarked that when a particular forest fragment has been affected by logging, the way in which it evolves after the disturbance will not be determined beforehand so that it would not automatically become a particular sort of formation (Verburg & van Eijk-Bos, 2003). In addition to that, these habitats are closely interspersed with mixed evergreen forest at the site instead of occupying large areas, and there are no sizeable dry deciduous woodland fragments close to the home range of the study group; also fires do not usually affect large sized trees as much as shrubs, seedlings and saplings (Marod *et al.,* 1999): both of these issues mean that that fire regimes would have to be quite destructive yet located enough that they do not extend very far, which does not seem very likely. Furthermore, it has been observed that forests found in the proximity of water bodies are able to better resist the effects of fires and maintain the original species assemblage (Ferry Slik *et al.,* 2008), and, as already mentioned, mixed deciduous forest fragments at VSSPCA are more frequently found in the close vicinity of water: the stream that ran through the langur home range was mostly surrounded by mixed deciduous forest, as it was the case with other waterholes and streams further afield. Further research on the effects of fire events on the different forest habitats in Indochina would better explain to what extent they have an influence on the transition of one kind of forest into other. Studies on the population dynamics of families characteristic of each kind of habitat, as well as any that are also present in several of them would also help the current understanding of any succession process that might happen. Analysis of soil composition on the different habitat fragments would greatly help explain differences in the plant species composition of the different forest types.

In relation to human impacts, an interesting issue comes with *Sterculia lychnophora*, one of the most dominant species in mixed deciduous forest. Absolute numbers of stems of these species would imply that it is not rare in the area, low frequency shows that all of these stems were observed in a single transect. Furthermore, these stems were all not fully matured individuals. The reason for this is the fact that the fruit of this species is a highly sought after item and as a result it has been heavily targeted by ruthless individuals that cut down the mature tree and pick up the fruit, thus heavily altering the ecosystem.

It can be observed from these results that the impacts of particularly intense logging efforts at localized areas within the study site show an obliteration of plants with stems larger than 20 centimeters of DBH, and taller than 10 meters. However, the true extent and long term impacts of logging in the plant communities at the site are currently unknown, although the sudden disappearance of plants that are among the most dominant species in an environment does not bode well if the damage caused by logging is high or prevalent. It has been observed that if logging is only done selectively, the overall structure of the forest would be maintained, as its impacts will be the most harmful to species that are rare in the assemblage, as opposed to a fire and in addition to that, if logging pressure abates, forest structure will recover over time, although the length of this process varies between studies, from less than twenty years (Ferry Slik *et al.,* 2002) to around fifty years (Okuda *et al.,* 2003; Plumptre, 1996). There are conflicting reports on the effect of logging on the diversity values of forests: While research in Africa registered an increase in the diversity of a forest after logging (Plumptre, 1996), studies in lowland dipterocarp forest in Borneo show that diversity values do not dramatically change after logging (Cannon *et al.,* 1998; Verburg & van Eijk-Bos, 2003), and to further confound the issue, it has also been noted in other studies that diversity diminishes after logging, and it does not recover in the short term (Ferry Slik *et al.,* 2002). These contrasting results most likely stem from the fact that the effects of selective logging on diversity values will greatly depend on the species that are targeted, and their dominance on the plant community (Canon *et al.,* 1998). Verburg & van Eijk-Bos (2003) noted that diversity will be most affected when logging focuses on particular species, so when they eventually disappear from the forest, diversity values will decrease. It is quite likely that if large tree species were to be eradicated from the study site and the surrounding areas, it would be nigh impossible for their numbers to reach those presented before the disturbance happened in a short period of years, and the diversity of the habitat would be compromised. As a result of this, it will not be possible to anticipate the effects on the ecosystem unleashed by the extirpation of particular species, but any other organisms that somewhat depended on those species that are gone will probably disappear from the area or become increasingly rare. All these can have an impact on the use of the habitat by langurs, as they tend to favor areas where canopy is closed and use tall trees with large DBH sizes. Disappearance of these habitat components will adversely affect langur presence in those forest areas.

4.4.3 Terrestrial vertebrate inventory

It is important to note that the species assemblage obtained in this work is not pretended to be a definitive registry of all species present in VSSPCA but a framework from which to expand knowledge of the biodiversity composition in the area and as a complement to understand the species that share the habitat of the Annamese silvered langur.

Thus, there are some taxons that are quite likely underrepresented because of the methodology used. Given that most registries were done by walking around trails in the langur home range mostly during daylight hours, without any trapping work other than the use of camera traps on a salt lick outside of the study group home range, many groups have been hugely underrepresented: Only 2 species each of bats and Murids (rats and mice) were positively identified, which is an insignificant number related to the possible amount of species from both taxons that are probably living in VSSPCA. A trapping work discovered at least 4 further bat species not seen by the author (Ith *et al.,* 2011). This is because in order to establish more species from these taxons, a targeted trapping effort needs to be done during night hours; the same could be said about nocturnal bird groups such as owls and nightjars, which were sometimes heard but not easily observed. Other groups that are underrepresented in the final results are amphibians and snakes, both of which need further trapping and observation under certain conditions, ground dwelling birds, mostly from the Phasianidae family, due to their cryptic coloration and shy habits, and passerines that frequent mixed evergreen fragments: their small size, their speed when moving through the undergrowth and the difficulty in determining colour in the forest shade makes it very hard to identify them, and chances are there are many further species of small forest passerines that are present but have not been identified. Further surveys and censuses will no doubt show further species to be present in VSSPCA, particularly in the most remote areas of it, closer to other protected areas in neighbouring countries.

While the obtained species composition is not historically representative because some species such as Asian elephant (*Elephas maximus*) and Indochinese tiger (*Panthera tigris*) used to be present in the area until recently, the species assemblage is an indicator that several species of large bodied animals are still in good shape in VSSPCA at the moment. In view of the current biodiversity crisis affecting the Indo-Burma Hotspot, these results are even more useful, showing the importance of preserving the protected Areas in the Annamite Region.

Regarding the ecological composition of the fauna in the langur home range, the most successful taxons are small carnivores, primates and squirrels for mammals, passerines and woodpeckers for birds, skinks for reptiles and narrow-mouthed frogs for amphibians.

Records show that there is a relatively healthy ecosystem in VSSPCA, and that even if some large animals have disappeared, many species of them remain in healthy quantities. Large animals found around O'Ksiap include herbivores such as the vulnerable sambar deer (*Cervus unicolor*) and the Indian muntjak (*Muntiacus vaginalis*) The vulnerable gaur (*Bos gaurus*) was present around O'Ksiap but after sustained logging activities in 2013 no more signs of their activity were found in the area. Predator species found in the langur home range include the fishing cat (*Prionailurus viverrinus*), dhole (*Cuon alpinus*), both of them considered endangered by the IUCN and both presenting signs of successfully breeding in the area, and the vulnerable Malayan sun bear (*Helarctos malayanus*).

VSSPCA harbors several species of primate, one of the most successful taxa in the area, with up to 6 primate species using parts of the langur home range. Northern buff-cheeked gibbons (*Nomascus annamensis*) were only established as a species very recently (Van *et al.,* 2010), so few estimates on its global population size or conservation status exist at this moment, but VSSPCA holds a very healthy population of the species, consisting of around 500 groups (Rawson *et al.,* 2011). Gibbons are very common in VSSPCA, and at least one lone male and a family pair share parts of their home range with the langurs. Other important primate species is the endangered red-shanked douc langur (*Pygathrix nemaeus*). This species was only found out to exist in Cambodia in 2008 (Rawson & Roos, 2008), but groups are relatively common in VSSPCA. Populations found in VSSPCA as well as in adjacent areas such as Virachey National Park might also make up significant populations vital for the conservation of the species. The study species, the Annamese silvered langur (*Trachypithecus margarita*) is considered endangered as forming part of the Indochinese silvered langur (*Trachypithecus germaini*) (Nadler *et al.,* 2008), although this status might change once it is widely recognized as an independent species. Regardless of this, populations of the species are common and healthy in VSSPCA, numerous groups of large size having been observed in other parts further away from the O'Ksiap group home range. Lastly, the vulnerable pygmy slow loris (*Nycticebus pygmaeus*) is also relatively common in VSSPCA. This, added with populations of pig-tailed and long-tailed macaques and the fact that hunting pressure up to this date is almost non-existent, especially when compared with neighbouring Laos and Vietnam, makes VSSPCA an important area in regards to primate conservation in Indochina. While stump tailed macaques are known to range in Virachey National Park, it is currently unclear whether they also do in VSSPCA. Further camera trapping efforts in the northern reaches of the site might bear proof of their presence, highly enhancing the present conservation values of the VSSPCA as one of the key sites for primate biodiversity in the region.

Further species of interest include the critically endangered giant ibis (*Thaumatibis gigantea*), the national bird of Cambodia. This species has experienced a population crash due to human activities, and it has been wiped out from most of its former distribution. It is considered that the adjacent Siem Pang Protected Forest is the world's largest stronghold for this species, and giant ibises are regularly spotted or heard an known to nest around O'Kseap, which probably means the population in VSSPCA, although not common, is healthy; conservation work in VSSPCA can only improve conditions for the reversal of the situation in which the species is at the moment. A bird group of conservation importance that were found in large numbers were hornbills. Both great (*Buceros bicornis*) and oriental pied hornbills (*Anthracoceros albirostris*) were found or heard at least once every day that we were out on the field, which probably means that populations in the region are very healthy, but also that they are not currently in danger from poaching from locals as they are in other areas. Birds that were also very common and their breeding observed, but are also known to be targeted by locals for the pet trade were hill mynas (*Gracula religiosa*) and red breasted parakeets (*Psittacula alexandri*). As their populations in the area are healthy but anthropic pressures are prevalent in the region, further conservation efforts should be addressed to curb their targeting for the pet trade, with stronger control on poachers and traders, and educational campaigns addressed to the populace.

Table 4.8 *Species of conservation interest observed in the langur home range*

Class	Species	Common name	Conservation Interest
Mammals			
	Nycticebus pygmaeus	Pygmy slow loris	Vulnerable
	Trachypithecus margarita	Annamese silvered langur	Endangered
	Pygathrix nemaeus	Red-shanked douc	Endangered
	Macaca leonina	Northern pig-tailed macaque	Vulnerable
	Nomascus annamensis	Northern buff-cheeked gibbon	Not known, annamitic endemism

	Prionailurus viverrinus	Fishing cat	Endangered
	Cuon alpinus	Dhole	Endangered
	Helarctos malayanus	Malayan sun bear	Vulnerable
	Arctonyx collaris	Hog badger	Vulnerable
	Aonyx cinerea	Oriental Small-clawed Otter	Endangered
	Cervus unicolor	Sambar	Vulnerable
	Bos gaurus	Gaur	Vulnerable
Aves	*Asacornis scutulata*	White-winged Duck	Endangered
	Pavo muticus	Green Peafowl	Endangered
	Ciconia episcopus	Woolly-necked Stork	Threatened in Cambodia
	Thaumatibis gigantea	Giant Ibis	Critically endangered
	Bubo ketupu	Buffy Fish Owl	Near Threatened in Cambodia
	Buceros bicornis	Great Hornbill	Near Threatened, Threatened in Cambodia
	Mulleripicus pulverulentus	Great Slaty Woodpecker	Vulnerable
	Psittacula alexandri	Red-breasted Parakeet	Near Threatened
Reptiles	*Ophiophagus hannah*	King Cobra	Vulnerable

On the other hand, some species that used to be frequently observed by locals not so long ago are sadly gone. This is particularly true of the Sunda pangolin (*Manis javanica*) and the Burmese hare (*Lepus peguensis*). Not a sign of their presence was seen nor they were recorded on the camera traps, and although they might persist in the more remote reaches of VSSPCA, they might still be in very low numbers. While *L. peguensis* is still present in many other areas around the country, it is considered to be threatened in the region (Gray & Phan, 2011). Both species should be considered as a cautionary tale of with how much ease can the current ecological balance be tipped by the demand of other countries for the local wildlife.

The conservation of these populations inside VSSPCA is very important given the steep decline of the populations of these species amongst many others not only in Cambodia or the Annamite region, but in the whole of Southeast Asia.

4.5 Summary

Species number, stem number, *H* and *E* were mostly found to not significantly differ between different forest types. If a particular transect with very anomalous values was removed from the analysis, *E* values were observed to be significantly higher in mixed evergreen forest than in mixed deciduous. The smallest amount of stems was found on the heavily logged transect. DBH size and height were found to be significantly different regarding forest type. Heavily logged forest showed an almost complete eradication of stems with DBH larger than 20 cm, and taller than 10 meters. Forest where a logging track goes through presents very similar values to those of unlogged evergreen forest, showing that the dangers of tracks are the openings for logging in their vicinity, more than a direct loss of biodiversity from its inception. Mixed evergreen forest presented significantly more stems between 12 and 50 cm, but less stems between 80 and 100 cm, and less trees with heights over 20 meters than mixed deciduous forest. Thus, mixed evergreen forest has a lower canopy, but more layers of it, and a denser structure, with smaller stems, and a more heterogenous species composition. Mixed deciduous forest presents a more open structure, with less canopy layers but a higher canopy limit and a more homogenous species composition.

Although many stems were not positively identified, even to family level, some conclusions can still be drawn. The species and families composition was also observed to be different in each forest type, with dipterocarps dominating in mixed evergreen forest and Lythraceae doing so in mixed deciduous. Lauraceae, Myrtaceae and Meliaceae were particularly important in mixed evergreen forest, while Malvaceae, Fabaceae and Phyllantaceae were important in mixed deciduous forest. Ebenaceae, Sapindaceae, and Combretaceae were important families in both forest types. Dominant species in mixed evergreen forest were *Dipterocarpus alatus*, *Irvingia malayana*, *Anisoptera costata,* *Cinnamomum cambodianum* and *Sandoricum koetjape*. Species with high dominance values in mixed deciduous forest areas were *Lagerstroemia calyculata*, *Sterculia lychnophora*, *Schoutenia ovata* and *Terminalia triptera*. *Diospyros pilosanthera* had a high importance value in both forest types.

Vertebrate fauna was observed to be relatively rich in spite of recent logging activity in the area. Good populations of many groups of conservation interest are still in the area, with large and small bodied ungulates and carnivores frequently observed, with some of the species known to be breeding in the area. Primates are highly diverse and mostly numerous, making VSSPCA a key area for primate conservation in the Annamese ecoregion. Many birds of conservation interest were also observed to be living and breeding in the area, including the national bird of Cambodia, the giant ibis, as well as hornbills, storks and owls. It can be observed that small intensity logging, if curbed early enough, will not have adverse effects on the majority of the vertebrate faunal community, although further law enforcement efforts are needed.

CHAPTER 5

Morphology and demography

5.1 Introduction

5.1.1 Morphological characters of T. margarita

The silvered langur species group is considered to be a monophyletic species group that shares a certain amount of traits, the most obvious one being the grey or silver appearance of the fur coat. The number of species that form this group and the phylogenetic relationships among them, however, are still very much in dispute (Denise *et al.,* 2008; Harding, 2010; Ingicco *et al.,* 2011; Roos *et al.,* 2007, 2008). The Annamese silvered langur is a species that has only been recently described as such, and even then, there is still a discussion on the validity of this assessment, and the IUCN has yet to accept this as a separate species (Nadler *et al.,* 2008). Annamese silvered langurs and Indochinese silvered langurs used to be merged together under the name of the latter, *T. germaini*, and even some recent studies did not consider either of them a species at all, but just subspecies (Brandon-Jones *et al.,* 2004). Studies on both species have erred on the side of caution given the current debate, considering both taxons as *T. germaini sensu lato* (Moody *et al.,* 2011; Timmins *et al.,* 2013), in wait for further evidences. There is a high degree of within species phenotypical variation (Hoang *et al.,* 2012), but some of the reasons for this ongoing debate are also methodological: Indochinese primates have been historically understudied, proper censuses centered on Indochinese silvered langurs have been scarce, and these species are skittish in the presence of human observers due to them being targets for hunters in many parts of their home range (Timmins *et al.,* 2013; Nadler *et al.,* 2007) and there has also been a lack of museum specimens to study for morphological characters, although it has been argued that museum specimens are not very helpful when looking at skin color as well as hair arrangements in the head (Hoang *et al.,* 2012). Furthermore, some studies argue that the different methods used by different studies looking at genetic differences between species have conflicting results or vary depending on the species concept used (Denise *et al.,* 2008).

Silvered langurs most obviously shared trait is the coloration of their coat. All species present some sort of silvery coloration, due to the fact that the tips of the hairs are whitish or creamish (Furuya, 1962; Rowe, 1996). Some species are darker and closer to black, such as the West Javan langur (*T. mauritius*), while other species are much lighter, such as the study species. Interestingly, red colored morphs of some species of silvered langurs have been observed, such as the famous orange morph of *T. auratus* (Nijman & Supriatna, 2008; Zinner *et al.,* 2013), and some individuals of *T. cristatus* observed in Malaysian Borneo also presented a bright red colored coat (Harding, 2011). Morphologically, species mainly differ in the coat and limb coloration, facial hair and hair crest shape.

The type specimen for *T. margarita* was described by Elliott in 1909 and it originated from the locality of Lang Bian, in the Dalat Plateau of South-central Vietnam (Zinner *et al.,* 2013), a geographical location which fits with the observed distribution of observed *margarita* silvered langur forms, but the origin of some other specimens marked as *T. margarita* were places at the Cambodian-Vietnamese border and places in Northwestern Thailand close to Central Laos (Brandon-Jones *et al.,* 2004), geographical areas that do not agree with the agreed geographical distribution of Annamese silvered langurs and would better fit with the agreed distribution of the Indochinese silvered langur (*T. germaini*). The type specimen, as reported by Nadler & Brockman (2014), was observed to present a greyish white fur coat, a black face with a pinkish area of skin around the eyes and a line of whitish hairs on the upper lip; hairs on the back of the head prolonged themselves into a point at the nape, while heads in the forehead were black colored, with a stiff and erect disposition. The top of the head, back, tail and upper limbs were bright silvery gray, hairs being bluish grey with a white tip, while the forearms, hands and feet were black.

The diagnostic coloration of the Annamese silvered langur is considered to consist of a pale grey color coat, head, flanks and tail, with a very pale underside and neck. The forehead, forearms, hands and feet, however, are black. The face is clearer, and presents clear skin in rings around the eyes. The disposition of the hair in the head may vary, but there is no crest on top of the skull as is typical of most silvered langur species and often observed in other species of the genus, the hair being flat, and hairs join in a point at the nape, giving the appearance of a hood; long, light colored hairs on the sides of the head extend into whiskers, while black hairs on the forehead are erect: this particular morphological character is shared with *T. germaini* and is called halo (Francis, 2008; Groves, 2001; Harding, 2010; Hoang *et al.,* 2012; Nadler & Brockman, 2014; Zinner *et al.,* 2013). A particular study in Ta Kou Nature Reserve, in Vietnam, noted that the clear patches of skin around the eyes were a sexual dimorphism, being only present on female individuals, while males presented a fully black face. An albino individual was also observed in this study (Hoang *et al.,* 2010) (Figures 5.1, 5.2).

***Fig.5.1** Trachypithecus margarita body: the coat has a clear color, and the tail, arms and legs are darker. Hands and feet are black. Hairs join occipitally forming a hood and there is no erect hair crest.*

Fig.5.2 *T. margarita face details: the hair on top of the head is flat. Whiskers are present at the sides of the head. The skin around the eyes and lips is clear in color, almost pink*

In contrast, Indochinese silvered langurs are more similar in color to *T. cristatus* and *T. selangorensis*, although the size is larger and the coat is paler than in these species. Fur color is gray, with lighter underside, shanks and throat. Forearms, face, hands and feet are black in color. This species presents a characteristic crest of hair on top of the head, absent in *T. margarita*, but it also presents the long hairs on the side of the head that project into whiskers. The face is uniformly black, and there is also a line of hairs over the upper lip (Francis, 2008; Hoang *et al.,* 2012; Nadler & Brockman, 2014; Zinner *et al.,* 2013). While body dimensions are very close in both species, and individual variability would prevent identification solely by size, it has been noted that body length, including the tail, is slightly larger in *T. germaini* (Francis, 2008) (Figures 5.3, 5.4).

Fig. 5.3 *Trachypithecus germaini body: the coat is darker than in T. margarita and an erect crest of hair can be clearly seen on top of the head*

Fig.5.4 *T. germaini face detail: the erect hair crest is clearly seen. The face is uniformly black. Whiskers on the sides of the head are present in this species as well as in T. margarita*

Studies centered on differences in mitochondrial DNA show that both species of Indochinese silvered langurs are well differenced, with samples from places east of the Mekong River being associated with *T. margarita*, while samples from locations west of the Mekong were associated with *T. germaini* (Hoang *et al.,* 2012; Roos *et al.,* 2007, 2008). This clear separation, however, does not apply to a great differentiation in regards to physical characters. While it would seem there would be enough phenotypic characters to tell both species apart, it is true that there is a high degree of variability in these characters within both species (Hoang *et al.,* 2010, 2012; Nadler & Brockman, 2014; Timmins *et al.,* 2011).

5.1.2 Group sizes and social organization

The number of individuals that can be found in a group of langurs varies widely within *Trachypithecus*, and in some cases, even within species (Biswas *et al.,* 2009; Kumar & Solanki, 2008). While demographic factors like migration, death and birth will mean that group numbers are never stable over time, groups with animals from both sexes should last considerably longer than several weeks to be considered a stable aggregation. Mixed sex groups can be as small as three (*T. auratus*, *T. geei*) (Medhi *et al.,* 2004; Nijman, 1998), and as large as 81 individuals (*T. crepusculus*) (Fan *et al.,* 2015). Regarding silvered langur group sizes, these varied greatly in the studies that focused on wild groups: *T. selangorensis* presented large groups with around 30 individuals on average: 22 and 44 (Furuya, 1962), while *T. auratus* presented smaller groups, with group size averages around 10 to 12 individuals per group or even less (Kool, 1993; Leca *et al.,* 2013; Nijman, 1998, 2014). Group size numbers of Indochinese silvered langur species have been based on observations during censuses more than on long term studies, so knowledge about average group size, group dynamics and the sex ratio for an average group of the species is scarce. *T. germaini* has been observed to present most commonly small sized groups of less than 10 individuals, although a group up to 19 individuals has been observed (Abramov, 2007; Coudrat *et al.,* 2011; Edwards *et al.,* 2012; Hoang, 2003; Le & Nguyen, 2010; Royan, 2010). In regards to group size and composition of *T. margarita*, Nadler and Brockman (2014) refer a previous work that states that group sizes for the species range between 5 to 15 individuals, but the largest known group in Ta Kou Nature Reserve, Vietnam, was observed to present more than 35 individuals (Hoang *et al.,* 2010).

The proportion of adult males to adult females, or sex ratio, of groups of *Trachypithecus* species varies. Some species have only been observed to present uni-male, multi-female groups as the only group structure, like *T. shortridgei* or *T. delacouri* (Li *et al.,* 2015; Workman, 2010), while some others present both uni-male and multi-male multi-female groups (Biswas *et al.,* 2009; Borries *et al.,* 2008; Curtin, 1980; Jin *et al.,* 2009b; Li & Rogers, 2004; Medhi *et al.,* 2004; Nijman, 2014; Schneider *et al.,* 2010); some species like *T. pileatus* and *T. leucocephalus* do present both group structures but there is a preferred tendency towards the harem, while other species lean more towards the multi-male multi-female group structure (e.g. *T. crepusculus*). Silvered langurs were considered to form groups containing several females and one single adult male, by extrapolating the case of *T. selangorensis* and *T. auratus* (Bernstein, 1968; Kool, 1993; Nijman, 2000; Wolf & Fleagle, 1977), but even within the former species, there was a lack of consistency on the information regarding social structure: some studies noted the absence of all male groups and solitary males in *T. selangorensis* (Bernstein, 1968; Furuya, 1962). Furthermore, Furuya observed more than one adult male in all the groups of *T. selangorensis* that he studied: two in one group and three in another. These contrasting results and the lack of further studies has meant that little is known on the social structure and group organization of species in the silvered langur group nowadays. These issues are especially dire in the case of the silvered langurs of Indochina: current research has not yet addressed the actual group composition in *T. germaini*, and it is currently unknown if they more commonly form uni-male or multi-male multi-female groups. *T. margarita* groups have been observed to present a multi-male multi-female structure, but sex ratio values were absent (Hoang *et al.,* 2010; Tran, 2013)

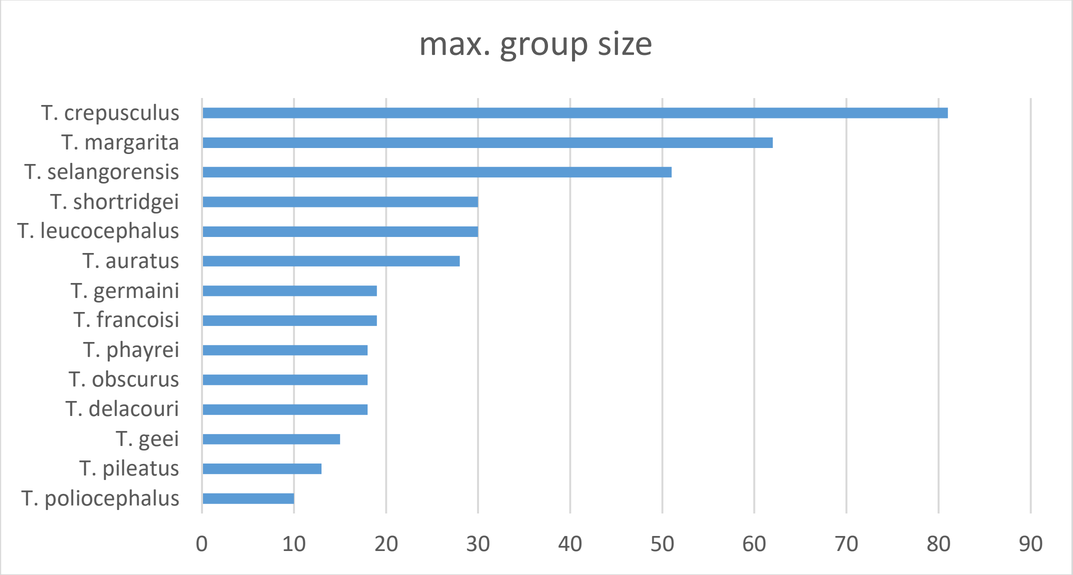

Fig.5.5 *Maximum group size recorded for species in the Trachypithecus genus. Data collected from: Chetry et al., 2010; Fan et al., 2015; Furuya, 1962; Gibson & Koenig, 2012; Hoang, 2003; Hu, 2011; Kumar & Solanki, 2008; Li et al., 2015; Md. Zain & Ch'ng, 2011; Schneider et al., 2010; Tsuji et al., 2013; Wojciechowski & Nguyen, 2013; Zhou et al., 2011b)*

The existence of all-male groups as social aggregations of bachelor males and even immature females or as temporary aggregations prior to formind bisexual groups, while common in odd-nosed colobines, does not seem as common in *Trachypithecus*, and all-male groups have only been observed in some species (e.g. *T. delacouri*, *T. leucocephalus*, *T. shortridgei* and *T. pileatus*) (Biswas, 2009; Green, 1981; Jin *et al.,* 2009b; Koenig & Borries, 2012; Li *et al.,* 2015; Workman, 2010), while, as mentioned above, they seem absent in others. In particular regard to silvered langurs, studies on them never detected the presence of all-male groups (Bernstein, 1968; Furuya, 1962), even though in the former study it seemed most groups had a harem structure with a single adult male. Some researchers suggested that the reason for the absence of these formations in the social organization is that when males reach maturity they might be allowed to stay temporally within the group. Males can also disperse outside of their natal groups in a solitary manner, a behaviour that has been observed in some studies (Jin *et al.,* 2009b; Wolf & Fleagle, 1977). There are a lot of questions on single dispersing individuals, as it is very hard to detect and follow a single animal of such a notoriously difficult taxon to keep track of in its natural habitat such as the colobines, and it is unclear for how long an individual will go on its own outside of other groups.

The aim of the study is to quantify the individual phenotypical variability of T. margarita at VSSPCA and the presence of key morphological characters of the species by focusing on the study group; also, to study group size and composition, and to look at any relationships and interactions between the study species and other sympatric primates found at VSSPCA.

5.2 Methods

5.2.1 Study Site and Study Group

The study was carried out in Veun Sai Siem Pang Conservation Area, Ratanakiri Province, Cambodia. From May 2013 to May 2014, and in the last fortnight of January 2015, an unhabituated group of silvered langurs was tracked in the area and, whenever it was encountered, it was followed until dusk or until the researchers lost the group, acknowledging this by determining no activity or signs of presence of silvered langurs in the area after an hour and a half had passed.

5.2.2 Data Collection

The study group was tracked in the area 5 days a week, starting from 5:30 am. Whenever the group was encountered, and from the encounter time onwards until the end of the day or until an hour and 30 minutes passed without any signs of presence whatsoever from the group showing the animals had not been lost, the group position was recorded every 30 minutes as a GPS point using a Garmin 62s GPS unit.

Group counts were attempted every time the group was found on the move, usually during early morning or evening periods, when the group moved out or into sleeping tree areas. The distance from the observer to the subjects varied, but it ranged from 20 to 100 meters. If individuals were close or the path they used was devoid of any foliage, no material was used to observe the langurs and they were just observed by the naked eye. If distance reached 40 meters or longer, binoculars were used to observe the subjects. Any individual that was observed was categorized in base to its age (adult, subadult, juvenile, infant) and sex class (male, female). The age and sex class categories are explained in detail in the methods chapter.

Several mineral licks were monitored by use of Bushnell Trophy camera traps set up in order to register the wildlife visiting the licks from April 2013 until May 2014. Two such licks a fair distance outside the study group's home range were frequented by Annamese silvered langurs, whose visits were registered from June and July 2013 respectively until November 2013 by images, and from then on to May 2014 by videos. For each visit, the approximate number of animals in the group was calculated, and the number of individuals in each age and sex class was registered, and phenotypical characters that could be observed were also recorded. Cameras recorded the date and time every time a picture or video was taken.

Pictures of silvered langurs during full day follows were taken with a Canon EOS650D camera during the length of the study, always when an animal could be well observed and foliage interference was small, either during movement or when the animal was resting or observant, and preferably whenever their face could be visible. Key phenotypic characters for the species were looked for, such as the shape of the head hair, body and limb fur color or facial markings and color. Given the fact that Annamese silvered langurs, as it happens with most colobines, were shy in the presence of human observers and tried to avoid making their presence known, the distance from the observers to the study subjects most of the time was further than 30 meters away, preventing a proper identification of the different individuals conforming the study group and a high degree of detail in all the animal parts in each of the images obtained , but the resulting images were more than enough for the aims of the study. Due to a lack of proper identification, it is also quite likely that some members of the group will appear more than once in the recorded images.

If the group was found in contact with any other wildlife, the date, GPS position, general group behavior and any interaction or lack of it of the langurs with the other species was registered.

5.2.3 Data Analysis

Group counts were analyzed and the maximum and minimum amount of individuals, both in total and for each of the age and sex categories, as well as mean group size and mean size of each of the age and sex categories.

Every recorded image of silvered langur obtained from full day follows was studied and, whenever each phenotypic character attributed to the species in the literature was visible in any of the photographs, they were noted by their presence or absence. In the former case, the prevalence of the character within the study group was calculated by obtaining the percentage of individual instances in which animals presented each phenotypic character. These characters were tabulated as the following categories: Hand color, feet color, absence of crest, presence of hood, whiskers, presence of eye rings, coat color, leg color, arm color, tail color, chest and belly color. All these characters are explained in detail in the methods chapter.

5.3 Results

A total of 175 photographs were obtained during full day follows, which consisted of 62 individual instances. During the study, 12 instances were of images of adult males (19%), while adult females were photographed in 15 instances (24%). Subadults were photographed in 14 different instances (23%), and juveniles were the age class with the highest number of appearances with 16 instances (26%). Infants, on the other hand, were the age category with the lowest amount of appearances, with only four (6%).

5.3.1 Group size

Thirty four group counts were done during full day follows throughout the study period. The smallest group size registered was of six individuals, while the largest group size recorded was of 62 individuals. Mean group size was very close to 16 individuals. When looking at group composition, adult males were observed to be present from a minimum of one to a maximum of six; mean adult male numbers were around three, and the standard deviation was of ±1.15. Adult female numbers oscillated between a minimum of two and a maximum of 20; the mean number of females in the group was around seven, with one of the higher standard deviation values, ±3.31. The amount of subadults counted ranged from a minimum of none to a maximum of nine; the mean of subadults found in the study group was of three, and presented a standard deviation value of ±2.1. Juveniles were found to be in numbers as little as none up to as many as 21; the mean number of juveniles was of three, with the highest standard deviation value, ±3.8. Infants were the rarest age class to be detected, with a minimum amount of none and a maximum amount of six; mean infant numbers in the study group were almost nonexistent (0.3), and the standard deviation value for this category was of ±1.1.

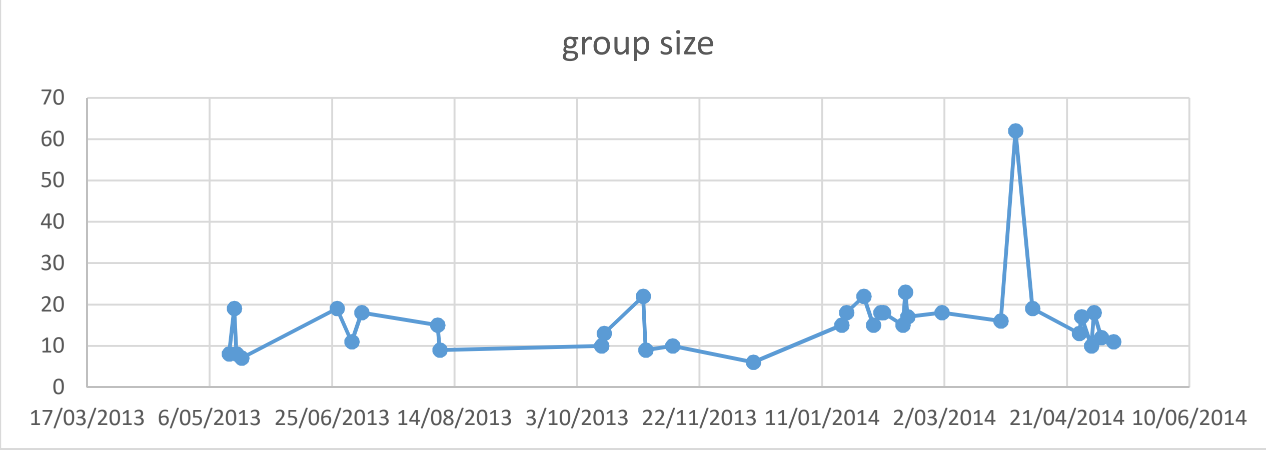

Fig.5.5 *Group size counts during the length of the study.*

Silvered langurs visited the mineral lick in 24 different instances. In seven of these (29%), there only was a single animal, of which six turned out to be subadults with the remaining individual not identified. In three instances (12.5%), only two individuals were observed visiting the mineral lick. In these associations there was always invariably a subadult and an individual which age and sex category could not be ascertained. In the remainder of the 14 instances (58%) the mineral lick was visited by a group of more than three individuals. The smallest amount of individuals recorded was of four, while the largest group recorded was of 20 individuals. Mean group size at the mineral lick was 11 individuals.

Of the groups formed by more than three individuals that visited the mineral lick, two different sets of values were most common. One consisted of three group size values around five, while another consisted of 11 values ranging from nine up to 20. The first set presented a mean number of individuals of five, with a mean amount of adult males of one and a standard deviation of one; the mean number of females was a little below three, and the standard deviation was of only ±0.6; the mean number of subadult and juvenile individuals were the same, and both the mean values and the standard deviation were very similar, 0.7 and ±0.6 in both cases; no infants were observed in this set of values. The second set of values that hovered over 10 individuals in group size presented a mean group size just below 13 with a standard deviation of ±3.1; adult male mean value was above two, with a standard deviation value of ±0.8; adult female mean numbers were of around four individuals, the standard deviation being of ±1.1; the mean number of subadults was a bit above two, and the standard deviation was of ±1; juveniles presented similar numbers, with a mean around two and a standard deviation of ±1.1; lastly, there was a mean of a single infant in the group, presenting a standard deviation of ±0.8. There was also one unidentified individual in one of the instances for this set of values.

5.3.2 Group composition

Male:female sex ratios for group counts obtained during full day follows had a minimum value of 1:1.25 and a maximum value of 1:3.33. The mean sex ratio value for the study group was of 1:2.77. When looking at the productive age ratios for the group, the minimum value was of 1:0.21, and the maximum value was of 1:1.38. The mean age ratio value for the study group was of 1:0.69.

5.3.3 Morphological characters

When looking at the prevalence of phenotypic characters, percentage results showed that both hands and feet were always black whenever they could be seen in the photograph (100%). A lack of upright hair crest on top of the head was noted for all individuals photographed during the study (100%). Long hairs joining at their tips on the occipital region of the head giving the appearance of a hood were observed in all except two instances in which the back of the head could be observed (93%). Long hairs on the side of the face forming whiskers were only missing in two instances as well (98%). Patches of clear skin around the eyes could be observed in a vast majority of the photographed animals (90%). Regarding coat coloration, the most commonly observed color tone was light grey (90%), followed by orange (6%), then medium and dark grey (2% each). Light grey was also the most common color observed for legs (85%). The most frequently observed arm color, however, was dark grey (62%), followed at a distance by medium grey tones (21%). Even less uniform results were obtained when looking at the color tones of the tail; in this particular case, the most common color tone observed was light grey (51%), followed by dark grey (23%), then medium grey (19%). Orange coloration of the different body parts studied had very constant values, always around 7%.

5.3.4 Interactions with sympatric primates

In three days out of the 49 in which langurs where detected, the study group was observed to be in close association with groups or individuals belonging to another species of primate for a certain amount of time (6.12%). The first instance happened on the 21st of August, 2013 at 17:03; the study group was observed to be on the move, and moving amongst them a subadult individual of indeterminate sex of red-shanked douc (*Pygathrix nemaeus*) was also observed. The second observation of association with other primate species happened on 12 March, 2014 at 10:42; the study group was found feeding in the mid canopy on and around a *Mangifera duperreana* tree, while a group of red-shanked doucs (*Pygathrix nemaeus*) were on the higher canopy feeding on the seeds of a *Anisoptera costata* tree. Both species were feeding one on top of the other, and most probably also in between. This association was only broken because of the presence of the researcher, to which the doucs reacted by moving away from the contact area, abandoning it for good at 11:07. Lastly, on the first of May, 2014, the study group was found in the high canopy at 9:42 in close association with Northern pig-tailed macaques (*Macaca leonina*). Both groups were quite active and noisy, and members of both species walked in line through the same path in the canopy at the same time. Around an hour later, the macaque group had left the area while the langurs remained.

5.4 Discussion

5.4.1 Morphology

Previous studies have stressed the fact that a high individual variability has prevented a definite morphological differentiation between *T. germaini* and *T. margarita* (Hoang *et al.,* 2010; Moody *et al.,* 2011; Timmins *et al.,* 2013). While there could be populations of either species with very variable morphological traits that could prevent their proper identification as members of one or other species unless observers manage to get close enough, the silvered langur groups observed in Veun Sai Siem Pang Conservation Area present a very homogenous appearance regarding the phenotypic characters most particular to *T. margarita*. These phenotypic features were highly prevalent in the study group, results that contrast with other studies that found that groups of the species presented more variable phenotypic characters, making it harder to determine if the observed individuals belonged to *T. margarita* or *T. germaini*. No observed animal presented an erect hair crest on top of the head, as *T. germaini* individuals do. Most individuals observed presented long hairs joining together at the occipital region of the head, the only exceptions being the infant individuals and a small juvenile; this probably means that this phenotypic character develops a certain point after an individual has several months of age and has acquired the grey pelage that is characteristic of the species group. The same can be said of long hairs on the side of the face extending and then joining into something akin to whiskers, although it is important to note that this particular phenotypic character is present in both species and is not useful as a defining morphological character that separates both species. The last phenotypic character observed was the presence of clear skin patches around the eyes. A vast majority of individuals observed presented these clear rings around the eyes. These results contrast with observations in other studies, where the rings around the eyes were not that prevalent in observed groups (Hoang *et al.,* 2010; Timmins *et al.,* 2013). One of the reasons for this disparity of results might be the fact that the rings of clear skin around the eyes are sometimes not easy to see with the naked eye due to uneven lighting conditions and the shyness of the study species, making hard for a human observer to note their presence or absence. Hoang *et al.* (2012) noted that the rings around the eyes were very markedly visible when using flash photography on subjects. A methodological issue that could pose problematic in this current study is the fact that some group members were most likely photographed more than once and thus skew the results. The fact that some individuals have figured more than once in the analysis is most likely, but when looking at the amount of instances for each sex and age group the numbers in which all of them appeared were very much the same with the exception of infants, the category which is the hardest to detect due to small size, lack of movement and possibility of being overlooked due to being physically attached to other individuals. Age classes that are easier to detect, like adult males, are present in almost the same numbers or even less than other less conspicuous categories, something that probably also applies at an individual level.

Hands and feet had an unsurprisingly uniform coloration within the sample, being the same as in other *Trachypithecus* species. The same can be said of the whitish colored underparts, with only one digressing result from non-infant individuals. The results for color show that body and legs can safely be considered to present a light grey coloration, and the arms a dark grey to black color. Results of orange color in each body part are pretty consistent (around 6% in all four body parts), given that it is a very striking color that can be hardly confusing in contrast with grey, and it was only presented by infant individuals. Some studies have argued that coloration of *T. germaini* and *T. margarita* is subject to a lot of individual variability and is not a good diagnosing character to separate the species. The main issue here can be related with the perception of an observer of the tone of grey presented by silvered langurs: the skin and lower parts of the hairs are close to black, as it can be seen on the feet, hands and most of the face of both species, and only the tips and superficial hairs in the coat are whitish. This means that the intensity and direction of the light bathing the animals, as well as differences in lighting between exposed places and places under forest cover will result in different tones of grey being appreciated. This is most obvious when observing the tail: under certain illumination conditions, the black skin and basal parts of hair have a great contrast to the outer whitish parts of hair, making it look black in the center and white around. Thus, depending on the light sometimes the tail will look quite whitish in color, while other times the same tail will present a very dark coloration. This factor can account for the lower prevalence values of any particular tone as opposed to other body parts Lack of agreement finally stems from the fact that both species of Indochinese silvered langur have been poorly studied and have almost never been present in zoological collections. The fact that, as with a large number of colobine species, both species are wary of the presence of humans in their vicinity, does not help when trying to assess the coloration and morphology of wild populations of both species.

5.4.2 Group size and composition

The maximum group size registered was only recorded once and as an outlier it might have been the result of the aggregation of two groups, as all other numbers obtained were below that particular one. However, due to the highly cryptic nature of the study species, it was hard to observe the group on most days of the study, let alone get a consistent grasp on the actual numbers in it. It could be argued that the large numbers were the result of two groups merging, but that would lead to discussion on the species presenting a modular society, something that will be discussed further in this section. Large numbers of animals have been observed when encountered, then gradually disapperared from sight, although group presence was ratified by some individuals vocalizing over time. A group size as large as the maximum observed for this study is not commonly encountered, but most definitely not unheard of. Other *Trachypithecus* species present far larger group numbers, like *T. crepusculus* (up to 81) (Fan *et al.,* 2015), and other silvered langur species present maximum group sizes slightly smaller than the study group, with 51 individuals (*T. selangorensis*) (Bernstein, 1968). It has been observed that, at least in the case of the former species, a wide range of items and species in their diet, as well as the ability to respond to seasonal changes on the availability of preferred food items is of key importance to keeping groups with such a high number of individuals (Fan *et al.,* 2015). Diet will be discussed in a further chapter, but results from the obtained data showed that the study species included many different items and species in their diet. In any case, such a large group size only means that the number is the smallest known amount of individuals that form the group, and it could very well be larger than that. The maximum group size was a conservative estimate, given that the main observer had trouble counting the individuals as they kept appearing through the canopy route, and that a further small amount of individuals moved through a different section of the canopy. Rosenbaum *et al.* (1998) already noted that counting the total number of individuals in an unhabituated group was bound to underestimate the actual group size.

The maximum amount of subadults, juveniles and even infants show large numbers of non-adult individuals, implying that the status of the study group, and probably the local population, is quite healthy. Predation pressures were probably low, and it seems that any human activities that were carried out in the home range not only did not target the langurs but that their impact on the survival of the group as of the current moment is quite low. This does not mean that things could not change in the future, or that these effects might take some time to get felt in the study group.

A group that large could also split up in smaller units in order to cope with food availability in the different seasons. There was no direct observation of the study group splitting up in smaller units. In one occasion, however, after spending the whole day with the study group without being able to detect a high number of animals, a further grouping of langurs was observed on the way back, less than 300 meters away from the other group. It could be argued that these could be two different groups of langurs, but encounter rates during the year were quite low, and they would be expected to be far higher in the case that there were several groups of langur in the area that was covered looking for the animals, even if none of the groups were habituated to human observers. Furthermore, there is only one side of the home range that is well connected to forest patches, being the westernmost areas of the home range. The southern borders of the home range eventually meet cut down areas where agriculture is carried out by local villagers, while in the east the encroachment of clear cut areas for farming is very close to the forest. In the northern parts of the home range there are veal or savannah formations. While Annamese silvered langurs were observed crossing small patches of veal, it is most likely they only cross those that are narrow, with forest formations close to each other, and not wide portions of veal as found north of the study group home range, where they would be very vulnerable to predators that are present or have historically been until recent times, such as dholes or tigers. Their skittishness and alertness whenever they were observed in the ground directly or with camera traps supports this assumption. Although fission-fussion dynamics have not been reported very often for *Trachypithecus* species, *Rhinopithecus* social groups often engage in it as a part of their modular societies, but also groups from other colobine species have been observed to engage in this behavior (Ruhiyat, 1983), sometimes as a response to logging activities in their home range (Chapman *et al.,* 2000), and sometimes as a foraging response to the absence of their preferred food items during times of scarcity (Johns, 1986). While further work is need in order to ascertain if fission-fussion episodes are indeed happening in the case of *T. margarita*, and what are the causes behind the langurs presenting such behaviors, it is important to bear in mind that colobine social organization in general, and of *Trachypithecus* in particular might also just be more complex than it was historically attributed to the group.

The information gathered in the camera traps shows that standard deviation values are lower than when the study group was directly observed by the researcher. Thus, it could be argued that camera traps are more accurate in estimating group size and composition. However, there are some arguments that should be taken into account. First of all, the different methods were used to look at different groups, so there is no direct way to compare any differences between the methods, and thus to see which should be a better fit. The second thing to have in mind is that while gathering the data from the files recorded by a camera trap might be more convenient and imply more accuracy, there is a strong lack of context, given that the only data analyzed will be only on those individuals that are recorded by the camera: In many files it could be observed that some individuals would stay out of sight, and only be observed as they would move covered by the canopy and barely framed by the device, or the movement of branches would betray their movement, happening out of frame. Furthermore, it is most likely that not all group members will be at the salt lick at the same moment, if at all. If this could be ascertained by looking at the images and videos, it is impossible for the observer how many other individuals would have remained unrecorded in each instance, being above or behind the camera. A further issue is the fact that it is not known if the two sets of group sizes do represent different groups or sections of the same group. As mentioned above, fission-fussion seems a possibility for the species, and it could be possible that the small set of values would just be small subsections of individuals belonging to the large set of values. Video quality was not good enough to enable any work towards identifying animals individually while still images were much clearer, although there was still a strong lack of context in the latter method due to the shortfalls of using a single camera focused on a certain place.

When analyzing the videos and images recorded by camera traps it appears that both sex classes dispersed out of their natal groups: both male and female subadult individuals were observed to approach mineral licks on their own, and the distinction between sex classes in these particular cases was easy due to the possibility of observing the white patch in the groin in females, which made it able to identify their sex class. These lone individuals may have been moving out of their groups as these events were not preceded or followed close in time by any further individuals or groups from the species, although there is still the possibility of them visiting the salt lick while . Historically, there has been doubt about how often colobine monkey females migrate out of their natal group, with data confirming it in some African (Clutton-Brock & Lukas, 2012; Korstjens & Schippers, 2003; Sicotte *et al.,* 2015; Teichroeb *et al.,* 2009) and Asian (Borries *et al.,* 2004; Koenig & Borries, 2012; Li & Rogers, 2004; Murai, 2004; Qi *et al.,* 2009; Sterck *et al.,* 2005; Zhao *et al.,* 2008) species. While the reasons behind female dispersal can vary within the species (Sicotte *et al.,* 2015), none of the studied colobines that present female dispersion have the same social organization as the study species, presenting groups with a small amount of adult males and all-male group associations (Sicotte *et al.,* 2015, Teichroeb *et al.,* 2009), although the modular societies of *Rhinopithecus roxellana* are very similar, at least superficially. This is of further importance regarding DNA analysis in order to characterize the species. Mitochondrial DNA analyses have been the most commonly used, but these tests rely on a low level of female dispersal, but if the species presents this frequently, the accuracy of these tests might be smaller that thought. With the current data it can only be used in order to call caution on the accuracy of some analyses; the only way to know up to what extent females migrate out of their natal groups would be to properly study their social organization and dynamics.

Langur social groups with several adult males are not a rare occurrence as it used to be thought until very recently, and many species have been observed forming multi-male groups, including the closely related *T. selangorensis* (Fan *et al.,* 2015; Furuya, 1962; Koenig & Borries, 2012; Ma *et al.,* 2015; Zhou *et al.,* 2011b). In the particular case of *T. leucocephalus*, it occurred in an area where harem social structure was prevalent, and it is argued that groups with several males in them are a response to a degradation in the habitat that would lead to a decrease in reproductive success; thus the use of a multimale group as a defence mechanism against large all-male units (Li & Rogers, 2004). On the other hand, studies on *T. crepusculus* in Thailand show that multimale groups form in order to protect their home range from the intrusion of neighboring conspecific groups (Koenig & Borries, 2012). All-male groups have mostly been observed in species in which the most common social structure are harems, formed by one single adult male and several adult females (Li *et al.,* 2015), although that is not always the case (Koenig & Borries, 2012). It is likely that the existence of all-male groups in a particular species would be linked with the development of harem social structures and a lack of social tolerance of group members towards subadult males. These subadult males might be eventually forced out of their natal groups by their sire, who would eventually see them as competition, in addition to adult female group members trying to avoid inbreeding. In the case of *T. margarita*, no all-male groups have been observed, but in *T. crepusculus* all-male groups are formed when subadult males leave their natal group together (Koenig & Borries, 2012). Furuya posited that subadult males might be allowed to stay within the group, at least for a certain amount of time, which would explain the absence of aggregation of young and single males in groups, but this theory would not explain the presence of more than five adult male individuals in a group, as it happened in the study group. Furthermore, solitary subadult males were also directly observed and recorded on camera traps, which might be due to them dispersing on their own; this implies that, if that social tolerance happens, it is definitely not a norm and would not satisfactorily explain the observed sex ratios. If, as previously mentioned, the group undergoes fission-fussion processes, it would be very interesting to observe the composition of the split units, and see the stability, dynamics between group numbers and the amount of males in the smaller units. The reasons for such a group composition could be complex, and in any case further research is needed in order to better understand the group dynamics of *T. margarita*.

Captive groups of silvered langurs have been house in medium sized groups with a multi-male multi-female structure (Shelmidine *et al.,* 2009) or in a harem structure (Amarasinghe *et al.,* 2009), or in small harems (Eakins, 2010; Witte, 2011). While it is true that there could be a certain degree of variability not only, as already observed, within the genus but also within a certain species, it does not seem that small harems are the most common social arrangement for silvered langurs, at least either for *T. selangorensis* or *T. annamensis*, and some zoological institutions housing silvered langurs in these conditions may have done so based on antiquated and unclear information. This is important in the sense that housing animals in numbers and structures that are not the most usual for them in the wild can have many effects on their behavior and social structure, and animals housed in captive or free ranging conditions should be so in the closest social conditions they present naturally.

It could be argued that no individual identification could not lead to certainty that it was always the same group that was encountered and that there could be more of them. However, the home range for the study group is physically isolated throughout most of its extent excepting its westernmost portion. Heavily anthropic influenced areas are found south and west of the langur home range and the geographical limits of the conservation area, with clear cut terrain for farmland use barring all southern and eastern access. The northern section of the home range limits with an extension of savannah, while the western section is indeed a more or or less continuous mosaic of forest. While langurs can move to the ground and both the study group and other groups were detected during the study by local guides on areas of savannah, it is most likely that this behavior, if it is common at all, might only be carried out during the wet season and through narrow patches of savannah that connect close forest fragments, but never to cross a wide expanse of open terrain. Knowing that access to other areas is very restricted in most portions of the home range, the fact that silvered langurs were encountered on a somewhat irregular basis and the fact that the group has a large size, it is more likely that not only there were not several groups of langur in the same area, but the study group would split into smaller units, maybe for days at a time, a factor that could also account for some disparity in group counts. One particular instance of two groups of The splitting of colobine groups into smaller units has been previously recorded in several other species (Ruhiyat, 1983; Nadler, 2009), sometimes in response to a shortage in preferred food sources (Johns, 1986), or to a fragmentation of the habitat due to disturbance caused by anthropic activities (Chapman *et al.,* 2000). Other related species were observed to fragment their groups into smaller units as a result of the fragmentation of the distribution of preferred food species caused by logging (Grieser-Johns & Grieser-Johns, 1995). In the particular case of the study species, both illegal logging and an uneven distribution of preferred food species due to the seasonality of the climate can act as factors that will facilitate the split of the large study group into smaller units.

5.4.3 Interactions with sympatric primates

Instances in which *T. margarita* is in close proximity with other sympatric primate species were not that rarely observed: langurs associated with one sympatric species of cercopithecine, the Northern pig-tailed macaque (*Macaca leonina*), and one of colobine, the red-shanked douc (*Pygathrix nemaeus*). Another species of cercopithecine, the long tailed macaque (*Macaca fascicularis*), is found in the area, but local populations of the species in Veun Sai Siem Pang Conservation Area have plummeted in recent times due to animals being captured and exported to Vietnam to be used in the medicine industry. Thus, it is possible that silvered langurs also associated historically with long tailed macaques, but it will be hard to observe it in the current conditions. This is very probable, though, as other silvered langur species in Western Malaysia and Bali, *T. selangorensis* and *T. auratus*, were observed to associate with *M. fascicularis* for travelling and feeding, and both species seemed to be very tolerant of each other (Bernstein, 1968; Furuya, 1962; Leca et al., 2013), and *Semnopithecus* species have been observed to associate with macaques in Southern India (Singh *et al.,* 1997). Doucs and silvered langurs shared at least one of their food species, a very important one that made up a large proportion of the silvered langur diet in the first two months of 2014. As most sympatric species of colobine usually move through different levels of the canopy, high tolerance on the part of both species could be expected from feeding out of a seasonally abundant resource as well as their capability to eat other plant parts or adjacent tree species. Other sympatric species of colobines were observed feeding in adjacent trees in Bangladesh (Stanford, 1991a). Interestingly enough, douc and silvered langur groups, while using different mineral licks in close proximity or even the same mineral lick at different times of day, did not share using the same mineral lick at the same time on any given day.

The time of the day in which macaques and langurs were observed was in the morning, and animals were seen moving through the canopy in a straight line with individuals of both species passing through the same route. Both species might be sharing their sleeping trees and associating in order to pass the night together, as this kind of association has already been observed in other species: Hatinh langurs (*T. hatinhensis*) and Assamese macaques (*M. assamensis*) have been observed to share sleeping trees (Haus *et al.,* 2009). Given the large amount of animals involved in these associations, the reasons for both species associating could only be explained only by a high predatory pressure or the sympatric species feeding on the same species of tree: while several species that can hunt these primates are known to occur in the area, such as the clouded leopard (*Neofelis nebulosa*) (Rawson, pers.comm.), a species known to prey upon proboscis monkey in Borneo (Bismarck, 2010), the king cobra (*Ophiophagus hannah*), the crested goshawk (*Accipiter trivirgatus*) or the reticulated python (*Malayopython reticulatus*), none of these predators target these primates in such quantities that they will be a driving reason behind the formation of these large associations. Furthermore, an incident was noted in which a yellow-throated marten (*Martes flavigula*) moved in the canopy while the silvered langur group was busy feeding, and no attention at all was paid to the predator while it was present. Having said that, it is most likely that the particular instance where the subadult douc was spotted with the study group does point to predator avoidance in a subadult that is dispersing out of its natal group. Given that silvered langurs and doucs associate together and tolerate each other very well, and being on its own renders it more vulnerable to predators, embedding itself within a silvered langur troop would be a safe way of dispersion. The alternative option is that both species used certain species of tree as both feeding and sleeping trees, and a big seasonal availability made it able for both animals to feed from the same trees. While no information on the pig-tailed macaque diet in the study site is known, it is known that silvered langurs were consuming a lot of unripe fruit at that time, something that will be discussed further in the diet chapter, so an abundance of certain species of fruit could very well be the cause for this association. Knowing that several of these instances were observed, it is highly likely that they might occur on a common basis and they would have been more commonly observed if those species were habituated to human observers.

5.5 Summary

Phenotypic feature analysis showed that *T. margarita* individuals in Veun Sai Siem Pang Conservation Area presented a very homogenous morphology, with very little individual variability, and all the diagnostic characters for the species in the original description prevalent in the study population: light grey coat, with dark hands and feet, absence of an erect hair crest on the head, light skin rings surrounding the eyes, hairs joining together at the sides of the face like moustaches, and at the occipital region, forming a sort of hood in conjunction with the erect hairs in the forehead.

The maximum group count proved to be of 62 individuals, the only species in the genus presenting larger groups being the Indochinese grey langur (*T. crepusculus*). This is still considered to be an underestimation of the actual number of individuals forming the group, given that the animals were not habituated to human observers. It is also possible that the study group experienced fission-fussion processes, with it splitting into smaller units at certain times of the year.

The group consisted of a multi-male multi-female social organization, where several adult males were found, in contrast to many other species in the genus; the adult sex ratio was of around 3 adult females per each adult male. Both male and female subadults were observed to migrate out of their natal groups and disperse in a solitary fashion, although groups of two individuals were also observed.

A large number of juvenile individuals was observed, which shows that the study group was not under a large degree of predation, and that human activities in the home range do not have a harmful effect on the demography of the group yet, also hinting that the species can be resilient to changes in the environment brought up by human activities.

Annamese silvered langurs were observed to associate with different sympatric species of primate. They shared sleeping trees with pig-tailed macaques and were found to feed in close proximity with red-shanked doucs. These latter primates were also observed to associate with the study species when dispersing out of their natal groups.

CHAPTER 6

Feeding and geophagy

6.1 Introduction

6.1.1 Colobine digestive adaptations

As mentioned in the introductory chapter, colobine monkeys have a unique morphological adaptation found in no other group of primates: a sacculated stomach. This specialized organ, in addition to presenting other morphological adaptations like high, sharp molar cusps, thinner tooth enamel, smaller incisors and wider molars, a robust mandibular morphology and larger salivary glands than in other primates, enable this group to better process leaves (Delson, 1975; Fleagle, 1998; Koyabu & Endo, 2010; Zinner *et al.,* 2013). This implies that colobines will be able to survive in harsher conditions than other primate species because of their ability to access readily available food sources regardless of the level of fiber and other plant structural carbohydrates. This is probably one of the driving reasons behind the large diversity of the group and their ecological flexibility as they are able to adapt to eat foods that other primates would not be able to digest. Colobines can thrive as they are also able to tolerate the presence of other primates in the same habitat by focusing on different food items, species or layers of the canopy, and they are better suited to surviving environmental or human disturbances that affect food availability or distribution (Fleagle, 1998; Zinner *et al.,* 2013).

Colobines as a group include a sizeable proportion of leaf matter in their diet. In order to be able to process the cellulose and get rid of the toxic compounds found in these food items, colobines engage in gastro-colic (combined foregut and colon) fermentation by use of a complex, distended and sacculated stomach that harbors symbiotic bacteria that help process these compounds, a feature unique in the order Primates. This stomach is separated into three chambers:

1- Saccus gastricus: where the bacteria are found and most of the fermentation takes place (Bauchop & Martucci, 1968; Caton, 1999; Suzuki *et al.,* 1985).

2- Tubus gastricus: reduces the flow of digesta into the distal parts of the digestive system, but is also engaged in the fermentation in its proximal part, and in the lysis of nutrients (Caton, 1999; Suzuki *et al.,* 1985).
3- Pars pylorica: the true stomach that engages in digestion (Caton, 1999; Milton, 1998; Suzuki *et al.,* 1985).

Reticulated grooves in the esophagus enable ingested liquids to bypass fermentation in the saccus gastricus so they are directly transported to the pars pylorica, facilitating access to nutrients in the liquid without having to wait through fermentation (Milton, 1998). The colon is very capacious and is also engaged in the fermentation of undigested material, at least in the case of *Trachypithecus* (Caton, 1999). It is important to note that even if this sacculated stomach is adapted to the digestion of leaf matter, it is not similar to that of ruminant mammals, being more similar to that of herbivorous marsupials as it presents a tubular shape with longitudinal muscle bands, rather than being multichambered like that of ruminants (Caton, 1999). In addition, the digestive processes are, not surprisingly, closer to cercopithecine monkeys (Caton, 1999). Furthermore, the amount of anaerobic fermenting bacteria inside colobine guts is much higher than in ruminant mammals (Bauchop & Martucci, 1968). Other primates have a simpler digestive system, with many species presenting hindgut fermentation (Lambert, 1998), but none with foregut fermentation. This particular digestive strategy is not only different from other primate groups but also among other herbivorous mammals, with truly chambered stomachs and larger caeca (Chivers & Hladik, 1980); this possibly relates to the smaller body size in relation to most other ruminant species (Caton, 1999; Lambert, 1998; Oates, 1988; Oates *et al.,* 1980). This adaptation enables colobines to thrive on very abundant though lesser quality food items due to their ability to better process high quantities of cellulose, so they can occur at higher biomasses than other primate groups. Thus, it is common to find different sympatric species of colobine in the same area, preferring different strata of the canopy, and sometimes focusing on different species or food items (Chivers, 1985; Davies *et al.,* 1999; Maisels *et al.,* 1994; Zinner *et al.,* 2013). Digestion of leaf matter, however, implies a high metabolic cost for folivorous animals: colobines need larger resting periods than other primates in order to process the compounds that make up their food items (Wich & Sterck, 2010; Zinner *et al.,* 2013).

6.1.2 Historical notions of specialized folivory in colobines

It has been historically thought that due to their specialized morphology, the diet of colobine monkeys was specialized as well, focusing mainly on leaves. In several studies leaves were observed to comprise more than half of what animals ate: they were around three quarters or more of the diet of several African colobines (Chapman & Chapman, 2002), species of *Trachypithecus* (Aziz & Feeroz, 2009; Gupta & Kumar, 1994; Li & Rogers, 2006; Li *et al.,* 2003; Suarez, 2013; Workman & Le, 2010; Yin *et al.,* 2011) and *Presbytis* (Nijman, 2010). In other species, leaves comprised from half to three quarters of their diet, such as in African colobine species (Davies *et al.,* 1999; Oates, 1977), several species of *Semnopithecus* from different habitats in South Asia (Minhas *et al.,* 2010b ; Ramachandran & Joseph, 2001; Roy *et al.,* 2012; Sayers & Norconk, 2008; Vandercone *et al.,* 2012), species in the genus *Trachypithecus* (Curtin, 1980; Hu, 2011; Li *et al.,* 2015; Solanki *et al.,* 2008; Stanford, 1991b; Zhou *et al.,* 2009a) and odd-nosed colobines (Hoang *et al.,* 2009; Yang & Zhao, 2001; Yeager, 1989). Even if leaves are not half of the total diet, they can still be the majoritary plant part consumed (Hanya & Bernard, 2012; Xiang *et al.,* 2012), although in the particular case of *Presbytis potenziani* some studies argue for a folivorous diet with 55% of the diet (Fuentes, 1996) while others point to a frugivorous diet with over 60 % (Hadi *et al.,* 2008). In many studies, quantification of plant parts was not stressed significantly enough (Hadi *et al.,* 2008; Matsuda et al., 2009a; Ruhiyat, 1983), while in others it was directly non-existent (Bernstein, 1968).

Despite this heavy reliance on leaves, colobines, like all primates, can present a high degree of variation in their diet both between different species and between different populations of the same species, something that has been observed in *P. badius* (Davies *et al.,* 1999; Maisels *et al.,* 1994), *C. guereza* (Harris & Chapman, 2007), *N. larvatus* (Yeager, 1989), *T. leucocephalus* (Li *et al.,* 2003; Yin *et al.,* 2011), *P. thomasi* (Wich & Sterck, 2010), *S. priam* (Vandercone *et al.,* 2012) and *S. entellus* (Koenig & Borries, 2001; Newton, 1992). The diet of a particular group varies with the seasons, as the distribution and availability of preferred food items varies (Davies, 1991; Dela, 2007; Ehlers Smith *et al.,* 2013; Hanya & Bernard, 2012; Fan *et al.,* 2015; Guo *et al.,* 2007; Hu, 2011; Kool, 1993; Li & Rogers, 2006; Maisels *et al.,* 1994; Oates, 1988; Rudran *et al.,* 2013; Phiapalath *et al.,* 2011; Xiang *et al.,* 2007, 2012). The diet of a particular group has also been observed to vary between different years (Chapman & Chapman, 2002; Hu, 2011; Li *et al.,* 2015; Zhou *et al.,* 2009a).

It has also been reported that individual trees from the same species targeted by colobine species can have a wide variability regarding their nutritional value (Chapman *et al.,* 2003). Thus, unsurprisingly, colobines, are not able to subsist on just any leaf matter, having to select between young leaves and mature leaves, with the former presenting a higher ratio of protein to fiber; the leaves of different plant species and the different parts of a particular species, given that there will be different proportions of compounds between different parts and/or species, and many will not be nutritious enough for the primates to consume it (Coe, 1984; Roy *et al.,* 2012; Zhou *et al.,* 2013). Sometimes, when feeding on mature leaves, colobines will not even eat the whole leaf, but eat only the petiole or the tip of the leaf, which is easier for them to digest (Davies, 1991; Le *et al.,* 2007; Oates, 1988; Stanford, 1991b). In fact, it has been noted that young leaves are much preferred to mature leaves and will be eaten in far larger proportions, as they have a larger ratio of protein to fiber (Chapman & Chapman, 2002; Davies *et al.,* 1988; Fashing *et al.,* 2007; Hanya & Bernard, 2012; Li *et al.,* 2015; Matsuda *et al.,* 2013; Yeager *et al.,* 1997; Wasserman & Chapman, 2003; Waterman *et al.,* 1988; Workman, 2010), which makes them an ideal food item as the amount of energy it takes to obtain a particular quantity of nutrients will be smaller than in mature leaves; the latter will mostly be targeted by many species only if there is no other source of food available in the habitat: young leaves make up more than three quarters of the diet in some species of African colobines (Chapman & Chapman, 2002; Davies *et al.,* 1999; Oates, 1988). While no Asian colobine species is known to reach those quantities, young leaves still make more than half the diet in many species, most of these from the genus *Trachypithecus: T. leucocephalus* (Li & Rogers, 2006; Yin *et al.,* 2011), *T. delacouri* (Workman, 2010), *T. francoisi* (Hu, 2011; Li *et al.,* 2015) and *T. pileatus* (Solanki *et al.,* 2008). Other species with the same proportions are *P. comata* (Ruhiyat, 1983), *S. vetulus* (Vandercone *et al.,* 2012), and *S. priam* (Vandercone *et al.,* 2012), with the latter species the only one from the Hanuman langur species group that routinely prefers young leaves to mature leaves. Young leaves are also preferred by species of *Colobus* (Davies *et al.,* 1999; Fashing, 2001a; Fashing *et al.,* 2007; McKey *et al.,* 1981; Oates, 1977), *Rhinopithecus* (Li, 2006; Liu *et al.,* 2013; Xiang *et al.,* 2012), *N. larvatus* (Yeager, 1989), *Pygathrix* (Hoang, 2007; Nguyen et al., 2012), *Trachypithecus* (Aziz & Feeroz, 2009; Fan *et al.,* 2015; Gupta &

Kumar, 1994; Kool, 1993; Suarez, 2013), and *Presbytis* (Davies, 1991; Fuentes, 1996; Hanya & Bernard, 2012).

Colobines, while better adapted to a folivorous diet than most sympatric species, are not as effective as herbivores as large bodied ruminant ungulates given their smaller size (a limitation brought by their arboreal life mode) and less complex gut structure (Fashing *et al.,* 2007; Kirkpatrick *et al.,* 2001). This means that they will not be able to process thoroughly any leaf matter that they can access, and they will have to be selective in regards to their diet composition. It has been observed that most species in this group will prefer plant species in which the ratio of protein content to fiber content in the leaves is high, with some studies pointing to this factor as the decisive one in regards to food item choice and mostly considering that the presence of secondary compounds is not a significant deterrent to colobine food selection (Chapman & Chapman, 2002; Davies *et al.,* 1988; Fashing *et al.,* 2007; Felton *et al.,* 2009; Hanya & Bernard, 2012; Li *et al.,* 2015; Matsuda *et al.,* 2013; Yeager *et al.,* 1997; Wasserman & Chapman, 2003; Waterman *et al.,* 1988; Workman, 2010). Some studies, however, have not found such results or have stated that while this has been mostly found to be the case, there are plenty of other factors to bear in mind and there could be exceptions to this trend: they noted that protein content is not always higher in the most consumed plants by colobines (particularly *T. auratus*) (Felton *et al.,* 2009; Kool, 1992), while in others the crude protein to fiber ratio varied significantly between main food species of *T. leucocephalus* (Zhou *et al.,* 2013). Bearing these observations in mind, it seems most of the gathered evidence does support the former observation.

Interestingly enough, it has been observed that Asian colobines have a smaller proportion of leaves in their diet than their African counterparts (Zinner *et al.,* 2013; Stanford, 1991b). These differences could be attributed to differences between species composition of the forests where the different colobines live, as Central and West Africa belong to a different floristic region (Guineo-Congolian) than Southeast Asia (Indochinese or Malesian), a different nutrient balance, given the different geomorphological history and features of both continents, or a different ecological assemblage with varied interactions between sympatric species of colobines and other primates (Stanford, 1991b). While looking at the evidence of numerous studies in the literature that colobines are not strict leaf eaters, this generalization keeps popping up, especially in studies looking at socioecology, behavior and social organization (Sayers, 2013; Snaith & Chapman, 2007): it is considered that as colobines present smaller groups with few incidences of intergroup conflict and a very lax hierarchy with minimal social bonding between adult females, group members must not be competing with each other for resources, thus feeding mostly on items that are easy to access and widely dispersed within their habitat, and they will not need to move through long distances to find food (Isbell & Young, 2002; Sterck *et al.,* 1997). This issue needs to be addressed in the future in further studies regarding the social organization of colobines.

Their adaptations to a folivorous diet notwithstanding, it has been observed in plenty of studies that colobine species do not focus their diet on leaves. Fruits and seeds were almost as common as leaves in the diet of several Asian and African colobine species: *T. pileatus* (Stanford, 1988, 1991b), *P. thomasi* (Wich & Sterck, 2010), *S. vetulus* (Hladik, 1977), *S. priam* (Vandercone *et al.,* 2012), *N. larvatus* (Yeager, 1989) and *C. guereza* (Fashing, 2001a), while in other species, consumption of fruits and/or seeds was larger than that of leaves, during the whole year: *C. angolensis* (Maisels *et al.,* 1994), *C. polykomos* (Dasilva, 1992), *R. avunculus* (Le *et al.,* 2007), *R. roxellana* (Guo *et al.,* 2007; Liu *et al.,* 2013), *P. nigripes* (Rawson, 2009), *S. vetulus* (Dela, 2007), *P. thomasi* (Supriatna *et al.,* 1986; Wich & Sterck, 2010), *P. potenziani* (Hadi *et al.,* 2012), *P. femoralis* (Curtin, 1980); or for a part of it: *N. larvatus* (Yeager, 1989), *S. johnii* (Ramachandran & Joseph, 2001), *S. priam* (Vandercone *et al.,* 2012), *P. rubicunda* (Davies, 1991; Ehlers Smith *et al.,* 2013), *T. auratus* (Kool, 1993), *T. francoisi* (Hu, 2011) and *T. crepusculus* (Fan *et al.,* 2015; Koenig *et al.,* 2004a; Suarez, 2013). Some studies have even posited the idea that colobines are most likely seed-eaters or granivores that resort to leaves as a fallback food whenever their preferred food item is not present (Koenig & Borries, 2001), because of all the evidence showing that seeds are a highly consumed plant part whenever they are available by African and Asian colobine species, in contrast to historical notions on the group.

It was also observed that many of the fleshy fruits targeted by colobine species were mainly unripe, green fruit that were closer to the composition of leaf matter (Aziz & Feeroz, 2009; Davies, 1991; Davies *et al.,* 1999; Davies *et al.,* 1988; Gupta & Kumar, 1994; Hladik, 1977; Hoang *et al.,* 2009; Le *et al.,* 2007; Matsuda *et al.,* 2009a; Oates, 1988; Suarez, 2013; Workman, 2010; Workman & Le, 2010; Xiang *et al.,* 2012; Yeager, 1989), which is most likely related to the fact that these are easier to digest for them given their anatomical characteristics. If the pH balance in the stomach were altered, which would happen if they tried to digest ripe fruit, the consequences could be fatal, as high amounts of sugar would cause high acidosis in the stomach, preventing fermentation from taking place (Davies, 1991; Davies *et al.,* 1988; Koenig & Borries, 2001; Kool, 1993; Milton, 1998; Lambert, 1990; Lambert, 1998). Some studies added that eating ripe fruit takes more energy to get the same amount of nutrients than seeds, and lower amounts of Nitrogen in them are also further reasons as to why colobines avoid eating mature fruit (Milton, 1998). Some species of *Semnopithecus*, however, consumed a high quantity of ripe, fleshy fruit (Koenig & Borries, 2001); so did three species of *Trachypithecus*, one of them a silvered langur, *T. auratus*, all presenting a relatively high amount of ripe fruit in their diet, although most likely under the threshold where it is anatomically viable for them to process the fruit: 24.4% of the total diet of *T. pileatus* (Stanford, 1991b), 25 to 32% of the total diet of *T. obscurus* (Curtin; 1980; Lambert, 1990;) between 27 and 37% of the total diet of *T. auratus* (Kool, 1993).

While the diets in the wild of Asian colobine genera such as *Rhinopithecus*, *Semnopithecus*, *Presbytis* or *Nasalis* have been the subject of many research efforts: *S. johnii* feeds mainly on mature leaves (Oates *et al.,* 1980; Ramachandran & Joseph, 2001; Roy *et al.,* 2012), as do *S. entellus* (Koenig & Borries, 2001; Newton, 1992; Sayers & Norconk, 2008) and *S. ajax* (Minhas *et al.,* 2010b), *S. priam* eats young leaves instead (Vandercone *et al.,* 2012); temperate *Rhinopithecus* species eat bamboo leaves, conifer parts, tubers and lichens (Ding & Zhao, 2007; Grueter *et al.,* 2009a; Guo *et al.,* 2007; Li, 2006; Li *et al.,* 2010; Liu *et al.,* 2013; Xiang *et al.,* 2007, 2012; Yang & Zhao, 2001), while others feed on bark and hard plant parts (Le *et al.,* 2007), *Simias concolor* is mainly folivorous (Hadi *et al.,* 2012), *Presbytis rubicunda* is a highly granivorous species (Davies, 1999; Hanya & Bernard, 2012), *P. thomasi* presents a similar proportion of fruit and leaves in their diet (Supriatna *et al.,* 1986; Wich & Sterck, 2010), while fruit predominates in the diet of *P. potenziani* (Hadi *et al.,* 2012) and *P. femoralis* (Curtin, 1980), and *P. hosei* is highly folivorous (Nijman, 2010), *N. larvatus* highly prefers young leaves and seeds (Matsuda *et al.,* 2009a, 2013; Salter *et al.,* 1985; Yeager, 1989; Yeager *et al.,* 1997); studies on the diet in the wild of *Pygathrix* (Hoang, 2007, Hoang *et al.,* 2009; Nguyen et al., 2012; Rawson, 2009) and *Trachypithecus* species have been far scarcer, in the case of the latter mostly focused on species found in South Asia or China, like *T. phayrei* (Gupta & Kumar, 1996; Solanki *et al.,* 2008; Stanford, 1991b) *T. francoisi* (Hu, 2011), *T. delacouri* (Workman, 2011) and *T. leucocephalus* (Li *et al.,* 2015; Li &

Rogers, 2006; Li *et al.,* 2003; Yin *et al.,* 2011; Zhou *et al.,* 2009a, 2013) and even fewer studies centered on the diet in the wild of species from Southeast Asia have been carried out, like *T. obscurus* (Curtin, 1980) and *T. crepusculus* (Koenig *et al.,* 2004a; Suarez, 2013).

It has been posited that *Trachypithecus* is the Asian colobine genus that is best adapted to a folivorous diet, due to a longer digestive tract, larger fermentation chambers, and molars that are more efficient at shearing, as a way of explaining high granivory in *Presbytis* species (Davies, 1991; Ehlers-Smith *et al.,* 2013). However, other studies centered on *Trachypithecus* species (*T. leucocephalus*) contend this (Li & Rogers, 2006); others point that *Pygathrix* species or *Rhinopithecus avunculus* might be better suited for food items with a large fiber content due to their extra stomach chamber and a stronger jaw morphology (Le *et al.,* 2007; Wright *et al.,* 2008)

6.1.3 Silvered langur diet

As with studies on most of the ecology and group dynamics of the species that form a part of the silvered langur group, studies focused on the diet of the silvered langur species are scarce, with most detailed information coming from *T. auratus* (Kool, 1992, 1993). Some general studies on what is now designated *T. selangorensis* also mentioned some information regarding their diet, but no numbers were given (Bernstein, 1968): leaves made up the larger part of their diet, particularly buds and new leaves, but flowers and seeds were also mentioned to be important, and fruit was also consumed. A study mentioned by Harding (2010) stated that *T. selangorensis* presented a mostly folivorous diet, with up to 91% of it being leaves, the rest being mainly fruit. A recent study was carried out on the composition of the diet of a population of the Annamese silvered langur (*T. margarita*), the same species as the present study, at the Ta Kou Nature Reserve, in Vietnam (Tran, 2013). In that particular case, young leaves were the most consumed plant part (over half the total), although the percentages of fruit and flowers were not insignificant, both being consumed in more quantities than mature leaves.

6.1.4 Geophagy

Consumption of soil is quite common in colobine species (Davies, 1991; Davies & Baillie, 1988; Hladik, 1977; Krishnamani & Mahaney, 2000; Matsuda *et al.,* 2009a, 2015; Newton, 1992; Oates, 1978; Oates *et al.,* 1980; Pages *et al.,* 2005; Ramachandran

& Joseph, 2001; Rawson & Luu, 2011; Wich & Sterck, 2010). This has been justified with several possible reasons: in order to supplement the mineral content in their diet, to neutralize the effects of the secondary compounds found in their diet items, to prevent gastric conditions brought by the alteration of the pH in the gut, or to get rid of internal parasites, but in most studies it was not possible to completely ascertain the driving reason behind the behavior. *Presbytis rubicunda* was never observed consuming soil from the ground, though, but from termite mounds (Davies, 1991; Davies & Baillie, 1988), a behavior also observed in *Nasalis larvatus*, *Semnopithecus entellus* and *Presbytis thomasi* (Matsuda *et al.,* 2009a; Newton, 1992; Wich & Sterck, 2010). Some species visit particular places called saltlicks or mineral licks, areas that seem to play a key role in the ecology of the colobine species that visit them (Pages *et al.,* 2005), which is also the case for the silvered langurs found in Cambodia, both the study species as well as the closely related *T. germaini*, both of which, in Veun Sai Siem Pang Conservation area and other parts of Cambodia, have been observed to visit on a regular fashion (Hayes *et al.,* 2015; Rawson & Luu, 2011).

The aims of this study were to establish in which proportions were plant parts consumed by Annamese silvered langurs, which species and families were consumed in the highest quantities and which were preferred by langurs, and if there was any differences in the diet between seasons. The patterns and frequency of visits to mineral licks were also observed.

6.2 Methods

6.2.1 Study Site and Study Group

The study was carried out in Veun Sai Siem Pang Conservation Area (VSSPCA), Ratanakiri Province, Cambodia, from May 2013 to May 2014 and in the last fortnight of January 2015. The rainy season ran from June to October 2013, while the dry season ran from November 2013 to May 2014. An unhabituated group of silvered langurs was tracked in the area and, whenever it was encountered, it was followed until dusk or until the researchers lost the group, acknowledging this by determining no activity or signs of presence of silvered langurs in the area after an hour and a half had passed.

6.2.2 Feeding Data Collection

The study group was tracked in the area 5 days a week, starting from 5:30 am. Whenever the group was encountered it was followed from the encounter time until the end of the day or until an hour and 30 minutes passed without any signs of the group's presence.

Animals were sometimes directly observed with the naked eye, but in order to ascertain small details such as food items, binoculars or a 70-135mm lens on an EOS 650D Canon camera were used. No systematized recordings were taken due to the difficulty in observing the langurs for long periods of time, so *ad libitum* sampling was used instead. Every time an animal was observed, its age (adult, juvenile, infant) and sex class was noted, as well as the canopy level in which it was found. Canopy levels were established as follows: low (0 to 10m), medium (10 to 20m), high (21m and over). The type of forest in which the animal was found was also noted (mixed evergreen forest, mixed deciduous forest, dry deciduous forest). Whenever a langur was observed eating something, the item was noted and the plant species on which they were feeding was identified as closely as possible to species level with the help of local guides who knew plant names in Khmer or Lao language, then translated with the help of documents referencing local vernacular names (Dy Phon, 2003; Inthakoun & Delang, 2008). In the case that the food plant could not be identified in the field, a sample of the fruit, leaves or flowers or a photograph was taken to the field station in order to ask other guides that worked there and could be able to properly identify the local vernacular name of the species. Also, when plant parts were dropped from trees in which animals were known to be, and they showed clear signs of being fed on (pieces abruptly cut, bite marks, particular plant parts missing from dropped items), the plant from which the parts had fallen was also taken into consideration as a feeding tree.

Plant parts were categorized as one of the following: fruit, seed, leaf, flower or other. Food tree growth types were categorized as one of the following: tree, shrub, vine. Categories have been explained to detail in the methods chapter. Seed eating was differentiated by direct observation of langurs ingesting only the seeds and discarding the fleshy portion of the fruit.

The geographical position of a food tree was marked in UTM coordinates by the use of a Garmin 62s GPS unit, and its height measured in meters with the help of a Haglöf Clinometer. The Diameter at Breast Height (DBH) of food plants was measured in centimeters using a Richter 5m Diameter Tape. Approximate crown area was measured by assuming the crown would present a somewhat elliptical shape, then measuring the two axes of said ellipse by using a 100 m Sterling measuring tape and standing right below the fringe of the crown at the end of each axis. Food trees were labeled by nailing aluminum tags to the plant. In a few cases, along tracks or heavily trodden areas the tags were removed by locals who had spotted them as many are hostile to conservation efforts in the area.

As there was no knowledge at all on the diet of *T. margarita* before the beginning of the study, no phenological information was registered for any species within the transects, as it was not known which of them were consumed by the langurs; only at the end of the study a general idea on the species' diet was achieved.

6.2.3 Mineral lick visits data collection

Several mineral licks were monitored by use of Bushnell Trophy camera traps set up in order to register the wildlife visiting the licks from April 2013 until May 2014. Two such licks a fair distance outside the study group's home range were frequented by Annamese silvered langurs, whose visits were registered from June and July 2013 respectively until November 2013 by images, and from then on to May 2014 by videos. For each visit, the approximate number in the group was calculated, and the number of individuals in each age and sex class was registered, and phenotypical characters that could be observed were also recorded. Cameras recorded the date and time every time a picture or video was taken.

Several camera traps were affected by the humidity brought on by the rains and had to be substituted by new cameras, while two of them were stolen by locals. One camera was set up at the beginning of the dry season in mid-November 2013 to record any images at an exposed mineral outcrop in an open grassland area, but it was stolen in less than 15 days after being installed, and no information was ever obtained from it. A second camera trap, overlooking a mineral lick which was used by red-shanked langurs, was used for much of 2013 and 2014, but was eventually stolen in February 2014. It is known that locals used to get into the forest area surrounding this and a nearby, more hidden lick, most likely looking for ground birds, Burmese hare or mouse-deer, because photographs of them with dogs were recorded in both of the camera traps, so it is likely that the stolen camera was taken by a disgruntled hunter. After consultation with the Conservation International Field Site Manager, it was decided that the stolen camera would not be substituted for the time being, which lasted until the end of this study.

6.2.5 Methodological issues and their effects on the present research

Issues regarding the lack of habituation of the group had certain effects on data collection. First of all, langurs were not habituated prior to the beginning of the study and remained so during the whole length of the project. Given that the natural predator avoidance behavior in langurs is to stay put in the high canopy and be as inconspicuous as they can, on most occasions, especially in the first six months, langurs were hard to spot once they got wind of the researchers' presence, and most behaviors observed were those related to movement, as the animals were easier to see and the sound of the canopy as the passed helped the researchers locate and observe the langurs. As feeding does not involve much movement from the subjects it means that most of the time langurs were feeding they were hidden from view and it was very hard to see what species or plant parts where they feeding on, and as such the present diet is most likely an underrepresentation of the actual diet of the Annamese silvered langur at VSSPCA. Such difficulties regarding all aspects of data collection were mentioned in other studies on Asian colobines (Cui *et al.,* 2006; Furuya, 1962; Li & Rogers, 2005; Rawson, 2009; Rudran *et al.,* 2013; Ruhiyat, 1983; Supriatna *et al.,* 1986; Umapathy & Kumar, 2003).

In addition to the noted difficulties in directly observing the subjects, when they were observed feeding on leaves it was hard to tell if langurs were actually feeding from mature leaves or young leaves. While in some cases it was possible to tell young leaves apart, most of the times it could only be assured that langurs were feeding on leaves. This issue has been noted by previous studies (Ang, 2010; Hladik, 1977; Sayers & Norconk, 2008). Another issue was that, even if it is known that colobines will sometimes only eat parts of mature leafs, such as tips or petioles (Davies, 1991; Le *et al.,* 2007; Oates, 1988; Stanford, 1991b), they were not easily observed and the distance between the subject and the observer meant that it was never appreciated whether the langurs were eating particular parts of leaves or the whole of them.

The obtained data were based on ad-libitum sampling methods; this, coupled with the lack of habituation of the subjects makes it most likely that there is some bias in the results.

These difficulties also applied to whenever langurs were found feeding on fleshy fruit, and sometimes it was not possible for the researchers to be able to discern if langurs were just feeding on a particular part of the fruit, or were just eating most of it. The only plant species in which it was clear that the fruit pulp was the only item the langurs were feeding on was *Sindora cochinchinensis*.

6.2.6 Data Analysis

Recorded food tree GPS points were plotted on maps using Google Earth Pro version 7.1.2.2041. The geographical distribution of the known food plants for the silvered langurs could be seen, and any differences in years or seasons could be observed.

Feeding episodes were counted and all food species and families were quantified and their proportions calculated. Similarly, this was also done with all ingested plant parts. A χ^2-square test was undertaken in order to see if there were any significant differences between the diet compositions in plant parts and plant families in each of the seasons of the year.

Selection ratios (SR) for those species as well as plant families that were found in botanical transects were calculated, by dividing the percentage in which it figures in the diet of the langurs by percentage of the total basal area for the species or family in question:

$$\text{SR(species)}=\frac{Proportion\ of\ the\ species\ from\ the\ total\ langur\ diet}{Proportion\ of\ the\ species\ basal\ area\ from\ the\ total\ stem\ basal\ area}$$

$$\text{SR(family)}=\frac{Proportion\ of\ the\ family\ from\ the\ total\ langur\ diet}{Proportion\ of\ the\ family\ basal\ area\ from\ the\ total\ stem\ basal\ area}$$

Recorded videos and images of Annamese silvered langurs were analysed, and the date, starting time of visit, ending time of visit, visit length in minutes and mean visit length in minutes were calculated. The frequencies of mineral lick visits at different times of the day were also calculated. In order to establish if the observed group size had any influence on the visit length or visiting time, Spearman correlation coefficients were calculated for both cases; times were converted into numerical form in order to be able to do the calculations.

6.3 Results

6.3.1 Food composition

A total of 37 food species were recorded for the Annamese silvered langur at VSSPCA. Of these, 25 were trees, 10 were vines, one was a shrub, and one was apparently invertebrates on an epiphytic fern. Thirty three of the food plants were identified at least to genus level, while three further species remained unidentified; the invertebrates remain unidentified as well, although the epiphytic tree fern on which langurs were feeding was also positively identified to species level. Out of those identified plant species, at least 15 known and identified different species of plant were known to figure in the diet of *T. margarita* by the end of the study period (Table 6.1), with three further species that were identifiable by local experts but no names could be found for them, even in local languages. The tallest recorded food tree measured 54.7m, while the minimum recorded height was 6.8m; mean height was 23.45m. The largest DBH also belonged to the tallest tree, 148.3cm and the smallest DBH was of 4cm, obviously belonging to a vine. Mean DBH was 55.87cm. When looking at crown size, the largest was the tree with the highest values for height and DBH, a *Dipterocarpus alatus* specimen, with 2381m^2; the smallest one was 21.12m^2; mean crown size was 467.58m^2. Vines, of course, do not present a crown.

Table 6.1 *Values for each of the species and families that were recorded for the Annamese silvered langur diet composition*

Family	Species	n of trees	leaves	fruit	seeds	flowers	Importance Value Index	Selection ratio
Anacardiaceae							5.27	1.77
	Mangifera duperreana	1	X				3.97	2.37
Apocynaceae							1.62	252
	Willughbeia edulis	7			X		-	-
Dipterocarpaceae					X		8.89	1.46
	Anisoptera costata	9	X				13.5	3.64
	Dipterocarpus alatus	2	X				26.8	0.21
	Hopea sp.	1					-	-
Ebenaceae							7.78	0.81
	Diospyros oldhamii	1		X			-	-
Elaeagnaceae		1					-	-
	Elaeagnus conferta	1		X			-	-
Fabaceae		3					5.56	5.6
	Peltophorum dasyrrachis	1			X		-	-
	Sindora cochinchinensis	1		X			4.1	4.86
	Dialium cochinchinense	1	X				4.16	12.6
Fagaceae		5					3.33	29.4
	Lithocarpus elegans	4			X		5.42	20.1
	Quercus sp.	1			X		-	-
Irvingiaceae							5.56	0.53
	Irvingia malayana	1		X			10.6	0.53
Rubiaceae							1.11	22.2
	Rothmannia sp.	1		X			-	-
Sapotaceae							-	-
	Madhuca sp.	1		X			-	-

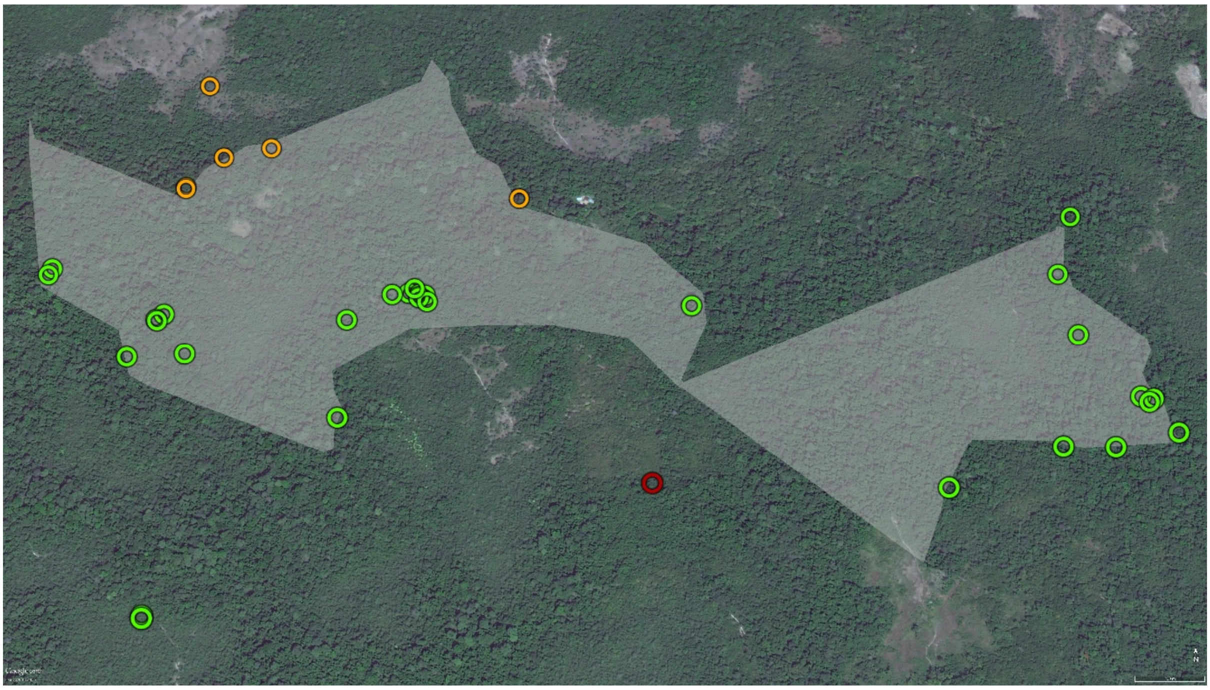

Fig.6.1 *Geographical distribution of known Annamese silvered langur food trees with the study site home range marked as a white area. Orange dots are food trees fed on during the rainy season of 2013, green dots are trees fed on during the dry season of 2013/14, and the maroon dot was a tree fed on during the dry season of 2015*

In total, 134 feeding instances were recorded. Thirty one of them recorded during the rainy season (23.1%), and 103 during the dry season (76.9%). In regards to the proportion of different growth types in the species' diet, the highest amount of instances by far was presented by trees, with 104 (78.8%), although vines constituted a significant part of their diet as well, with 25 instances (18.9%); shrubs were the least frequent growth type consumed, with just three instances (2.3%) (Figure 6.2). The only growth type on which langurs were observed feeding during the rainy season was trees, with all 31 instances. During the dry season, most growth types consumed were trees, with 73 (72.3%), while vines followed with 25 instances (24.8%), and shrubs were last with only 3 (3%) (Figure 6.3).

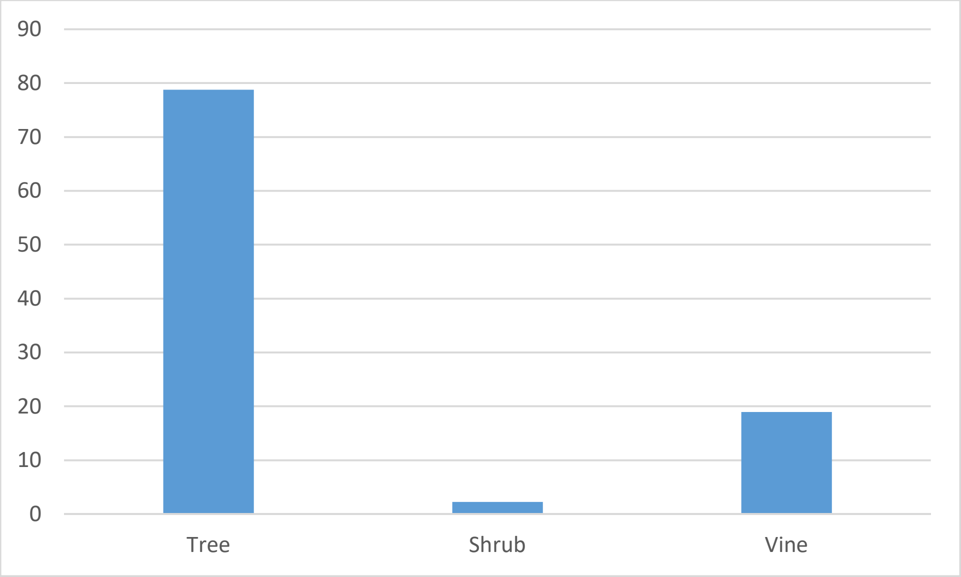

Fig.6.2 *Proportion of the different plant growth types in the Annamese silvered langur during the length of the study*

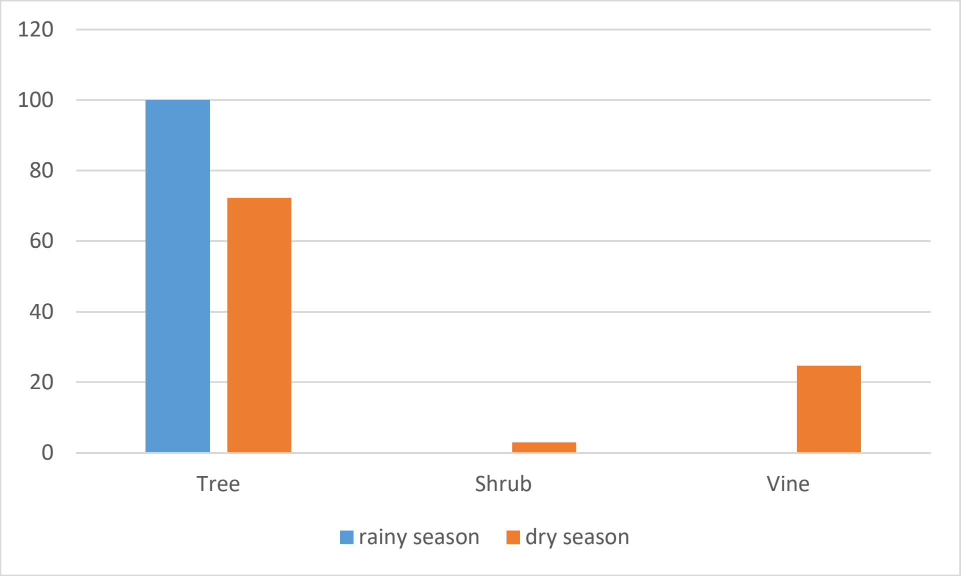

Fig.6.3 *Proportion of the different plant growth types fed on by the Annamese silvered langur diet in different seasons. Blue columns represent proportions during the rainy season while orange columns represent proportions during the dry season.*

Analysis of the different height tiers where langurs were observed feeding showed that *T. margarita* generally feeds on the highest tier of the canopy, above 20 meters of height, with 83 recorded instances (61.94%), followed by the mid canopy, with 42 recorded instances (31.34), while feeding on the low canopy was not common, with only 9 instances (6.72%) (Figure 6.4)

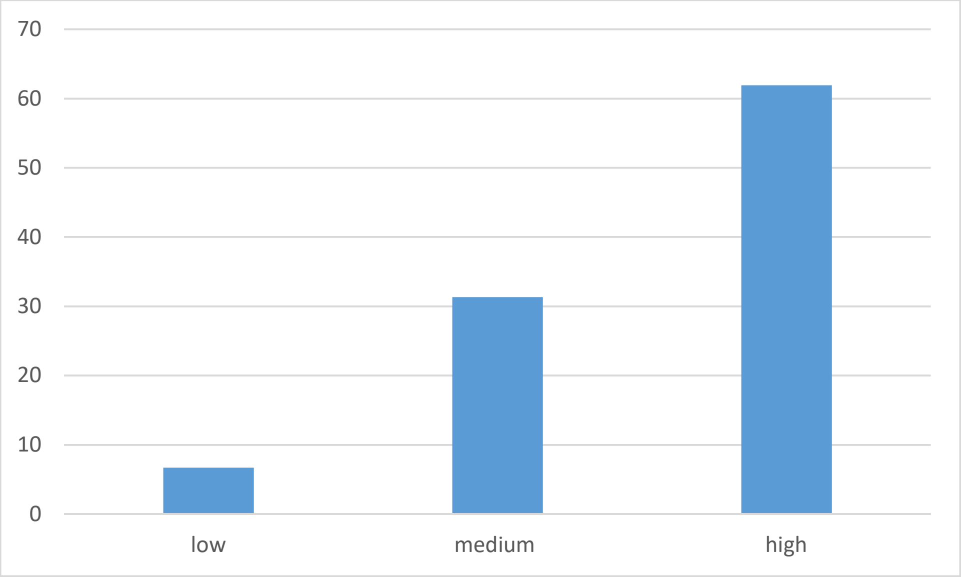

Fig.6.4 Proportion of instances in which langurs were found feeding on the different canopy layers

When looking at the different proportions in which plant parts figure in the diet during the study, the largest proportion was of seeds, with more than half of all consumed items that were recorded: 92 instances (68.7%), followed by fruit, with 28 instances (20.9%), leaves being the next most consumed plant part, with 11 instances (8.2%); far below were other items with 2 instances (1.5%), and the plant part that was least commonly being fed on were flowers, with just one instance (0.7%) (Figure 6.5).

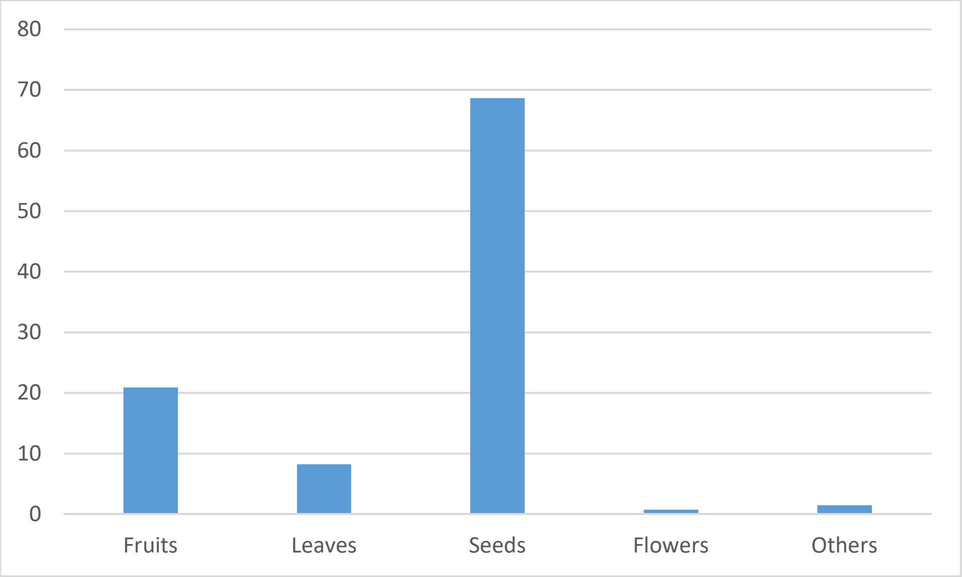

Fig.6.5 Proportion of the different plant parts in the Annamese silvered langur diet throughout the study

If proportions were divided by seasons, the rainy season presented similar proportions of fruit (15 instances, 48.8%) and seeds (13 instances, 41.9%); leaves followed afterwards with just 3 instances (9.7%), while there were no instances where langurs were observed consuming flowers or other items. The dry season diet was dominated by seeds, which made up for more than three quarters of all observed feeding instances (79, 76.7%), with fruits being the next most commonly consumed item, presenting 13 instances (12.6%). The following item were leaves, with 8 instances (7.8%), then invertebrates and flowers, with 2 (1.9%) and 1 (1%) instances respectively (Figure 6.6).

The results of the χ^2-test show that there was a significant difference (χ^2= 19.79, df= 4, p= <0.01), so langurs showed a difference in the composition of their diet in the different seasons. This result is largely due to differences in fruit and seed consumption between seasons.

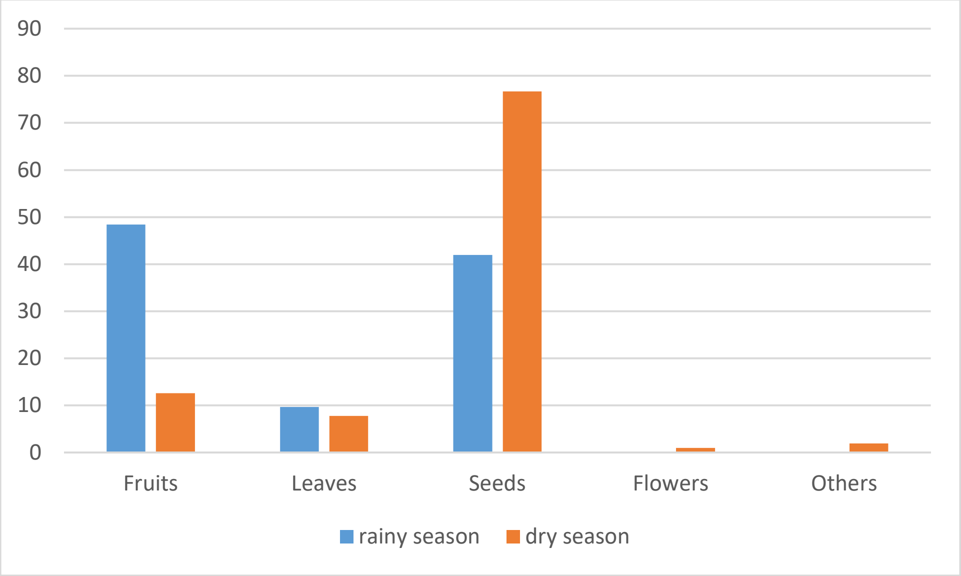

***Fig.6.6** Proportion of the different plant parts in the Annamese silvered langur diet in different seasons. Blue columns represent proportions during the rainy season while orange columns represent proportions during the dry season.*

When looking at the composition of the diet, the two instances where langurs were observed looking under the leaves of epiphytic ferns were left out of the calculations. Regarding the proportions in which species figure in the langur diet, the highest belongs to *Anisoptera costata*, with 39 instances (29.5%); the next most consumed species was the vine *Willughbeia edulis*, with around half of the instances as the first species, 21

(15.9%); the next most commonly eaten plant species was *Lithocarpus elegans*, with 13 instances (9.8%), after which came *Sindora cochinchinensis* and *Peltophorum dasyrrachis* with similar numbers, 9 (6.8%) and 8 (6.1%) instances, respectively. Below these there was *Quercus* sp., with 6 instances (4.5%) *Irvingia malayana* and *Rothmannia* sp. present 5 instances each (3.8%), while *Dipterocarpus alatus* and *Mangifera duperreana* present both 4 instances (3%). Several species present 3 instances or less, and the amount of instances in which the species was unknown was of 6 (4.5%) (Figure 6.7). The only species that langurs were observed to feed on during both rainy and dry seasons was the dipterocarp *Dipterocarpus alatus*.

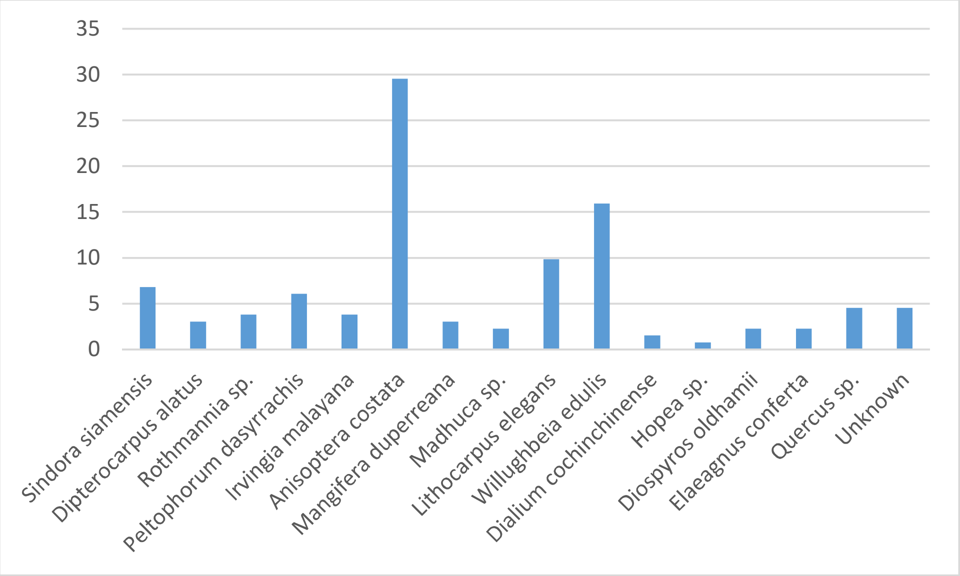

Fig.6.7 *Proportion of the recorded species in the yearlong diet of the Annamese silvered langur*

When analyzing the proportions in which different families appear in the diet, the family that dominates are the Dipterocarpaceae, which were fed on in a third of all instances: 44 (33.3%); Second in importance was the Apocynaceae, with 21 instances (15.9%), all of them pertaining to *W. edulis*; not far behind were both Fagaceae and Fabaceae, both with 19 instances (14.4%). All other families were recorded in 5 instances or less (Figure 6.8). In terms of species diversity in the diet, both Dipterocarpaceae and Fabaceae had 3 different species targeted, while Fagaceae presented 2 food species. All other families of plants that langurs were observed feeding on were only represented by a single species.

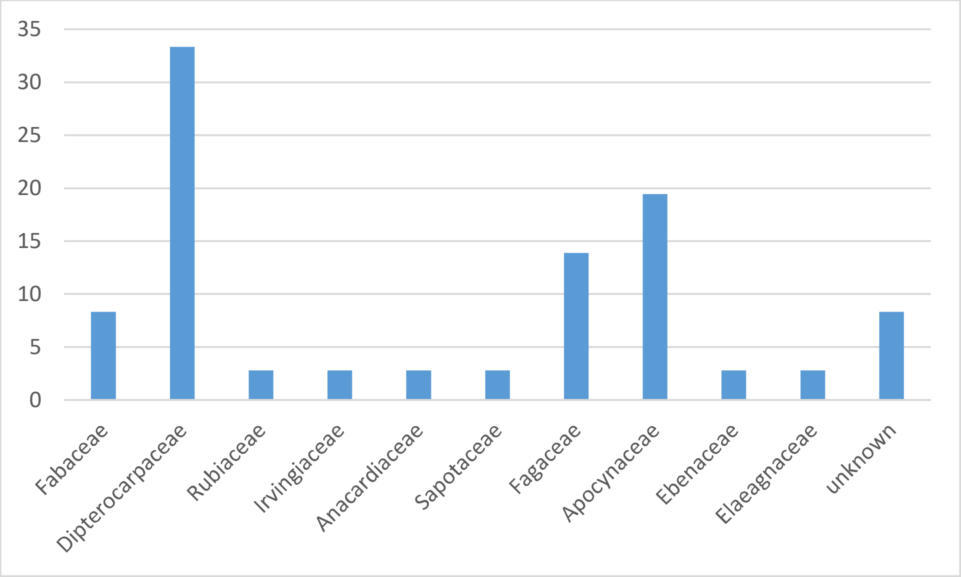

Fig.6.8 *Proportion of the recorded plant families in the yearlong diet of the Annamese silvered langur*

When looking at differences between the family proportions in the diet in the different seasons, we find that most families were observed either during the rainy season or the dry season, with the exception of dipterocarps and legumes. Legumes were more commonly consumed during the rainy season, where they comprised more than half of the diet with 17 instances (54.8%), followed by Irvingiaceae and Rubiaceae, both with 5 instances (16.1 %), then dipterocarps with 3 instances (9.7%); this latter family represented a larger proportion of the diet during the dry season, while legumes were the last most commonly consumed item. 6 families were exclusively consumed during the dry season: Apocynaceae, Fagaceae, Anacardiaceae, Sapotaceae, Ebenaceae and Elaeagnaceae (Figure 6.9). The χ^2-test result showed significant differences in the plant family composition in between the different seasons (χ^2= 103.530, df= 11, p= <0.01). This result is largely caused by differences in fruit and seed consumption between seasons, as different families and species will present different phenology.

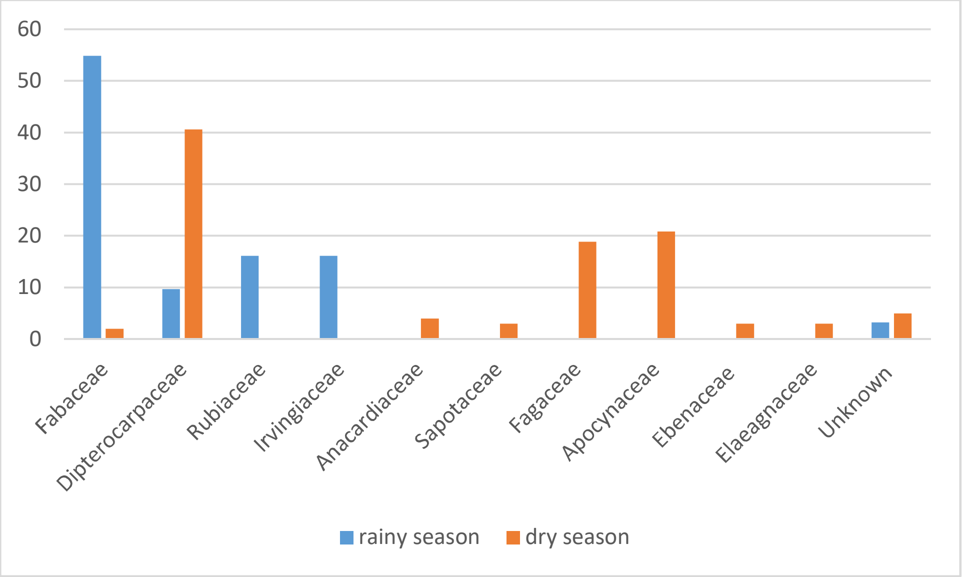

***Fig.6.9** Proportion of the different plant families in the Annamese silvered langur diet on the different seasons. Blue columns represent proportions during the rainy season while orange columns represent proportions during the dry season.*

When comparing the proportion of families in the diet with their dominance in the home range, it is seen that 39.4% of the langur diet came from the 5 most dominant families. If the topmost 6 families are included so that legumes can be part of the results, the proportion of these families rose to more than half of what was eaten (53.8%).

Selection ratio values obtained for the species that were present in the diet and also found in the botanical transects were mostly above 1: the highest SR was that belonging to *L. elegans*, a tree from the Fagaceae, with 20.08; the following species was *D. cochinchinense*, a legume tree, with 12.58. Far below but very positively selected were *S. cochinchinensis* (4.86), *A. costata* (3.64) and *M. duperreana* (2.37). *Irvingia malayana* and *D. alatus* presented values between 1 and 0, the latter being the one most selected against (0.21). No correlation was found between the proportion in the diet and proportion of total base area (r_s=0.49, p>0.05, n=6) (Table 6.1).

In regard to the SR values for the different plant families, the highest value was for the Apocynaceae, with a staggering 251.5; the second most sought after family were the Fagaceae, with a value of 29.36, followed by the Sapotaceae, with 22.24. Fabaceae, Dipterocarpaceae and Anacardiaceae were selected for with less strength, presenting SR values beyond 1 and 2, while Ebenaceae presented a value just below 1 (0.81) and

Rubiaceae had the smallest family SR (0.53). No correlation was found between the proportion in the diet and proportion of total base area (r_s=-0.24, p>0.05, n=8).

6.3.2 Geophagy

Camera traps showed 25 instances in which Annamese silvered langurs visited the mineral licks where the camera traps where set up. During most of the study length a single solitary animal, most likely a juvenile female, was recorded on a camera trap by a salt lick that was regularly used by red-shanked doucs. The rest of the images or videos were recorded at an adjacent mineral lick.

Of all 25 geophagy instances, 11 were of only one or two observed individuals (44%) and the 14 remaining pertained to aggregations of 4 or more observed individuals (56%). No identification was possible to determine whether these were always the same particular individuals in every single case. These 11 instances were included when calculating the frequency for the species visits, duration and most frequent times of visit, but they were not used when analyzing the dynamics of mineral lick visits of langur groups.

Two different groups could be distinguished when looking at group numbers; one was between 4 and 6 in number, while another numbered between 9 and 20. While this is not definite proof that the two groups were separate entities and not subsections of the same group that sometimes split up within the home range, because they could not be individually identified, they were considered as separate groups for the analysis.

The langurs visited mineral licks during all the months of the study with the exception of July 2013. The months that presented the highest number of visits were December 2013 and February 2014, both with 5 visits (20%), closely followed by August 2013 with 4 visits (16%) and January 2014 with 3 (12%). April 2014 presented 2 visits (8%) and the rest of the months presented 1 visit each (Figure 6.10).

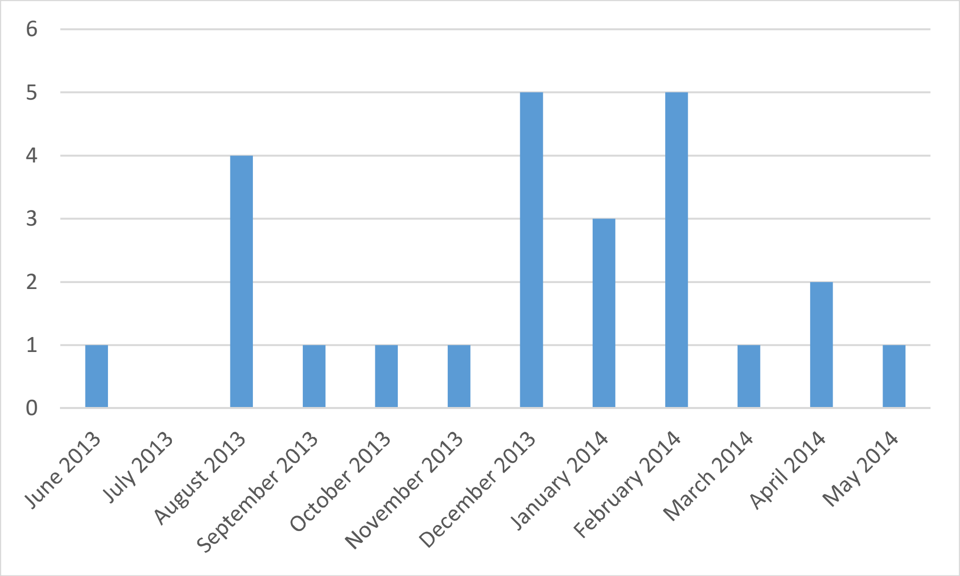

Fig.6.10 *Number of visits by month of Annamese silvered langurs to the mineral licks overlooked by camera traps during the study*

Langurs visited the mineral licks far more often during the dry season, when there were 18 visits, almost three quarters of the total (72%). The number of visits during the rainy season was smaller, but still considerable, with 7 (28%) (Figure 6.11)

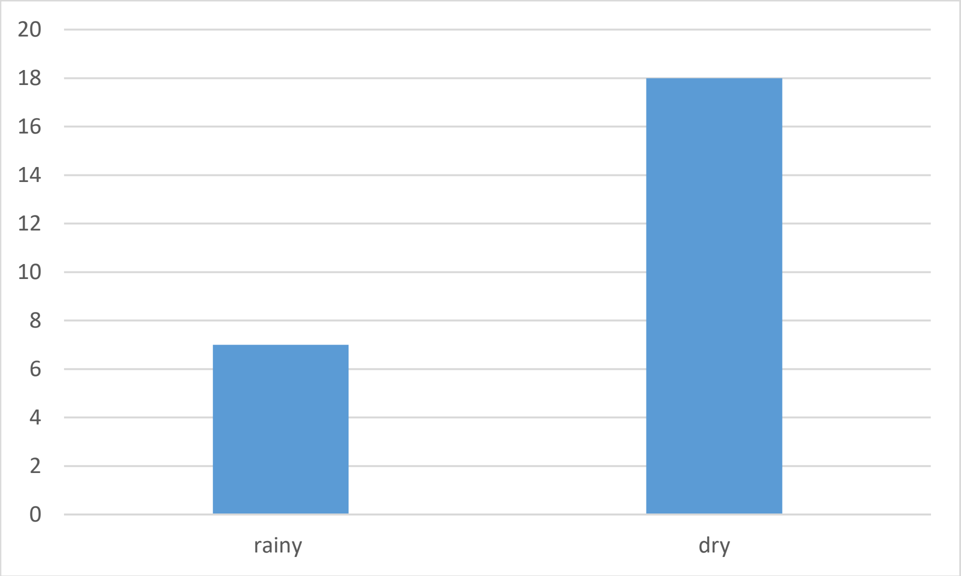

Fig.6.11 *Number of visits by season of Annamese silvered langurs to the mineral licks overlooked by camera traps during the study*

Analysis of visit lengths showed that the total amount of minutes spent by the langurs was 1407 minutes approximately (23 hours and 27 minutes), the mean amount of time spent being 117 minutes (1 hour and 57 minutes), the maximum length of a visit being 261 minutes (4 hours and 21 minutes), which was on January 2014, while the shortest amount of time spent at the mineral lick was of less than 30 seconds, when langurs would appear in an image or video, and the following one that came after 30 seconds would show no langurs in sight. This particular event happened 5 times during the length of the study. The month with the highest amount of minutes spent at the mineral lick was January 2014, with an accumulated 428 minutes (7 hours and 8 minutes), followed by February 2014 with 294 minutes (4 hours and 54 minutes), then April 2014 with 243 minutes (4 hours and 3 minutes), then December 2013 with 226 (3 hours and 46 minutes). October and November 2013 barely amounted to 10 minutes when put together, and June and September 2013 and March 2014 all presented less than 30 seconds long visits, although the former month presented data from only one of the mineral licks, particularly the one that was most commonly visited by red-shanked doucs, so it is possible that the actual amount of visits and time spent by langurs at salt licks for this month were under-recorded (Figure 6.12).

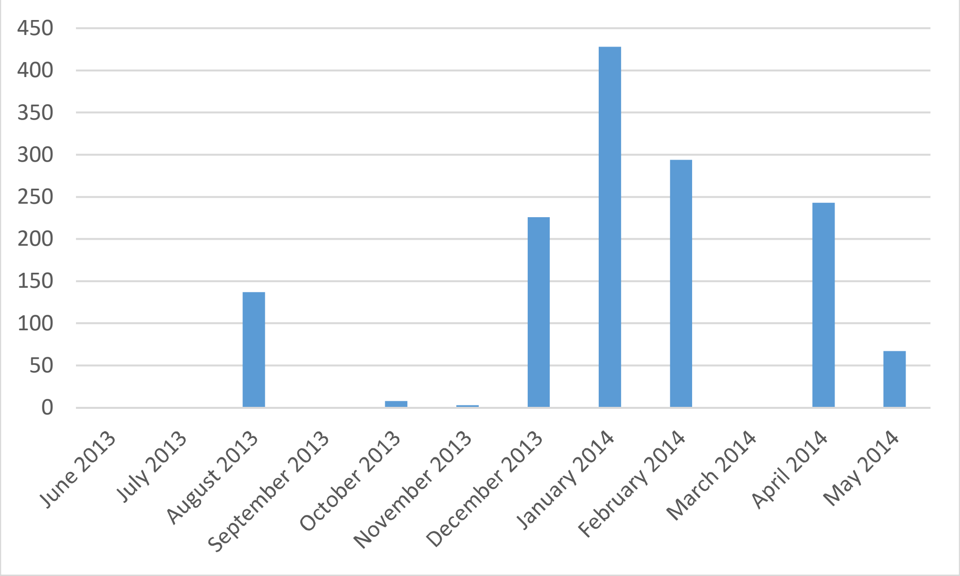

Fig.6.12 *Amount of minutes spent by month by Annamese silvered langurs at mineral licks*

The amount of minutes that langurs spent at mineral licks during the rainy season was much smaller, only a tenth of the total amount with 145 minutes (2 hours and 25 minutes), even if August 2013 was one of the months with the highest amount of visits; on the other hand, the quantity of time they spent during the dry season amounted to 1258, almost nine tenths of all recorded minutes.

The earliest time when langurs were recorded visiting the mineral licks was 7:39 am, while the latest visiting time was 5:58 pm, although that particular instance involved a lone individual. The mean time to visit the mineral lick was 12:41 pm. The different times of the day were divided into parts from 7:00am until 7:00pm every two hours, and observing the number of visits that started in each time bracket showed that most visits started either in the early afternoon or the late morning, with the highest amount of visits, eight, starting between 1:01 and 3:00pm, followed by the 11:01am to 13:00pm and 9:01 to 11:00am time brackets, with 6 and 5 starting times respectively. Two visits were started in the early morning and a single visit started after 5:00pm, the one which was previously discussed (Figure 6.13)

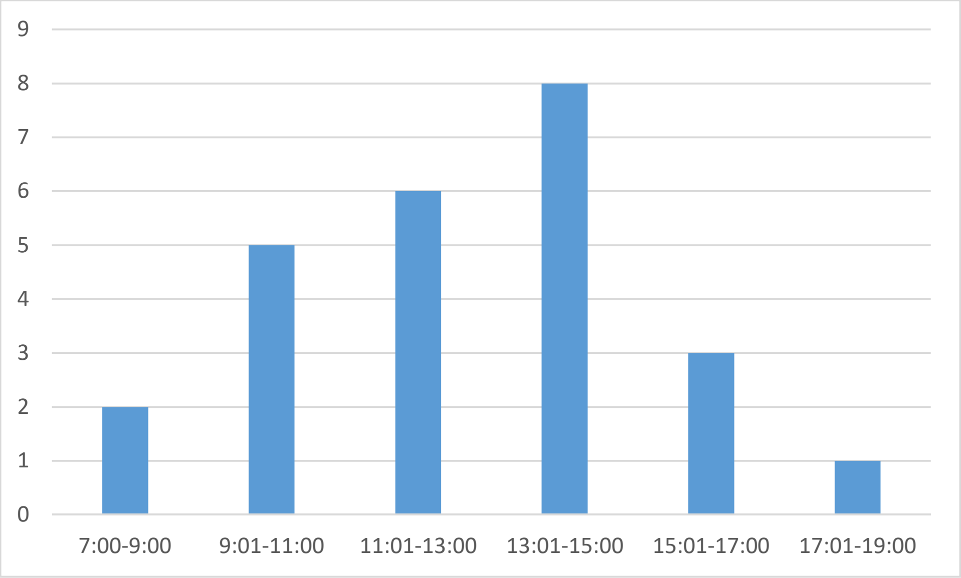

Fig.6.13 *Number of times visits to the salt lick started at times within a particular time bracket*

Spearman's correlation coefficients were calculated for the relationship between the number of individuals visiting and the amount of time spent at the mineral lick; between the number of individuals visiting and the starting time of the visit; and between the starting time of the visit and the amount of time spent at the lick were calculated. In the first case, the test result shows that there is a significantly strong correlation between the amount of time langurs spent in the mineral lick and the amount of animals visiting it (r_s=0.77, p<0.01, n=25) (Figure 6.14). The result of the second comparison shows there is no correlation between the amount of animals in the group and the time they started consuming soil (r_s=-0.34, p>0.05, n=25), and the correlation coefficient value for the third comparison means that there was no correlation between the first time the langurs arrived at the mineral lick and how much time they spent at it (r_s=-0.34, p>0.05, n=25).

Mean days between visits were calculated for the two aggregations that most likely represented two different groups. The smaller aggregation was recorded only three times during the study, and the mean inter-visit interval was 90 days. For the larger aggregation of individuals, the mean inter-visit interval was 18.5 days.

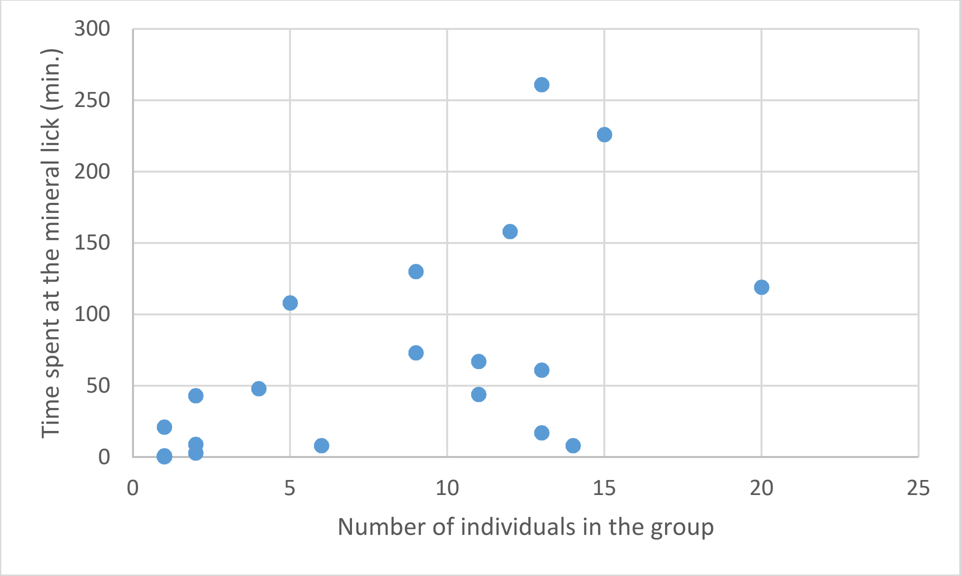

Fig.6.14 *Scatterplot showing the mild correlation between group size and length of the geophagy episode (r_s=0.77, p<0.01, n=25)*

6.4 Discussion

A factor with great significance, which was discussed in a previous chapter, is the significant lack of knowledge of the flora of Cambodia, particularly the northeast of the country, both locally and internationally. Lack of reference material meant that in the case of the three food trees registered during the research that could not be identified, it was not because the local researchers did not know what plants they were, they just did not know any names for them, even if they knew to tell them apart from other plant species in the habitat. Further floristic research is needed not only for more comprehensive studies on the diet and ecology of the Annamese silvered langurs and other local primate species, but also to better know the dynamics of the different plant families, as well as to better categorize plants that can have an economic importance in order for local natural resources to be used in a sustainable fashion by the human populations of nearby villages.

The results obtained in this study show a diet consisting of a very low diversity of species, although it is most likely that this is partly because of the methodological issues previously outlined. Having said that, the only other study on the species' diet found that their study group fed on only 33 species, so it is plausible that *T. margarita* is a species with a very restricted diet. Some colobine species were observed to present diets formed by a low diversity of plant species, like *S. priam* with 58 (Vandercone *et al.,* 2012), *T. pileatus*, with 52 (Solanki et al., 2008; Stanford, 1991b), *P. verus* with 50 (Oates, 1988), *S. ajax* with 49 (Minhas *et al.,* 2010), *Colobus angolensis,* with 46 (Maisels *et al.,* 1994), *T. delacouri* with 42 (Workman, 2010; Workman & Le, 2010), *S. vetulus* with 41 (Rudran *et al.,* 2013), *R. avunculus* with 31 (Le *et al.,* 2007), *Presbytis comata* with 28 (Ruhiyat, 1983), *T. auratus* with 23 (Kool, 1993). Other species present a high dietary diversity, like *N. larvatus* with 188 (Matsuda *et al.,* 2009a; Salter *et al.,* 1985), *T. francoisi*, with 164 (Hu, 2011), *T. crepusculus* with 148 (Fan et al., 2015), *T. obscurus* with 137 (Curtin, 1980), *Pygathrix nigripes* with 152 (Hoang *et al.,* 2009), *P. cinerea* with 135 (Nguyen et al., 2012), *T. leucocephalus* with 128 (Zhou *et al.,* 2013), *Presbytis rubicunda* with 122 (Hanya & Bernard, 2012), *Presbytis potenziani* with 118 (Hadi *et al.,* 2012), *R. brelichi* with 107 (Xiang *et al.,* 2012), *S. concolor* with 99 (Hadi *et al.,* 2012), *S. johnii*, with 97 (Oates *et al.,* 1980; Ramachandran & Joseph, 2001; Roy *et al.,* 2012) and *P. badius* with 84 (Maisels *et al.,* 1994). In other cases there was intraspecific variability, like in *S. entellus* (Hladik, 1977; Newton, 1992; Sayers and Norconk, 2008), *Presbytis thomasi* (Gurmaya, 1986; Wich & Sterck, 2010), *T. obscurus* (Curtin, 1980), *T. phayrei* (Gupta & Kumar, 1994), *R. bieti* (Grueter *et al.,* 2009a; Xiang *et al.,* 2007) and *R. roxellana* (Guo *et al.,* 2007; Li, 2006; Li *et al.,* 2010). Some species, while presenting a diverse amount of species in their diet, focused mainly on a small number of them (Ehlers Smith *et al.,* 2013).

While the results obtained by this study do not show a high dietary diversity for Annamese silvered langurs, a more diverse diet has been observed in closely related species living in habitats under strong seasonal fluctuations or human disturbance (Hu, 2010; Li *et al.,* 2015; Li & Rogers, 2006; Zhou *et al.,* 2013), and other studies mentioned that species with a diet low in folivory, like the present study species, would also present a high diversity of food species (Li *et al.,* 2003); on the contrary, other studies have found that highly granivorous colobines have a low diverse diet, but more diverse than folivorous species (Maisels *et al.,* 1994). Fashing (2001a) noted that African colobines living in dry and gallery forests, which are close in structure and climatic conditions to those of Annamese silvered langurs at the study site, presented a low diversity diet. While there are probably several ways in which human disturbance of the habitat affects the number of species in *Trachypithecus* diets, removal of key species for the diet of local langurs forces them to diversify the number of species they consume to make up for the loss (Hu, 2010; Li *et al.,* 2015; Li & Rogers, 2006; Zhou *et al.,* 2013). The results obtained in this study make it hard to know if the diet of the study group was impacted in any way by seasonality or human disturbance, although it is most likely that these factors played some part; it seems likely that human disturbance at VSSPCA was not as strong as the Chinese sites in the mentioned studies and that most of the floral assemblage is still present in the study site, so that the diet has not been heavily altered. In order to ascertain and the effects of logging on the study species' diet and to determine the number of species targeted, further research is needed, while also aiming to improve our knowledge of other species consumed by silvered langurs would help management plans in order to better deal with human activities and the different effects that the change of seasons would have on langurs.

Annamese silvered langurs were observed to be mainly high canopy feeders, foraging mostly on heights of 20 meters or above, and only seldomly foraging on shrubs or the lower parts of the canopy. Other *Trachypithecus* species have been observed to engage in this as well (*T. obscurus*) (Curtin, 1980). This can account for the low amount of feeding instances recorded, as feeding langurs would not be particularly obvious and could have been hidden from the researcher's view. Having said that, in one particular instance, an adult female was observed to descend to the ground, completely unaware of the researcher's presence, and forage on the forest ground for just below two minutes. Given the fact that the observer did not want to advertise his presence, and that the subject was partially hidden by vines and shrubs, it was not possible to confirm what sort of food it was looking for in the ground. It most likely meant some particularly rare item, as langurs were observed to drop uneaten seeds, fruit and leaves mixed with eaten parts, so they would not descend to the ground in order to retrieve such items: it could be speculated that it could be epiphytic fungi or mushrooms, some insect, or even eggs or small vertebrates, but only further dietary studies could hint at which of these items might form part of the langur diet.

Contrary to the results obtained by the study in Vietnam, this study found seeds were the most frequently consumed plant part by the langurs in VSSPCA throughout the year; they were the dominant plant part in the diet during the dry season, and though behind fruit pulp or whole fruits during the rainy season, they still constituted quite close to half of the total amount consumed. As noted by earlier works (Davies *et al.,* 1999; Koyabu & Endo, 2010; McKey *et al.,* 1981), as well as some others referenced by Fashing *et al.* (2007), the particular digestive system of the colobine monkeys does not only enable them to be able to digest leaf matter and process secondary compounds produced by the host plant in order to make their parts unpalatable and thus deter herbivores from feeding on them, it also allows colobines to better process and digest seeds. As seeds are a key plant part, they can also store secondary compounds to protect them from predation, so the colobine digestive morphology poses a strong advantage if animals focus their diet on seeds. One study noted that three sympatric African colobines in Sierra Leone, consumed the seed of a particular species at different stages of maturity (Davies *et al.,* 1999). Results like these emphasize that colobine monkeys are not exclusively specialized folivores, but can also have a much broader diet closer to other primate groups, whether annually or seasonally, which hints at a higher degree of ecological, and probably social complexity. Nijman (2010) observed that the proportion of leaves and flowers in the diet of some *Presbytis* species was reduced while the proportion of fruit and seeds was increased, when populations were living in forests under logging conditions. While it is hard to draw comparisons with the current set of data, it is possible that some parts of the diet would be the result of the study group reacting to the logging activities in their vicinity.

Importantly, the study species can clearly be considered a seed predator. Given that Annamese silvered langurs destroy the seeds of most fruit that they consume, not only do they not act as a seed dispersal vector, but they have a great impact on the population dynamics of the plant species that they consume, which will probably have an effect on the ecosystem. Yeager (1989) posited that granivorous colobines could maintain a balance in the vegetable communities of those habitats they inhabit, preventing the species they target from dominating the community, thus permitting the establishment of other minor plant species that would otherwise be at a disadvantage. It would be of importance to look in what way seed destruction by the Annamese silvered langurs affects the targeted species.

More than half of the diet of some colobine species is constituted by fruit: more than 60% in *S. vetulus* (Dela, 2007; Hladik, 1977), about 50% in *S. johnii* (Ramachandran & Joseph, 2001), up to 67% of feeding time in *P. thomasi* (Supriatna *et al.,* 1986) and *P. potenziani* (Hadi *et al.,* 2012), while in other species, even if their proportion is not over a half, it is still the highest of all food items: 48% in *P. femoralis* (Curtin, 1980), 47% in *R. avunculus* (Le *et al.,* 2007). The same can be said for seeds: 76 % *P. rubicunda* (Ehlers Smith *et al.,* 2013), 60-75% in *C. badius* during the latter part of the year (Maisels *et al.,* 1994), 50% or more during the whole year in *C. angolensis* (Maisels *et al.,* 1994), 35% in *C. polykomos* (Dasilva, 1992), 34.7% in *P. nigripes* (Rawson, 2009), around 30% in *R. roxellana* (Guo *et al.,* 2007; Liu *et al.,* 2013). In many of these studies, however, there was not a clear separation established between seeds and other fruit parts consumed by the study species, which makes it hard to tell if they were centered on the whole fruit or in only a single part of it. A particular study centered on the diet of a limestone *Trachypithecus* species did note, however, that while fruits were sometimes targeted by the study species, seeds were a very low priority food item (Li & Rogers, 2006). Annamese silvered langurs either consumed the whole fruit, such as the case of seed pods, very small sized fruit and fruits where only the prickly skin was thrown away, or just the seeds where the rest of the fruit was clearly discarded, although in some cases part of the flesh was consumed along with the seeds. This selectivity has been observed within the silvered langur species group (Kool, 1993), as well as within the other genera of African (Davies *et al.,* 1999; McKey *et al.,* 1981) and Asian colobines (Davies, 1991; Hoang *et al.,* 2009; Newton, 1992; Phiapalath & Suwanwaree, 2010; Stanford, 1991b).

Contrary to observations showing colobines generally feed on unripe fruit for anatomical reasons, the phylogenetically related *T. auratus* has been observed to feed on ripe fruits (Kool, 1993). The only ripe fruit that Annamese silvered langurs were observed feeding on here was that of *Sindora cochinchinensis*, where the taste of the fruit is tart rather than sweet, which suggests that the nutrient composition of the fruit may not be harmful for the langur's digestive balance. The targeting of tarty tasting ripe fruit has also been observed in another species within the same genus, *Trachypithecus pileatus* (Stanford, 1991b). The fruit of *Sindora cochinchinensis* was manipulated by opening and disposing of the thorny cover, removal and ingestion of the pulpy aril connected to the seed, and finally by dropping the seed to the forest floor. Interestingly, it seems the pulpy aril of *Sindora* species has compounds that have an important role in regulating seed dormancy, and thus the seedling will not germinate until the aril has been completely detached from it, or the inhibitors have been diluted by the actions of the environment (Schmidt, 2007). This means that Annamese silvered langurs most likely represent a key role for the dispersion and germination of *S. cochinchinensis*, removing the pulpy arils from the seed, preventing seed dormancy and helping the species recruitment. Thus, even if silvered langurs are mostly granivorous and might hinder the recruitment of species such as *A. costata* or *W. edulis* by destroying their seeds, at the same time they are putting other species like *S. cochinchinensis* at a competitive advantage by dispersing their seeds and promoting their growth. This might even happen with other plant species that so far we are unaware of. Further research should be undertaken by looking at the presence of seeds in langur faeces at times when seed consumption is observed to be high in order to look at the survivability of seeds that are ingested by langurs. Also, in order to look at a potential role of recruitment facilitator of *S. cochinchinensis* or other plant species, looking at seedling recruitment in plots around registered food trees, and in particular areas where langurs are known to gather or defecate.

Although it has been argued that colobines avoid feeding on dipterocarp species, exceptions to this do happen (Davies *et al.,* 1988; Newton, 1992; Rudran *et al.,* 2013; Salter *et al.,* 1985), and the results obtained in this study also show otherwise: dipterocarps were actively selected by langurs during the length of this study, with at least two species being observed as part of their diet; one of them, *Anisoptera costata*, not only provided almost a third of the total recorded diet, but it was also the source of most of the food that the study group consumed during the first two months of 2014 and was strongly selected by langurs. Other Asian colobine species from different genera (*Presbytis potenziani*, *Semnopithecus vetulus*) have also been observed to be reliant on dipterocarps for food (Fuentes, 1996; Rudran *et al.,* 2013). Given the amount of seeds consumed by the study group, it is likely that seasonality will have a big impact on the proportion of seeds in the group's diet. Production of seeds is not only seasonal, but also some species produce seeds differently in different years (Zhou et al., 2009a; Sakai, 2002). The family Dipterocarpaceae presents one of the most extreme examples of irregular production of seeds: Dipterocarps reproduce in a particular manner called mast fruiting, with all individuals of a particular species in a forest engaging in reproduction at the same time, although these phenomena do not happen in time or space in a regular manner, and several years will pass in between each of them (Appanah, 1993; Ehlers Smith *et al.,* 2013;

Medway, 1972; Sakai, 2002). This means that in the particular year during which the study was carried out, mast fruiting of *Anisoptera costata* took place and the study species took great advantage from the phenomenon. Considering that different species of dipterocarps, as well as different parts of them, were targeted by the langurs, it is evident that they are key factors in the Annamese langur ecology. All these factors mean that a complete study on the diet of the study species and its effect on the species' ecology would need to involve more years in order to look at differences between years as well as between seasons, and look at how the study group would change its diet in the absence of mass dipterocarp breeding events. While it is not possible to confirm without further results, it is most likely that Annamese silvered langurs consumed seeds in direct relationship with their availability, as is expected given the fruiting conditions of the dipterocarps, as well as the seasonality of the area in which they live and its effects on the other different plant species, some of them also consumed by the study species. Langurs were also observed feeding on the leaves of a species of *Hopea*, given that species from this genus flush leaves twice every year (in the particular case of a species in Malayasia one of these periods starting in April (Medway, 1972)) it is possible that animals were feeding on young leaves during one of this flushing episodes. These characters might make *Hopea* trees a valuable resource for langurs by making new leaves available when other species are not flushing.

Studies that focused on other colobines with a large proportion of seeds in their diet showed that many of these species targeted plants from the family Fabaceae (Aziz & Feeroz, 2009; Davies *et al.,* 1999; Gupta & Kumar, 1994; Kool, 1993; Maisels *et al.,* 1994; Suarez, 2013), something that also applies to neotropical folivorous species (Bicca-Marques, 2003). Legume species, while not the most sought after group during the study, were still well within the 4 most consumed families by Annamese silvered langurs, which were very partial to selecting members of the family as food. Members of the study group were observed feeding on seeds and leaves of three different plant species that were identified as belonging to that particular family on 19 different instances. It is of interest to compare results of the floral analysis of the langur home range, showing that legumes presented a high dominance value, were the sixth most dominant family in the habitat, and were also selected over other families that were even more dominant, some of them also highly consumed by langurs, such as dipterocarps. The lower amount of Fabaceae than other families obtained in the study, as compared with other granivorous colobines has several possible explanations: one being that the amount of Fabaceae consumed by Annamese silvered langurs was underestimated during the study. *Trachypithecus* and *Presbytis* differ in their diet composition, as the two genera have a somewhat different digestive morphology (Davies, 1991; Ehlers-Smith *et al.,* 2013); it can also be due to the fact that both studied species were found in different habitats, as *T. margarita* inhabits assemblages with deciduous species in the tropic, while P. rubicunda lives in equatorial evergreen forests (Davies *et al.,* 1988; Ehlers-Smith *et al.,* 2013; Hanya & Bernard, 2012; Kool, 1993; Waterman *et al.,* 1988); a third option is silvered langurs might eat a larger proportion of dipterocarp seeds some years, while in others the proportion of Fabaceae or other families might be much higher. Only a further analysis on the composition of the the study species' diet over the different seasons and at the study site will establish if this is the case. At any rate, it is important to note that even if they are granivorous, silvered langurs focus on different plant families compared to other African or Southeast Asian colobines that mainly feed on seeds.

There are some interesting implications to the high amount of plants from the Fagaceae that were present in the diet. Fagaceae were as commonly consumed as legumes, with another 19 recorded instances, but selection towards species from this family was even stronger than with legumes. Tropical species of Fagaceae that are found in lowland formations are able to flower and flush not only yearly, but several times during a single year, and fruits can be kept on their stalk in the tree's canopy for several months (Kaul, 1986; Kaul *et al.,* 1986; Medway, 1972). Furthermore, as it seems these processes can vary not only within the family but also within the genus, it means that there would be a vast amount of potential food for animals which fed on these plants. Langurs in the present study feed on both leaves and acorns of different genera, tied to the high selectivity towards the family, which probably implies that Fagaceae are a key resource for the diet of the Annamese silvered langurs at the site, providing them with leaves and seeds throughout the whole year. The dominance value of the family in the habitat is not particularly high and strongly contrasts with dipterocarps and legumes, which are more widely distributed and consumed by *T. margarita*. Indeed, it seems that Fagaceae stem distribution in lowland tropical forest in Asia is scattered (Kaul *et al.,* 1986). This means that langurs are highly selective of Fagaceae plant parts and not only do they probably consume them when available, but they also depend on the accessibility of their seeds and young leaves whenever those resources are not presented by other species of plant. Further proof of this is the fact that *T. margarita* were observed feeding on *Quercus* acorns in January 2015, while the previous year they were feeding on the seeds of masting dipterocarps. Himalayan grey langurs (*Semnopithecus ajax*) have also been observed feeding on *Quercus* plant parts, but interestingly only buds were recorded as a food part, and not acorns (Minhas *et al.,* 2010b).

The flesh and seeds of a species of *Diospyros* were consumed by the study group. Feeding on flesh and immature seeds of *Diospyros* plants is known to be common in many species of African primates (Tutin *et al.,* 1996), but also in Asian colobine species, such as *Semnopithecus priam* (Unanthanna & Wickramasinghe, 2010), or even one that is sympatric with the study species in some parts of their range, such as the black-shanked douc (*Pygathrix nigripes*) (Hoang, 2007). This, in addition to the fact that the family to which this genus belongs, the Ebenaceae, is the third most dominant family in the habitat, implies that it is entirely possible for langurs to consume other *Diospyros* species in addition to *D. oldhamii*. Then again, selection ratio values for the family Ebenaceae were relatively low, falling barely below 1, so further information is needed in order to confirm each possibility. Another group that has been observed as food for other colobines were *Elaeagnus* species, of which fruits were also noted as a food item in the diet of Himalayan grey langurs (*S. ajax*) (Minhas *et al.,* 2010b).

A group of plants known to occur in the study group home range but were not registered as langur food items during the project were fig trees (*Ficus sp.*). Other species in the genus, like *T. obscurus* (Curtin, 1980; Lambert, 1990), *T. phayrei* (Gupta & Kumar, 1994), *T. crepusculus* (Suarez, 2013) *T. leucocephalus* (Li & Rogers, 2006; Li *et al.,* 2003; Yin *et al.,* 2011). *T. pileatus* (Solanki *et al.,* 2008) *T. delacouri* (Workman, 2010) and *T. francoisi* (Zhou *et al.,* 2009a) and even other silvered langur species, like *T. auratus* (Kool, 1993), have been observed to feed on fruits or leaves from this genus, in some cases even focusing on ripe fruits. As the dietary list for the species is far from complete, it is quite possible that Annamese silvered langurs feed on the fruit and/or seeds of *Ficus* species: *T. margarita* was indeed observed feeding on plant parts of up to ten different species of *Ficus* at Ta Kou NR in Vietnam (Tran, 2013), which hints that it is likely that plant parts of species within the genus will figure in the langur diet at the study site, although the dominance of Moraceae at VSSPCA was radically low when compared to that at Ta Kou, where it was the most dominant of all families. One of the reasons for this difference is that it seems that human disturbance has been much lower at VSSPCA, with the vegetational composition at this site presenting a higher diversity of plant groups and a larger amount of tall canopy trees than in Ta Kou, which might actually include more preferred food items, and populations at Ta Kou had to adapt to the local conditions by focusing on other species or groups for food. It is also possible that langurs at VSSPCA do not particularly target figs for feeding because they are rare in their habitat. *Ficus* stems were rarely chanced upon in vegetation plots that were set up for previous studies in VSSPCA (Frechette, 2014). At the same time, this rarity might be the reason for the absence of feeding records of langurs on fig fruit, even though species within the genus fruit asynchronously and several times a year in some cases (Corlett, 1987; Damstra et al., 1996; Kannan & James, 1999; Lambert & Marshall, 1991; Medway, 1972; Milton *et al.,* 1982) and thus it could be a resource of particular importance to species in the habitat. Only further studies focused on both the vegetation composition of the habitat as well the langur diet at the study site will elucidate if, and to what extent, *T. margarita* feed on fig trees at VSSPCA.

The amount of leaves observed in the diet was very low, conflicting with other results obtained for species of the genus, like *T. phayrei* (Aziz & Feeroz, 2009; Gupta & Kumar, 1994), *T. obscurus* (Curtin, 1980) and *T. leucocephalus* (Li *et al.,* 2015; Li & Rogers, 2006; Li *et al.,* 2003; Yin *et al.,* 2011). It is likely that the amount of leaves in the diet was underestimated: the animals being shy and elusive, it was not possible to observe them closely most of the time, particularly when they were stationary in the canopy. This means that some or many feeding instances were not observed. While leaves and leaf parts could be overlooked on the ground while monkeys are feeding on them in the canopy, the same may be true of seeds of small-sized fruit, as well as small fruits and flowers. In addition, studies on *Presbytis rubicunda* (Davies, 1991; Ehlers Smith *et al.,* 2013) showed that leaf consumption was low most of the year, particularly mature leaves, so it is possible that leaf proportions in the study species' diet are low anyways. It is important to note, however, that the species in those two studies belongs to the genus *Presbytis*, considered to be more frugivorous than *Trachypithecus* (Davies, 1991; Ehlers-Smith *et al.,* 2013; Zhao *et al.,* 2009). Contrary to other studies (Supriatna *et al.,* 1986), langurs were not found particularly easy by the sound of fruit being dropped from the canopy by langurs feeding, but feeding behaviors or signs of it were already observed once the group was located.

Interestingly, the most dominant genus in the langur home range, *Lagerstroemia*, was found to be regularly consumed by the conspecific group found at Ta Kou NR (Tran, 2013). Furthermore, leaves from *Lagerstroemia calyculata* or other species within the genus were consumed by other Asian colobines as well (Matsuda *et al.,* 2009a; Rawson, 2009; Stanford, 1988). While langurs at VSSPCA were never observed feeding on *L. calyculata* leaves during the study, the study group tended to spend most of their time in mixed deciduous forest areas, the patches of forest where the species was dominant, during most of the rainy season, which is the time of the year when this deciduous species presents foliage. This, coupled with the fact that *T. margarita* does regularly feed on *L. calyculata* at Ta Kou (Tran, 2013), means that it is likely that this species of Lythraceae is present in the silvered langur diet at VSSPCA.

Flowers appear not to be eaten in high proportions by langurs. It may be that the true amount of these plant parts was underestimated in the study, but it is important to note that low proportions of flowers were also found for other granivorous Southeast Asian colobines (*P. rubicunda*) (Davies *et al.,* 1988), so in the present study, the overall proportion of them in the diet might after all not have been underestimated. In contrast to this, *T. margarita* significantly fed on flowers at Ta Kou NR in Vietnam. Then again, further differences in diet between the two populations have been already observed, and in several colobine ecology studies (Harris & Chapman, 2007; Rawson, 2009; Vandercone *et al.,* 2012) it has been noted that variation in the diet between different populations from the same species can be high, even more so than differences in diet between totally different species. It would have been interesting if the unknown vine species of which flowers were eaten would have been identified, because it might have belonged to a family with dietary importance for the study species.

Another vine that was fed on in addition to the unknown one was *W. edulis*, which comprised a high proportion of the langurs' diet during the study. While Apocynaceae were not a dominant family at all in the habitat, most vines were not positively identified by locals so it is unknown if there would be a large proportion of Apocynaceae vines. *Trachypithecus pileatus* has also been observed feeding on a particular species of vine leaf flowers (Stanford, 1991b). Sadly, due to the inability to positively identify the species of vine that Annamese silvered langurs were observed to eat, it is not possible to look for similarities or differences in the vines targeted by these two species of *Trachypithecus*. Young leaves, fruit and seeds from vines were also key food items in other colobine species (Ang, 2010; Dasilva, 1992; Davies, 1991; Davies *et al.,* 1988, 1999; Fuentes, 1996; Hu, 2011; Li *et al.,* 2015; Oates, 1988; Oates *et al.,* 1980; Ruhiyat, 1983; Stanford, 1991b; Workman, 2010).

In some studies it was observed that high fruit (Ang, 2010; Dela, 2007; Fashing, 2001a; Hladik, 1977; Hoang, 2007; Hoang *et al.,* 2009; Hu, 2011; Kool, 1993; Li, 2006; Matsuda *et al.,* 2009a; Newton, 1992; Ruhiyat, 1983; Sayers & Norconk, 2008; Stanford, 1991b; Vandercone *et al.,* 2012; Yeager, 1989), flower (Dela, 2007; Hoang *et al.,* 2009; Li, 2006; Minhas *et al.,* 2010b; Newton, 1992; Sayers & Norconk, 2008; Vandercone *et al.,* 2012; Xiang *et al.,* 2012) or seed (Davies *et al.,* 1999; Guo *et al.,* 2007; Hanya & Bernard, 2012; Oates, 1988) consumption was tied with a high availability of these in the first place, or, while not directly observed or looked at in detail, results pointed in that direction (Hoang *et al.,* 2009; Li *et al.,* 2010; Ramachandran & Joseph, 2001; Zhou *et al.,* 2009a, 2013). *Trachypithecus leucocephalus* consumed the highest amount in fruits in the months of transition between the dry and wet seasons (Zhou *et al.,* 2013), a time of the year where langurs at VSSPCA also consumed vast amounts of seed from the already mentioned vine *Willughbeia edulis*, which fruits in that particular time of year, as well as other fruits whose fruiting period is unknown to me but most likely present fruit only at that particular time of the year. Other studies, however, have shown that *Presbytis rubicunda* consume seeds independently of their availability (Ehlers Smith *et al.,* 2013). The reliance of some colobine species on seeds might be linked to the dominance of the plant groups that they feed on in the habitat in which these colobines are found, as it has been observed in some studies (Fashing, 2001a; McKey *et al.,* 1981; Yeager, 1989). This could also be the case of *T. margarita*, given that they were observed to heavily consume the seeds of *A. costata* while they were mast fruiting, and this species is relatively dominant in the species habitat. This could be extended to other species: langurs were observed to feed on *Dipterocarpus alatus* leaves, albeit only a few times, and they most likely consume leaves of *Lagerstroemia calyculata*, as it has already been discussed above. Both of these species present high dominance values. Further research on the species that compose the langur diet at the site could shed further light, particularly if this could mean more selectivity ratios of other species in the habitat.

Results of some previous studies (Harris, 2006; Li, 2006; Li & Rogers, 2006; Li *et al.,* 2003; Vandercone *et al.,* 2012), where Asian colobine species focused on rare species that were clumped and not widespread in their geographical distribution, Annamese silvered langurs in the study site followed with those results, targeting families that were not common, such as Fagaceae, or that while dominant and present throughout the whole extension of the langur home range, do present an irregular and clumped distribution in habitats like the study site, such as legumes or dipterocarps (Bunyavejchewin *et al.,* 2003). The contrary, however, has been observed in other species as well, but not in the genus *Trachypithecus* (Fashing, 2001a; McKey *et al.,* 1981; Yeager, 1989). It has been proposed that species with a focus on widespread species will have a diet that is not very diverse (Yeager, 1989). In the present case, the relatively low number of feeding observations probably means that there are several species consumed by Annamese silvered langurs that have been omitted, and thus it cannot be stated with the current knowledge that the study group presented a very low dietary diversity.

Why would a group with an anatomical specialization for a particular kind of food would have a generalist diet? Previous studies have noted that Liem's paradox addressed such a coupling of features (Koenig & Borries, 2001; Sayers, 2013): colobine species target items that are high in protein and low in secondary compounds and cellulose, just as other primate groups do, but their anatomy enables them to have an adaptive edge over animals that do not present it and thus are able to better survive in times where their habitat is poor in preferred foods with a more suitable nutrient content. Thus, the study animals focused on what could be considered as preferred foods, such as seed and fruit, seasonally available in high quantities, with high protein contents and easy to digest, taking advantage of seasonal phenomena such as mast fruiting, while also able to feed on leaves when these food items were not available in the habitat. This ability to exploit the available food in their home range is of particular importance given the current status of conservation. If silvered langurs are able to make the most out of the available seasonal food items in their environment while being able to survive the lean times by reason of their anatomical specializations for digestion, Annamese silvered langurs are not only well adapted to getting the most out of habitats that are influenced by the different seasons, such as some areas of their home range, but they also have an adaptative advantage over other species regarding their survival close to areas of human habitation, as long as there are large enough patches of forest and there is no direct pressure over their populations.

It was decided not to separate the diet between sex and age classes because the dataset did not consist of a particularly large amount of recorded feeding instances, in addition the general methodological issues which made it hard to positively identify individuals in the field, particularly if they were feeding in areas where canopy cover was thick. Previous work on dental morphology suggested that the dental patterns of *T. cristatus* in Sumatra pointed to the possibility that males would present a more folivorous diet than females (Wright & Willis, 2012). It would be of interest to analyze any differences in diet between sex and age classes in further research projects.

Annamese silvered langurs were observed manipulating leaves and parts of the tree fern *Drynaria fortunei*, in a behaviour that suggested they were looking for a particular item. It is hard to believe that they would be looking for seeds or leaves that had fallen into the ferns, as the animals had plenty of these food items at hand when they were feeding on them, and there were also plenty of such items discarded and lost in the ground below where they were feeding. While group members were never directly observed feeding on any animals, the most likely explanation for the observed behaviour is that the species feeds on invertebrates and they were actively looking for them. Consumption of invertebrates by Asian colobine species has been previously observed in numerous studies: the phylogenetically close *T. auratus* fed on insect larvae from inside a tree trunk (Kool, 1993), while *T. crepusculus* were also observed feeding on insects (Koenig *et al.,* 2004a; Suarez, 2013); *Semnopithecus* species and populations in both hill forest and lowland environments presented a broad diet regarding food categories consumed, including the targeted consumption of insects (Koenig & Borries, 2001; Minhas *et al.,* 2010b; Newton, 1992; Oates *et al.,* 1980; Ramachandran & Joseph, 2001; Sayers & Norconk, 2008; Srivastava, 1991), with these constituting up to a quarter of the diet at certain parts of the year. *Nasalis*, *Presbytis* and *Rhinopithecus* species were also observed consuming invertebrates (Davies, 1991; Matsuda *et al.,* 2009a; Nijman, 2010; Wich & Sterck, 2010; Xiang *et al.,* 2007, 2012; Yeager, 1989). Other colobines, while not directly observed ingesting invertebrates, also displayed behaviors indicative of it (Salter *et al.,* 1985). A phylogenetically close species, *T. selangorensis*, was also observed manipulating sections of loose bark and wood from decaying tree trunks (Bernstein, 1968), and although no invertebrate ingestion was directly observed, these behaviors most likely hint at a search for particular invertebrates. On a side related note, hunting and consumption of vertebrate animals was also not observed during the study, but there were no behaviors that could hint that langurs were targeting vertebrates for food, although this behaviour has been observed numerous times in *Rhinopithecus* species (Grueter *et al.,* 2009a; Ren *et al.,* 2010; Yang & Zhao, 2001; Zhao *et al.,* 2008), it has only been observed once in one species of Southeast Asian colobine (Goodman, 1987). Further studies are needed in order to confirm invertebrate consumption by Annamese silvered langurs, and if so, to ascertain the groups targeted, the quantities in which they are ingested, and in which times of the year they are eaten.

6.4.3 Geophagy

Soil consumption behavior was mainly undertaken during the dry season, particularly during January and February 2014, during which the amount of minutes spent by langur groups amounted up to 30% of the total for the whole study. Although the results show that langur group size certainly has influence over the amount of time that is spent at a mineral lick, it is entirely possible that the diet composition during the dry season had a part in the amount of time that langurs spent engaging in geophagy. Knowing that langurs were feeding on *Anisoptera costata* seeds in vast quantities particularly during those first two months of 2014 makes it seem like both factors might be connected. If that is the case, it would not be connected to detoxifying, as dipterocarp seeds do not present particularly high quantities of secondary compounds that would deter seed predators (Nakagawa & Nakashizuka, 2004); maybe the reason is a lack of mineral balance in the diet during those months. Only a closer analysis of the composition of the soil in licks and the nutrient composition of *A. costata* seeds, as well as an analysis on the visits and times spent by langurs over several years, would confirm or refute the idea. The langurs observed on the salt lick most likely belonged to a different group than the study one, and the diet and habitat composition of such groups were not known, so it is not possible to know if they were also feeding on *A. costata*, even if this is quite likely.

The results are very similar to those presented by previous studies in the same site (Rawson & Luu, 2011), although it has to be said that there were two to three months fewer observations. In any case, if the diet has a strong influence over consumption of soil material, it is entirely possible that variations could be due to changes of diet composition in the different years where data was recorded.

The specific reason for *T. margarita* to engage in soil consumption is currently unknown. The study of Hladik (1977) found that, although both *S. priam* and *S. vetulus* engaged in geophagy, they obtained enough minerals from the plant parts that they consumed; further research is needed to clarify the causes of geophagy by this species, not only by expanding current knowledge about the Annamese silvered langur diet at the site, but also by looking at the composition of their diet items, identifying any lack of important minerals as well as the presence of particular secondary compounds in the consumed plant parts that would hinder digestion. Chemical analysis of soils in the study site in general and of the materials in mineral licks in particular would also be of great help.

6.5 Summary

Annamese silvered langurs at VSSPCA were observed to feed on 18 different species of plant, with a further 3 species that were identifiable by local experts but it was not possible to find their scientific name. The vast majority of the recorded food species grew as trees, although vines were also present in the diet being seasonally important, and the animals were also observed foraging into nooks from epiphytic tree ferns, most likely for invertebrates. Most feeding instances were found to happen in the highest canopy tier, from 20 meters height upwards.

The yearlong langur diet was dominated by seeds, above 60%. Whole fruit or fruit pulp was the next most commonly consumed plant part, even being the most frequently recorded plant part during the rainy season. Leaves were the food item with the third highest proportion, followed by invertebrates, while langurs were observed feeding on flowers only once. Due to methodological hindrances, it is possible that the quantities of different plant parts in the diet might have been underestimated in some cases, and further research should be carried out in order to clarify this issue.

The most consumed species during the length of the study was *Anisoptera costata*, followed by the vine *Willughbeia edulis*, then *Lithocarpus elegans*. Analysis of selectivity ratios showed that the most sought after species was *L. elegans*, followed by *Dialium cochinchinense*, then *Sindora cochinchinensis*. The family with the largest proportion in the diet was Dipterocarpaceae, their proportion almost a third of the langur diet and dominating the diet during the dry season, followed by the Apocynaceae, then legumes and the oak family with equal proportions; Fabaceae were the most consumed family during the rainy season. When looking at the selection ratios, the most sought after family were the Apocynaceae, while Fagaceae were the next in line, although with a far lower SR. Rubiaceae were another family that was also highly sought after. This diet composition highly contrasts with that obtained by another study on the same species in

Vietnam, where Moraceae were the most dominant family in the langur diet, with others falling far below, and where many families do not concide. This is most likely a result of human activity in the habitat of the population studied in Vietnam, where some key species or families might have disappeared from the study site.

While there were no phenological data to confirm it, it is most likely that langurs modified their diet in order to focus on the different availability of the plant parts that were preferred, such as *A. costata* seeds, a resource with a highly irregular availability that were highly consumed when they were available due to mast fruiting. Families like the Fagaceae or genera like *Hopea*, that flush and seed sometimes twice in a single year seem to be key resources for local populations of langurs due to their reliability as food sources during the year. Interestingly, *Ficus*, a genus that also fruits all year round and is a key food resource for other groups, such as birds and apes, and was commonly consumed by *T. margarita* in Vietnam, was not observed to form part of the diet of the study group.

A highly granivorous diet shows that langurs seem to be seed predators that will affect the recruitment of certain species and genera, and thus influence the setup of the plant community in their habitat, but they have also been observed to feed on the pulpy arile of *Sindora cochinchinensis*, which keeps the seed dormant as long as it is attached to it. Thus, Annamese silvered langurs probably contribute to the recruitment and dispersion of individuals belonging to this species, making the role they hold and the dynamics in which they are involved in their environment much more complex.

Annamese silvered langurs regularly visited mineral licks, but the highest amount of time by far was spent during the dry season, particularly the months of January and February 2014. A strong correlation was found between the amount of animals that were visiting the lick and the amount of time that the group spent at the lick in each visit.

CHAPTER 7

Ranging and habitat use

7.1 Introduction

7.1.1 Primate ranging behaviour and influences on it

As the subfamily Colobinae presents a large amount of different species and they are found over a wide geographic area including a great variety of habitats, it is anticipated there will be significant diversity in ranging behavior. It is understood that differences in ecological factors such as habitat, diet and social organization will have an effect on home range sizes, and on what height layers of the habitat the primates will be found. Home range size as well as the amount of distance a group travels daily can vary widely between different species, Furthermore, not only are there interspecific differences, but also home range sizes can vary not only within the same species (Hubrecht, 1985; Matsuda *et al.,* 2009b; Milton & May, 1976; Minhas *et al.,* 2013; White *et al.,* 2010) and, in the case of primates that do not aggregate in groups, also within the different age and sex classes (Singleton & van Schaik, 2001).

The home range of a particular primate group is not always constant, varying with time and seasons (Hemingway & Bynum, 2005; Li *et al.,* 2000; Li *et al.,* 2010; Minhas *et al.,* 2013; Zhou *et al.,* 2011; Wada & Ichiki, 1980). It has also been remarked that a certain group's home range can differ between years even during the same seasons depending on food availability and environmental factors, so it is of interest to compare home ranges over several consecutive years (Clutton-Brock, 1977). In some particular species, even the location and extension of a home range has been observed to change after an alpha male is deposed (Gurmaya, 1986). Within a particular home range, some areas will be used or accessed more frequently than others by members of the group: those areas conform what is called the core area, which is consider to contain all the necessary resources for the group to survive (Bates, 1970; Poirier, 1968a). There are many ecological factors that affect primate ranging behavior, but the main factor in is generally considered to be the variation in the spatial and temporal distribution of preferred food items.

This has been observed in most primate taxa, from Neotropical frugivorous primates (Chapman, 1988; di Bitetti, 2001), to macaques switching between leaves and fruit in different seasons (Erinjery *et al.,* 2015; Wada & Ichiki, 1980), to different genera of African (Clutton-Brock, 1975) and Asian colobines, such as *Presbytis* (Ampeng & Md-Zain, 2012), *Semnopithecus* (Chhangani & Mohnot, 2006; Minhas *et al.,* 2013), *Nasalis* (Yeager, 1989) or *Rhinopithecus* (Kirkpatrick *et al.,* 1998; Li *et al.,* 2000; Li *et al.,* 2008; Li *et al.,* 2010; Tan *et al.,* 2007; Yang, 2003) that look for seasonally available food, to gibbons of different genera that respond to different fruit availability in their habitat (Bartlett, 2009; Fan and Jiang, 2008b; Gittins & Raemaekers, 1980; Zhang *et al.,* 2014).

Home range size is generally considered to be larger when primate groups forage for nutritious food items that are temporally and spatially dispersed, and smaller when individuals eat nonpreferred food items with less nutrient quality (Clutton-Brock, 1977). Other important factors known to affect ranging are sleeping site selection (Matsuda *et al.,* 2009b; Riley, 2008; Zhou *et al.,* 2011b), water scarcity (Chapman, 1988; Chopra *et al.,* 2012; Mishra *et al.,* 2012; Xie *et al.,* 2012; Zhou *et al.,* 2011a), presence of other groups of the same species in the area (Gibson & Koenig, 2012; Minhas et al., 2010a; Newton, 1992; Poirier, 1968a; Riley, 2008; Whitten, 1982), disturbance by human activities (Guo *et al.,* 2008; Isbell *et al.,* 1990; Johns, 1986; Li *et al.,* 2000; Li & Rogers, 2005; Moore *et al.,* 2010; Poirier, 1968a) or topography (Fan and Jiang, 2008b; Whitten, 1982). Group size also has an effect on home range size, with very large primate groups having an accordingly large home range size (Grueter *et al.,* 2009b; Koenig *et al.,* 2013; Takasaki, 1981). That said, values observed for a large horde of mandrills are in the same proportion as those for other species or groups of the same species with smaller group sizes (White *et al.,* 2010), and *T. crepusculus*' daily group path length and time spent travelling are not larger than in smaller groups (Fan *et al.,* 2015), so aside from the need to accommodate large numbers of individuals in a proportional area, group size influence does not seem to be the most significant driving reason behind home range size.

Some primate groups seem to be territorial and react with aggression to the presence of other conspecific groups in their vicinity. This happens in different taxa including marmosets (Hubrecht, 1985), macaques (Albert *et al.,* 2011) and African (Fashing, 2001b) and Asian (Gibson & Koenig, 2012; Koenig & Borries, 2012; Koenig *et al.,* 2013) colobines, all of which were observed engaging in conflict with conspecific groups over patches of territory. Gibbons advertise their presence, particularly when other groups where close to them and react to them (Gittins & Raemaekers, 1980; Kenyon *et al.,* 2010). Chimpanzee groups are known to attack other groups when they meet (Manson & Wrangham, 1991; Mitani & Rodman, 1979).

Presence of territorial behavior in colobines is irregular at best: while it seems to be a persistent feature of langur species in Southern Asia (Grant *et al.,* 1992; Minhas *et al.,* 2010a; Newton, 1992; Poirier, 1968a, 1968b; van Schaik *et al.,* 1992), and it is widely displayed by groups of some Southeast Asian species, such as some *Presbytis* species (Ruhiyat, 1983; Steenbeek, 1999), it does not appear to be particularly extended in the region's colobines (Yeager & Kool, 2000). Not many species within the genus *Trachypithecus* are territorial, with only two species, the white-headed langur (*T. leucocephalus*) and the Indochinese grey langur (*Trachypithecus crepusculus*) confirmed to present territoriality (Gibson & Koenig, 2012; Koenig & Borries, 2012; Koenig *et al.,* 2013; Li & Rogers, 2005; Li *et al.,* 2011).

It has been proposed that territoriality in group living primates will most likely be related to the male strategy of defending the females within their group, as opposed to them defending a particular geographical area (Green, 1981; Manson & Wrangham, 1991; Ruhiyat, 1983; Steenbeek, 1999; van Schaik *et al.,* 1992). This is particularly seen in species where groups in which groups have only one male with several females, where males will try to prevent females from leaving to the other group. Such behavior has has been observed in *S. johnii* (Poirier, 1968b), *T. leucocephalus* (Li & Rogers, 2005; Li *et al.,* 2011) and *T. selangorensis* (Bernstein, 1968; Wolf & Fleagle, 1977), where most of the aggression came from males and was directed at other males. Even if females and juveniles join an adult male in aggression against other groups (Minhas *et al.,* 2010a), they could be doing so because of the prospective infanticide that would result from a takeover in the case of the former and the risk of being cast out with the deposed male, in the case of the latter (Steenbeek & van Schaik, 2001), which further supports the mate defense theory. However, intergroup fights have also been observed in the context of defending food patches (Fashing, 2001b; Steenbeek, 1999) and territories (Gibson & Koenig, 2012; Koenig & Borries, 2012; Koenig *et al.,* 2013), and adult males purposefully attacking females and juveniles from other groups has been documented in *P. comata* (Ruhiyat, 1983). This supports resource defense as the driving reason behind such animosity.

Thus, no definite answer seems applicable to the territoriality of many colobines, and seems to only happen on some species or populations, and sometimes for conflicting reasons (Steenbeek, 1999; Steenbeek & van Schaik, 2001): As was mentioned before, Bernstein (1968) noted that *Trachypithecus selangorensis*, a close relative of *T. margarita*, engaged in territorial scuffles with neighbouring groups, but even then, conspecific groups were not observed to invariably display aggressiveness and territoriality every time they happened to meet each other.

7.1.2 Colobine home range sizes

Historically, it has been thought that as specialized folivores, colobines had smaller home ranges than other primate groups with different diets because of a more even distribution of their main dietary items, leaf matter, and the fact that, as canopy living species using the different tree heights, there is an additional vertical dimension that will heavily affect range size and the way it is used (Clutton-Brock and Harvey, 1977; Milton & May, 1976). However, more recent research has shown a high degree of variability between the home range sizes presented by the different genera that form part of it, particularly regarding Asian species, with some averaging as little as 1.7 ha (*Presbytis thomasi*) (Gurmaya, 1986), while others can be as large as 5600 ha (*Rhinopithecus bieti*) (Grueter *et al.,* 2008). The genus with the largest home range sizes is *Rhinopithecus*: *R. bieti* have been observed to be between 2325 ha up to 5600 (Grueter *et al.,* 2008; Ren *et al.,* 2009), while *R. roxellana* home ranges varied between 1830 and 2250 in the same study area, Zhouzhi Natural Nature Reserve (Li *et al.,* 2000; Tan *et al.,* 2007). Proboscis monkeys hold smaller ranges than the previous groups, but still larger than *Pygathrix*, *Trachypithecus* and *Presbytis*. Their home range size ranges from around 130 ha (Matsuda *et al.,* 2009b; Yeager, 1989) to 270 ha (Salter *et al.,* 1985). Doucs (*Pygathrix* spp.) present much smaller ranges still, even if their social organization seems to be based on aggregated one male units (OMU), much like *Rhinopithecus*, with ranges between 20 and 50 ha, although these dimensions are most likely underestimations due to a lack of data over a long amount of time (Hoang, 2007; Rawson, 2009), and there are references to some that claim groups to have much larger home ranges (Hoang, 2007; Kirkpatrick, 1998). Another odd nosed colobine, *Simias concolor*, presented the smallest recorded overall home ranges for an Asian colobine species, with sizes between four and ten hectares (Hadi et al., 2012)

Species of the genus *Semnopithecus* presented a high variability on their home range sizes: some species with populations of *S. vetulus* under human pressure had very small ranges, of around 3 ha but up to almost 10 ha (Dela, 2007; Moore *et al.,* 2010), while others, like *S. entellus* and *S. johnii*, presented a range of sizes from 74.5 ha (Newton, 1992) up to 106 (Chhangani & Mohnot, 2006), indeed, *S. ajax* presented ranges as high as 328 ha (Minhas *et al.,* 2013). *Presbytis* groups generally presented smaller home range sizes than the previous genera, with *P. thomasi* sizes ranging from 1.7 ha for an all-male group in a degraded forest area to a bit above 50 ha for harem groups (Gurmaya, 1986; Steenbeek & van Schaik, 2001), *P. comata* between 14 and 40 ha (Ruhiyat, 1983), *P. potenziani* having sizes between 20 and 40 ha (Fuentes, 1996; Hadi et al., 2012) and *P. melalophos* was recorded having a home range of 21 ha (Curtin, 1980); *P. rubicunda*, however, generally had home range sizes closer to those of S. entellus, between 74 and 100 ha (Davies, 1991; Ehlers-Smith *et al.,* 2013; Supriatna *et al.,* 1986), but they can also be lower (Hanya & Bernard, 2012).

As there have not been many studies on the ecology of *Trachypithecus* species, the picture remains quite incomplete, with disparate values. When looking at home range sizes, most species from which information is known (*T. francoisi*, *T. leucocephalus*, *T.obscurus*) present small range sizes that can be as small as below 10 ha (Zhou et al., 2007, 2011b), but more commonly between 20 to 30 ha, with a maximum of approximately 50 ha (Curtin, 1980; Li & Rogers, 2005; Zhou *et al.,* 2011a, 2011b). The largest home range size, however, belongs to *T. crepusculus* with 446 ha (Fan *et al.,* 2015): this large home range is not only the largest of the whole genus, but makes *T. crepusculus* one of the species with the largest home ranges of the whole subfamily, surpassing records for other groups with larger home range sizes, such as *Nasalis*, *Rhinopithecus* and *Semnopithecus*.

These vast differences in home range sizes can be most likely related to the climatology and its influence over the habitat of some species. For example, the largest home range sizes in *Rhinopithecus* and *Semnopithecus* are held by species living in mountainous temperate areas, where seasonality is more marked than in tropical habitats, and the ecology of plant species works accordingly. Phenology in these areas is very variable, with plant parts only present at some times of the year, and thus food availability is subject to strong seasonal fluctuations, so groups need to move accordingly in order to make the most when and where preferred seasonal food is present (Kirkpatrick et al., 1998; Li *et al.,* 2000; Matsuda *et al.,* 2009b; Minhas *et al.,* 2013; Tan *et al.,* 2007; Yeager, 1989). This high heterogeneity, with areas with food plants interspersed with patches of vegetation that cannot support the species, also causes home range size to increase (Boonratana, 2000; Grueter *et al.,* 2009b).

Specifically regarding *T. margarita*, as has been mentioned in the background chapter, the relative lack of studies on wild populations on any of the species that forms the group results in poor knowledge on the way any of the species use and move in their habitat. Silvered langurs are most frequently found in lowland forest environments associated with water bodies: Selangor silvered langur (*T. selangorensis*) groups live in mangrove and riverine forests in Peninsular Malaysia (Bernstein, 1968; Furuya, 1962; Harding, 2010; Southwick & Cadigan, 1972), while Sunda silvered langurs (*T. cristatus*) in Borneo are more frequent in riverine forests than further inland (Harding, 2010; Matsuda *et al.,* 2011; MacKinnon, 1985), but East and West Javan langurs can be found in hilly and mountainous terrain as well (Nijman, 2000, 2014; Nijman & Supriatna, 2008; Zinner *et al.,* 2013). Regardless of their taxonomical status, silvered langurs in Indochina have been frequently observed in mixed-evergreen forest in mosaic with more deciduous formations, but generally associated with lowland riparian habitats (Campbell *et al.,* 2006; Coudrat *et al.,* 2011; J. Eames, pers. comm.; Moody *et al.,* 2011; Royan, 2010; Ruggeri & Timmins, 1996; Starr *et al.,* 2010; Timmins *et al.,* 2013), although there have been some exceptions in particular populations (Hoang *et al.,* 2010; Nadler *et al.,* 2007; Tran, 2013). Silvered langurs seem to tolerate human presence in their vicinity (Bernstein, 1968; Southwick & Cadigan, 1972) or a light degradation of their natural habitat (Timmins *et al.,* 2013).

Given the lack of data, there is little information the size of silvered langur species' home ranges, with the only information being a rough estimate of 20 ha for a study group of *T. selangorensis* in Peninsular Malaysia (Furuya, 1962). There is no information available on the ranging behavior of the silvered langur species of Indochina.

7.1.3 Sleeping tree use

Unsurprisingly, diurnal primate groups need to be selective when choosing a sleeping site, and the presence and number of these will in turn affect the primate group ranging behavior. While most primate species use trees as sleeping sites, primates living in areas where there are few trees use caves, like hillstone and Hanuman langurs (Huang *et al.,* 2003; Li *et al.,* 2011; Mishra *et al.,* 2012; Nguyen, 2006; Wang *et al.,* 2011; Workman, 2010); cliffsides, like baboons (Hamilton, 1982; Iwamoto *et al.,* 1996) and even abandoned human structures, as in Hanuman langurs (Mishra *et al.,* 2012).

The reasons for choosing particular kinds of trees over others, as well as particular places or heights within a sleeping tree, will vary not only between different species, but even sometimes between different populations of the same species (Mendes Pontes & Soares, 2005). Underlying reasons range from maximizing the access to food (Li *et al.,* 2006, 2011; Kowalewski & Zunino, 2005; Teichroeb *et al.,* 2012; Tutin *et al.,* 1995;) and reducing the costs of travel in order to reach food trees (Chapman, 1989; Chapman *et al.,* 1989; Day & Elwood, 1999; Mendes Pontes & Soares, 2005; von Hippel, 1998; Zhou *et al.,* 2009b), or facilitating the access to food from human settlements close to the group's home range, in species that are able to exploit such conditions, like macaques (Albert *et al.,* 2011; Brotcorne *et al.,* 2014; José-Domínguez *et al.,* 2015) or Hanuman langurs (Chhangani & Mohnot, 2006).

Other reason is to access secure places where group members will be in a safe position while they sleep and minimizing the risk of predation by nocturnal predators or humans by different means: by switching sleeping trees on consecutive days to reduce detectability, choosing trees or places within them with reduced potential routes of access, several routes of escape or with dense cover to go unnoticed, or making any unintended approach obvious to the sleeping primates. These have been observed in almost all primate groups, from New World monkeys avoiding human poachers and other predators (Aquino & Encarnación, 1986; Barnett *et al.,* 2012; Day & Elwood, 1999; di Bitetti *et al.,* 2000; Duarte & Young, 2011; Holmes *et al.,* 2011; Souza-Alves *et al.,* 2011; Zhang, 1995) to baboons (Anderson & McGrew, 1984; Brotcorne *et al.,* 2014; Hamilton, 1982; Schreier & Swedell, 2008), guenons (Wahungu, 2001) and macaques (Albert *et al.,* 2011; Iwamoto *et al.,* 1996; José-Domínguez *et al.,* 2015; Matsuda *et al.,* 2011). Among colobines, it was also observed in *Rhinopithecus* (Xiang *et al.,* 2010), *Nasalis* (Bernard *et al.,* 2010; Matsuda *et al.,* 2010, 2011), *Semnopithecus* (Chhangani & Mohnot, 2006; Chopra *et al.,* 2012; Minhas *et al.,* 2010b; Mishra *et al.,* 2012; Unanthanna & Wickramasinghe, 2010) and *Trachypithecus* (Li *et al.,* 2011; Nguyen, 2006;); all of them mostly try to avoid large felines. Even apes, particularly gibbons (Cheyne *et al.,* 2012; Fan & Jiang, 2008a; Fei *et al.,* 2012; Matsuda *et al.,* 2011; Reichard, 1998; Phoonjampa *et al.,* 2010; Tenaza & Tilson, 1983), but also orangutans (Sugardjito, 1983), avoided large felines, large bodied constrictor snakes and human poachers.

Other driving reasons for sleeping site selection are those related to comfort and hygiene, such as avoidance of areas with a high concentration of parasites (Anderson, 1998; Hausfater & Meade, 1982); shelter from climatological events such as strong wind, heavy rains or snow (Anderson, 1998; Aquino & Encarnación, 1986; Cui *et al.,* 2006; Hoang, 2007; Li *et al.,* 2006, 2010; Liu & Zhao, 2004; Mishra *et al.,* 2012; Nguyen *et al.,* 2006; Tsuji, 2011; Workman, 2010; Xiang *et al.,* 2010); to absorb and maintain the maximum amount of heat under climates with low temperatures (Anderson, 1998 ; Liu & Zhao, 2004; Xiang *et al.,* 2010; Zhang *et al.,* 2011); avoid being pestered by other animal species (Chhangani & Mohnot, 2006) or other neighbouring, conspecific groups (Anderson, 1998; Li *et al.,* 2011; Minhas *et al.,* 2010b). Some studies also argue for the facilitation socialization during night time (Anderson, 1998; Bernard *et al.,* 2011; di Bitetti *et al.,* 2000; Li *et al.,* 2006; Kowalewski & Zunino, 2005; Zhang, 1995). Research on sleeping site use has not been uniformly conducted on all primate species, and the degree of quantification when studying sleeping site use varies between studies (Anderson, 1998). Also, the fact that primates switch trees on a regular basis could be confounding, because possible factors behind the behavior could not just only be predator detection avoidance, but also choosing sites with a lesser amount of parasites, avoiding neighbouring groups or protecting border areas of the home range or just moving along the home range following food distribution (von Hippel, 1998).

African colobines appear to choose sleeping trees mainly to facilitate the access to food sources, although at the same time they seemed to try to avoid predators by switching sleeping trees and choosing sleeping places in farther parts of horizontal branches (Teichroeb *et al.,* 2012; von Hippel, 1998). Among Asian colobines, *Nasalis larvatus* groups select trees sited at riverbanks in order to significantly reduce predator risks (Bernard *et al.,* 2011; Matsuda *et al.,* 2011; Salter *et al.,* 1985), sometimes favoring trees in inundated inland forest because of a reduced possibility of ground predators being present in the area (Matsuda *et al.,* 2010), but it was observed that the species also selected large trees with a wide crown and large branches, probably so that all individuals within the group could sleep together in the same place (Bernard *et al.,* 2011); in *Semnopithecus* species it has been argued that sites are selected to avoid predators (Minhas *et al.,* 2010b), adverse weather (Mishra *et al.,* 2012), or even other conspecific groups (Minhas *et al.,* 2010b), while sleeping site selection in most species of *Rhinopithecus* seemed to be heavily influenced by the extreme weather conditions brought by their cold and mountainous natural habitats (Cui *et al.,* 2006; Li *et al.,* 2006; Liu & Zhao, 2004; Xiang *et al.,* 2010), and *Pygathrix* seemed to prefer sleeping sites that would protect them from the wind (Hoang, 2007) or in order to avoid predators (Rawson, 2009).

Most of the current information on the sleeping sites of the genus *Trachypithecus* has been collected from species within the limestone langur group, which occupy peculiar sleeping sites, forced by the karst hill habitats where they are found, and not a lot is known about the sleeping sites of species belonging to other *Trachypithecus* species groups that can be found in forest areas. Limestone langurs select sleeping sites like caves, apparently in order to avoid predators (Huang *et al.,* 2003; Nguyen, 2006) or adverse meteorological conditions, such as heavy rain (Nguyen, 2006; Workman, 2010), but also to maximize the access to food or water resources (Li *et al.,* 2011; Wang *et al.,* 2011; Zhou *et al.,* 2009b).

In this chapter I aim to analyze home range size, its differences over the different seasons and the possible reasons behind these differences. Canopy use and habitat type preferences are also looked at.

7.2 Methods

7.2.1 Study Site and Study Group

The study was carried out in Veun Sai Siem Pang Conservation Area, Ratanakiri Province, Cambodia. From May 2013 to May 2014, and in the last fortnight of January 2015, an unhabituated group of silvered langurs was tracked in the area and, whenever it was encountered, it was followed until dusk or until the researchers lost the group, acknowledging this by determining no activity or signs of presence of silvered langurs in the area after an hour and a half had passed.

7.2.2 Data Collection

The study group was tracked in the area 5 days a week, starting from 5:30 am. Whenever the group was encountered, and from the encounter time onwards until the end of the day or the animals had not been lost, the group position was recorded every 30 minutes as a GPS point in UTM coordinates using a Garmin 62s GPS unit. The group was considered lost when we waited for an hour and 30 minutes to pass without any signs of presence whatsoever from the group. This is because the group went very quiet after being aware of the presence of humans in the vicinity or during the middle of the day.

Animals were sometimes directly observed with the naked eye, but for small details such as food items, binoculars or a 70-135mm lens on an EOS 650D Canon camera were used. Every time an animal was observed, its age (adult, juvenile, infant) and sex class was noted, as well as the canopy level in which it was found. Canopy levels were established as follows: low (0 to 10m), medium (10 to 20m), high (21m and over). The type of forest in which the animal was found was also noted (mixed evergreen forest, mixed deciduous forest, dry deciduous forest).

If the researchers were able to follow and stay with the group until the end of the day and langurs were observed settling on the branches of a particular tree without any signs that the group intended to further move, the particular tree where langurs were observed was recorded as a sleeping tree. The geographical position of such a sleeping tree was marked in UTM coordinates by the use of a Garmin 62s GPS unit and its height measured in meters using a Haglöf Clinometer. The Diameter at Breast Height (DBH) of sleeping trees was measured in centimeters using a Richter 5m Diameter Tape. An approximate crown area was measured by assuming the crown would present a somewhat elliptical shape, then measuring the two axes of said ellipse by using a 100 m Sterling measuring tape and standing right below the fringe of the crown at the end of each axis. Sleeping trees were labeled by nailing aluminium tags to the plant, but along tracks or heavily trodden areas, some of the tags were removed by locals who had spotted them, as many local inhabitants are hostile to conservation efforts in the area.

7.2.3 Data Analysis

In order to plot the graphical representation of the group home range, Google Earth Pro version 7.1.2.2041 was used. GPS data were entered and several maps were produced.

Home range, both total and seasonal, was established by using the Minimum Convex Polygon method (MCP), by linking all outer GPS locations, then calculating by means of using the Google Earth Pro tools for calculating area size. Low encounter rates and a lack of connection of the home range with further forest areas on all sides but the western area point to langurs observed in this range always being the same group.

Total and seasonal home range estimation by using the grid cell method was also used. The map was divided in grids of 250 by 250 meters, given that the study group had a big spread, well over a hundred meters. Thus, home range size would result from multiplying the number of cells used by the group by 6.25 ha, which is the area of a single grid cell.

Home range use intensity and differences between seasons were determined by the amount of ranging GPS points present in each cell in the home range, to which end three categories of use-intensity were used: <2.0% of total use, 2.01 to 5.0% of total use, and >5.0% of total use. Only total home range, dry season range and wet range were assessed, given that the group was unhabituated, and it was not easy to find it or keep up with it for the whole day, and not many full-day follows were achieved, so the assessment of monthly home ranges was discarded. The average number of ranging points per month was 36.08.

Habitat selection and any differences between seasons were calculated by using the preference index (P_i) equation established by Jacobs (1974), which has previously been used in other studies when looking at habitat preference by herbivorous mammals (Barnes *et al.,* 1983; Newton, 1992),

$$P_i = \frac{Ri - Qi}{Ri + Qi},$$

where R_i is the proportion of ranging points out of the total for habitat i, and Qi is the proportion of occupied cells out of the total for habitat i. If P_i is positive, there will be a positive preference of the species towards that habitat, a negative value will mean a negative preference towards that particular habitat, and a value of 0 will show that the species has no preference towards that habitat. Habitat type per cell was determined based on forest type data recorded from full-day follows. If there were two types in the same cell, the forest type with the largest amount of records was used as cell forest type.

In order to establish the relationship between age/sex classes and canopy layer use and any differences between them, χ^2-tests were used. Statistical analysis was performed using Microsoft Excel 2007 and IBM SPSS Statistics 23.

7.3 Results

The study group was found in 49 days in total. Of these, 14 (29%) were during the rainy season, while 35 (71%) were during the dry season. August was the month with the most sightings, with 7 (14%); while September was the month with the lowest, with none because the field station was isolated by flooding, which also inundated the forest surrounding it and made it impossible to go into the study area (Figure 7.1).

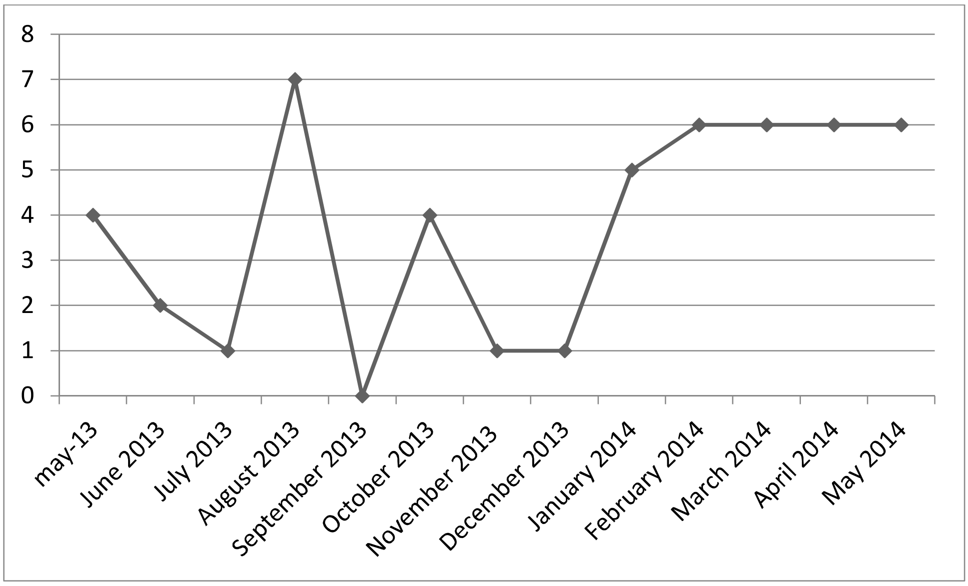

Fig.7.1 *Number of days the study group was found and followed during the study*

7.3.1 Canopy level

Seven hundred and twenty five instances where animals use could be observed were registered for canopy use. Of these 725, in 10 instances it proved impossible to ascertain the age and sex classes of the individuals observed, so they were discarded when looking at habitat use. Of the remaining 715 instances, 70 were in the lower layer of the canopy (9.8%), 303 in the medium layer (42.3%), and 342 were in the higher canopy levels (47.8%). During the wet season there were 123 instances, of which only 1 was for the lower canopy level (1%), 40 for the medium layer (33%), and 82 for the higher canopy level (66%). During the dry season there were 592 instances recorded; 69 of them being for the lower canopy level (12%), 263 for mid level canopy (44%), and 260 for the highest layer (44%). A χ^2 test showed that there was a significant relationship between the canopy tier used by group members and the season (χ^2= 26.65, df= 2, p= <0.01).

When breaking down canopy use instances between age and sex classes for adult males, out of 159 instances registered, 16 were in the lower canopy (10%), 64 in mid canopy (40%), and in high canopy in 159 (~50%). Instances with adult females numbered 303, of which 23 were in the lower canopy (7.6%), 127 were in the mid canopy (42%) and 153 in the higher canopy layer (50.4%). Subadult individuals were observed in 59 instances: 11 were found to be in the low canopy level (18.6%), 18 in mid canopy (30.5%) and 30 in high canopy (50.9%). Lastly, juveniles were present in 194 instances, 20 of which were in the lower canopy (10.3%), 94 of them were in mid canopy (48.4%) and 80 in the high canopy (41.3%) (Figure 7.2).

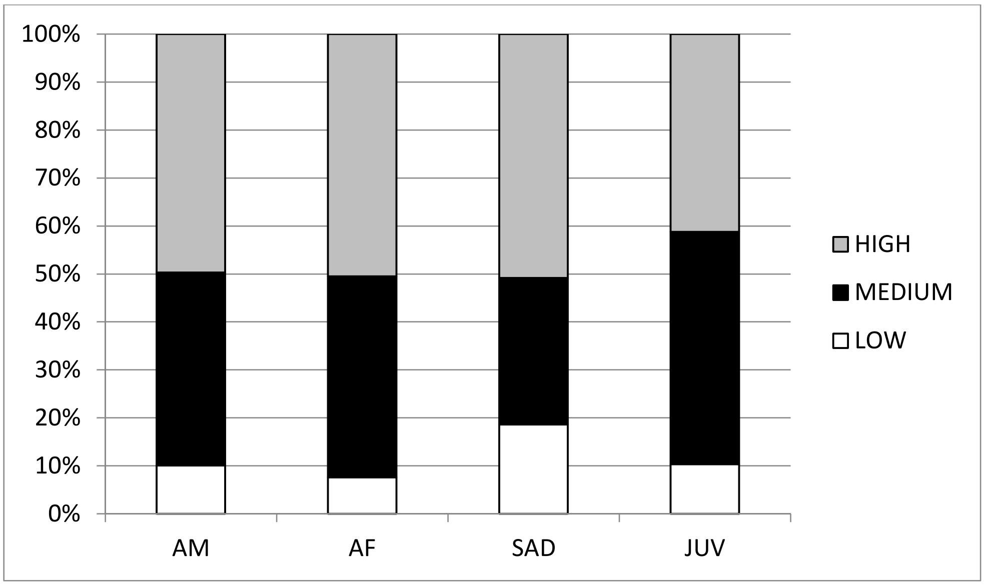

***Fig. 7.2** Percentage of instances for the use of each canopy layer by each age/sex class*

There was no significant difference in the way adult males and adult females used the canopy layers (χ^2= 0.84, df= 2, p= >0.05), but when adults were lumped together and compared to the other age classes, there was a significant relationship between age class and canopy use (χ^2= 11.83, df= 4, p= <0.05). Both adults and subadults spent significantly more time in the high canopy, while juveniles spent significantly more time in the mid canopy level. Subadults were the age class that spent most time in the lower strata of the canopy.

7.3.2 Home range

Four hundred and eighty one GPS ranging location points were obtained during the study: 152 (32%) during the rainy season (June to October) and 279 (58%) during the dry season (November to May). When looking at numbers by month, April 2014 was the month with the highest amount of ranging points with 78 (16% of the total ranging points). On the other hand, the month with the lowest amount of ranging points was September 2013, with none (Figure 7.3).

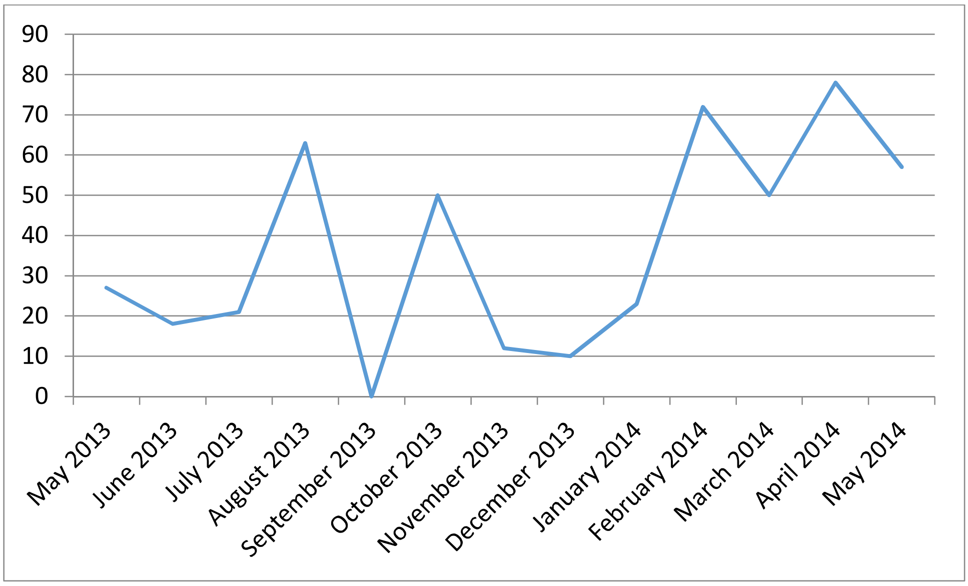

Fig.7.3 *Number of ranging GPS points obtained each month during the study*

Home range size by use of MCP method was 221 ha (Figure 7.4). When looking at differences in the home range between seasons, home range size was 203 ha during the dry season while it was 66.3 ha during the wet season (Figure 7.5).

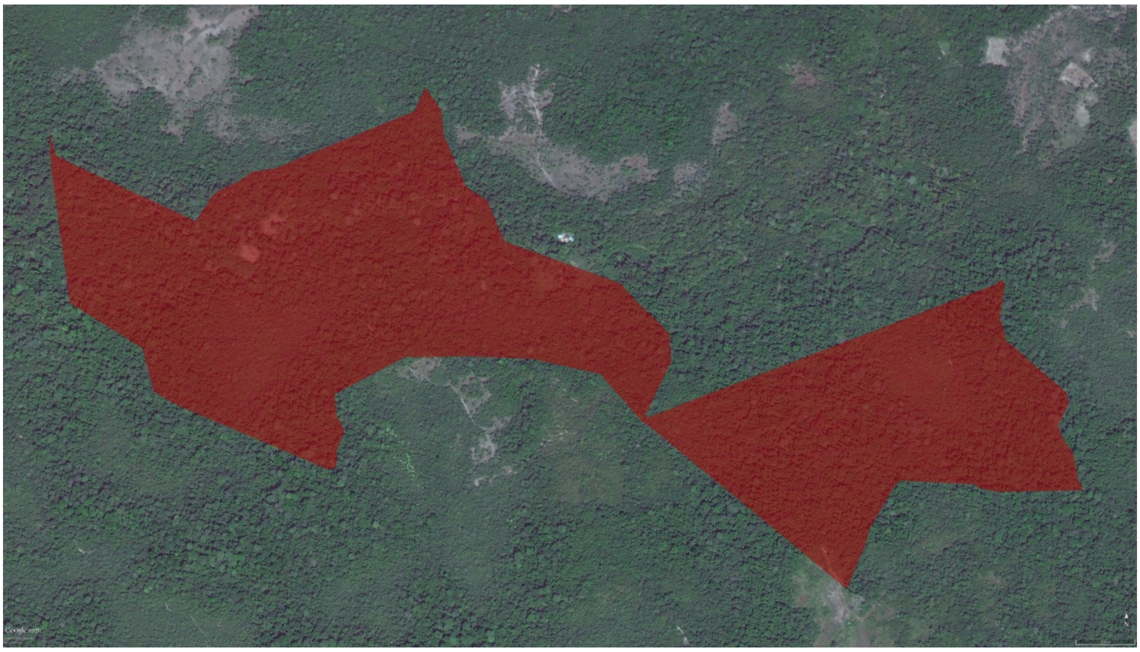

Fig.7.4 *MCP representation of the total home range for the study group, obtained by joining the outer ranging points together. The size was 221 ha*

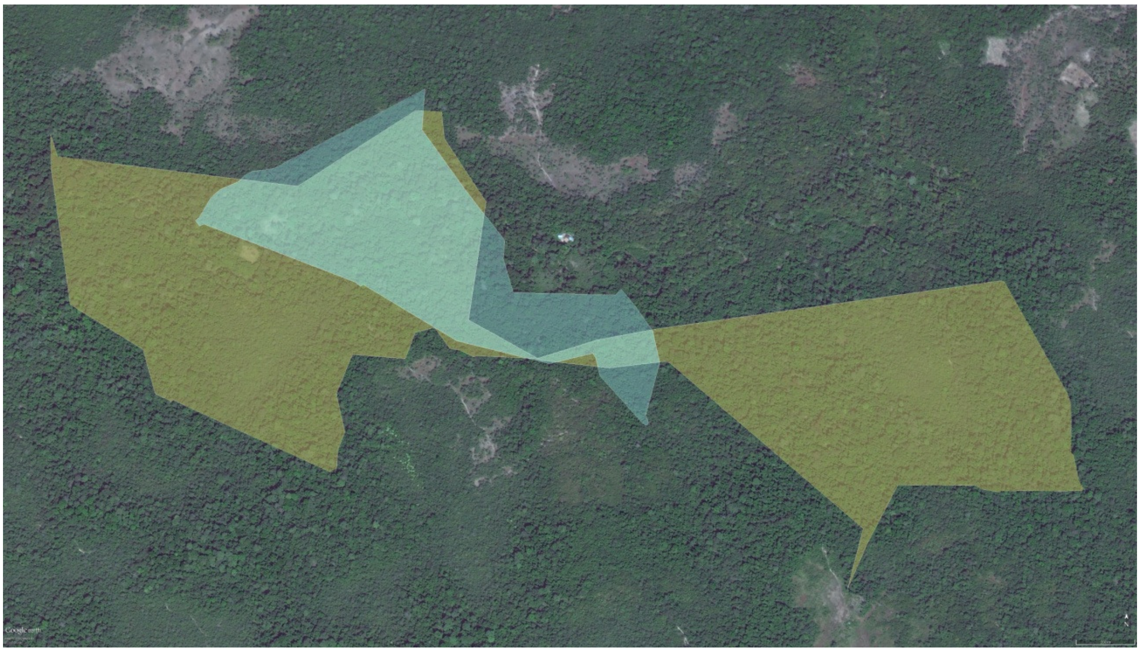

Fig.7.5 *MCP representation of the seasonal ranges of the study group. In blue, the smaller wet season home range with 66.3 ha; in green, the larger dry season home range with 203 ha.*

When assessing the home range by using the grid cell method, it was found that the group entered a total of 41 of cells divided in two main unconnected blocks, giving a total home range of 256.25 ha (but note that one GPS point in particular from March 2014 was removed from the analysis as it was a bit anomalous, so the corresponding cell was also removed from the analysis. This will be explained in detail in the discussion).

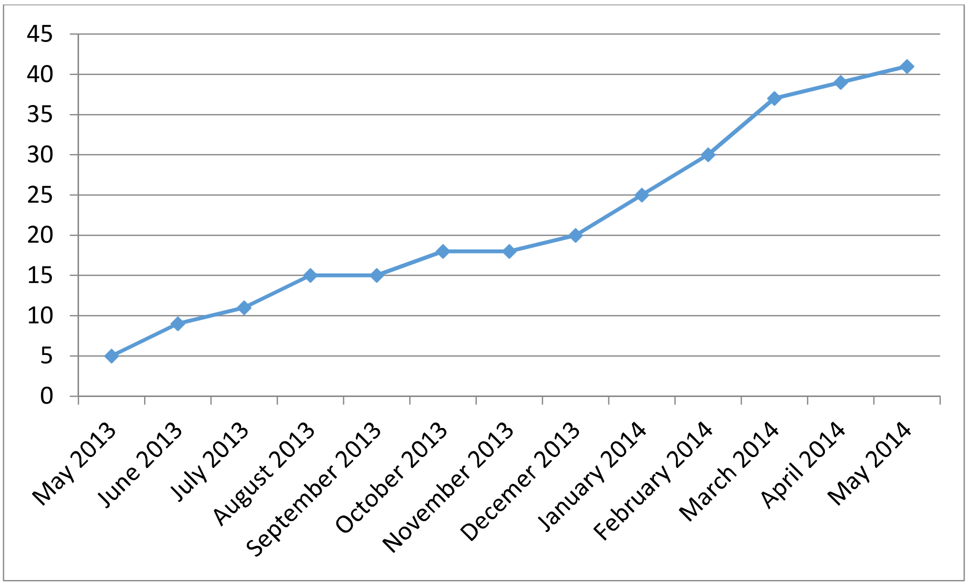

***Fig.7.6** Graphical representation of the cumulative number of visited cells by the study group by the end of the study*

Regarding the intensity of use of the home range as a whole, of the 41 total cells; nine were in mixed deciduous forest and 32 in mixed evergreen forest. The five cells with the highest amount of ranging points were pooled together in the first category making up 5.1% or more of the total amount of ranging points that were recorded with the GPS unit. These five cells include 36% of all collected ranging points, so they can be considered the core areas within the group home range. A further 22 cells are in the second category, presenting 2.1 to 5% of all collected ranging points. The last category included cells that presented 0.01 up to 2% of the total ranging points, and it consisted of 14 cells (Fig.7.7).

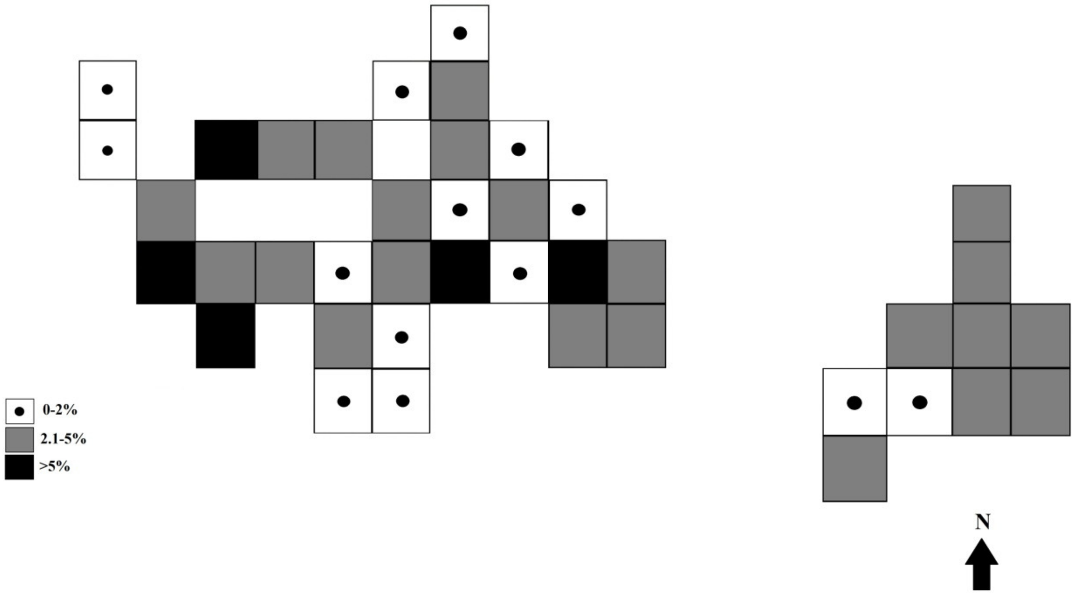

Fig.7.7 *Total home range map showing the intensity of quadrat use*

During the rainy season, the group entered 15 cells, making a seasonal home range of 93.75 ha. Out of the 15 cells that comprise the home range, nine were mixed deciduous forest and six were mixed evergreen forest. Regarding home range use, eight cells figure in the first category, those cells with more than 5% of the recorded ranging points. One cell in particular is interesting in presenting more than one quarter of all location points obtained during the rainy season (25.7%). Only one cell was part of the second category, with between 2.1 and 5%. The remaining six cells belonged to the last category, 0.1 to 2% (Fig. 7.8).

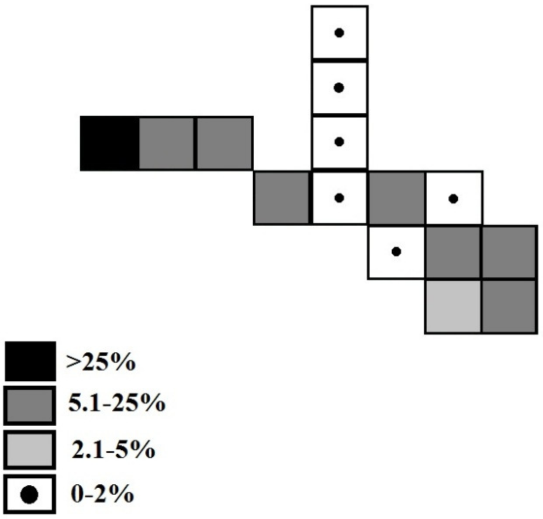

Fig.7.8 *Home range map during the rainy season, showing the intensity of quadrat use*

Thirty two cells were occupied by the group during the dry season, giving a home range size of 200 ha. 28 cells consisted in mixed evergreen forest, while four were mixed deciduous forest. The dry season home range consisted of two main unconnected blocks. Six cells were part of the first category, forming the core areas for the group during this part of the year. 13 cells were part of the remaining categories (Fig. 7.9)

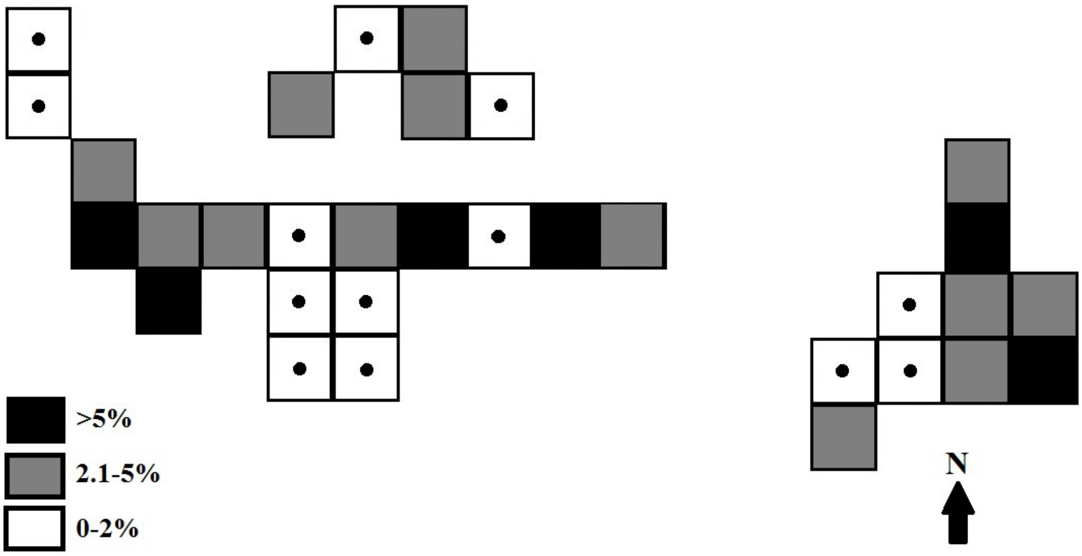

Fig.7.9 *Home range map during the dry season, showing the intensity of quadrat use*

Habitat selection index (P_i) values were obtained for each of the forest types that were represented in the habitat cells. Mixed deciduous forest P_i was of 0.03 for the whole study, 0.1 for the rainy season and -0.3 for the dry season. Mixed evergreen forest P_i values were -0.008 for the whole study, -0.1 for the rainy season and 0.02 for the dry season.

7.3.3 Sleeping trees

Only nine trees were positively confirmed to be sleeping trees during the length of the study, mainly because the study group was not habituated to human observers and most of the times it was not possible to follow the group until the end of the day because they tended to slip away undetected, and no sleeping tree was seen to be repeatedly used by the study group. While trees were only considered to be used as sleeping sites if they presented monkeys at the end of the day, this does not mean that the group only used thise particular trees in that day, and it is likely that other adjacent trees were used as sleeping sites. Sleeping trees do not correlate with intensity use when looking at the length of the study, but during the dry season, those sleeping trees in the far west and east portions of the home range were found in areas of intense use. The species that was most frequently observed being used as a sleeping tree was *Dipterocarpus alatus*, with four different stems (44.4%), followed by *Irvingia malayana* with two stems (22.2%), while three other species presented one observed stem: *Anisoptera costata*, *Hopea* sp. and *Parinari annamensis* (Fig.7.11).

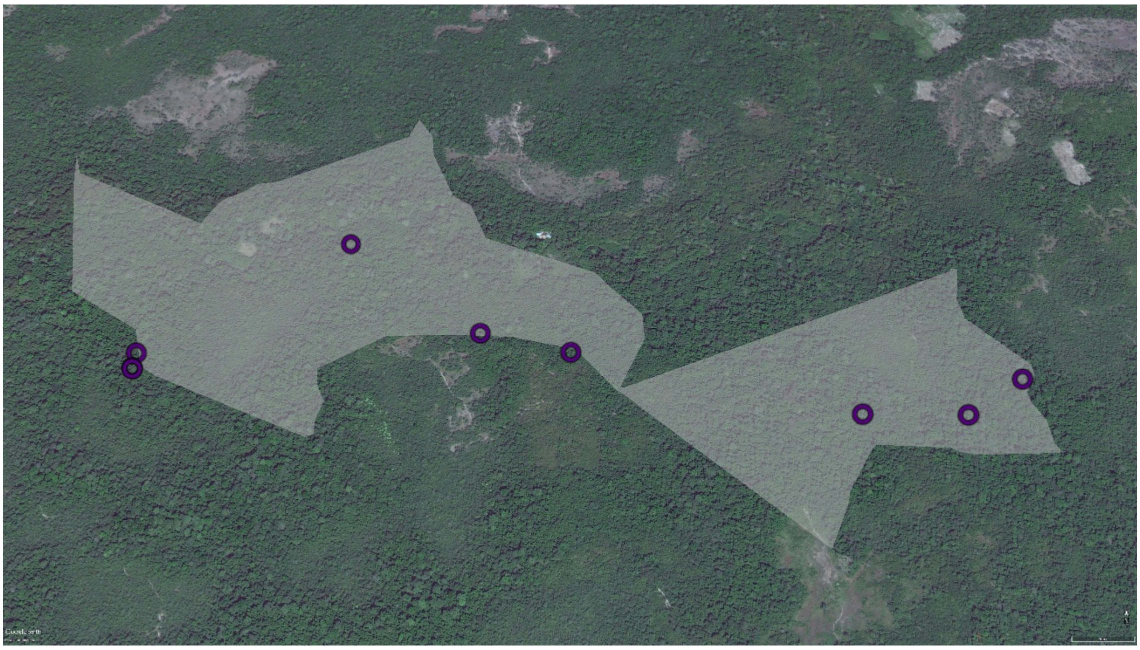

Fig.7.10 *Geographical distribution of known Annamese silvered langur sleeping trees with the study site home range during the study marked as a white area*

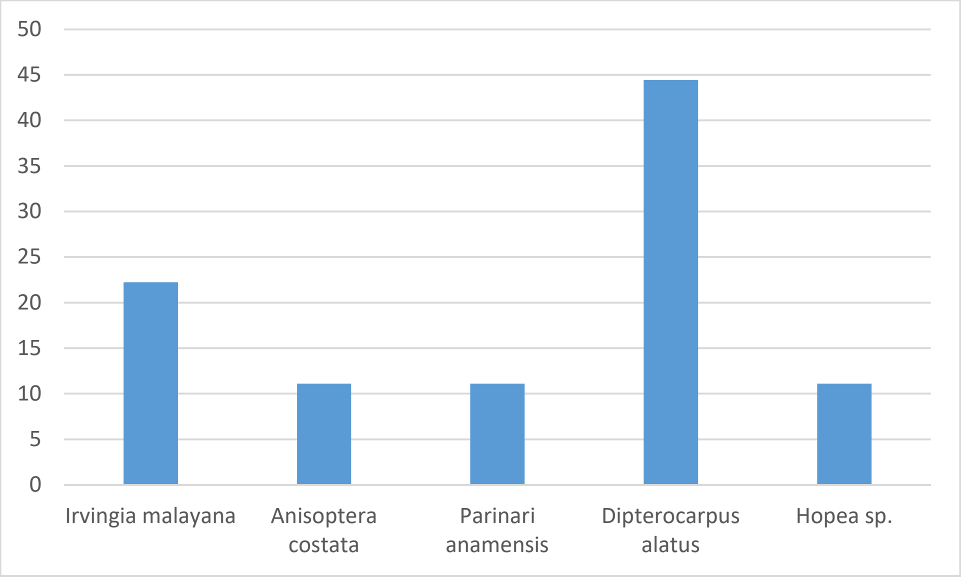

Fig.7.11 *Proportion that each different species represents from the total amount of sleeping trees*

When looking at the sleeping tree composition by families, species belonging to only three families were observed being used as sleeping trees: the most frequently used family were the dipterocarps, with three species and two thirds of all sleeping trees, with the Irvingiaceae second with one species and two stems, while the only other observed family was the Chrysobalanaceae, with one species and one stem (Fig.7.12)

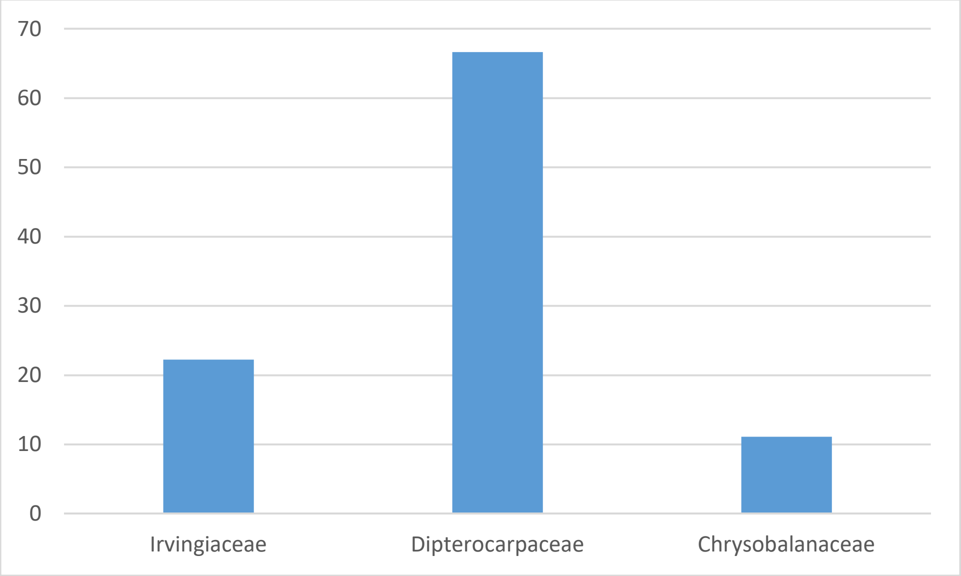

Fig.7.12 *Proportion of each family from the total amount of sleeping trees*

Sleeping tree dimensions ranged from a minimum height of 24.9 meters to a maximum height of 53.6 meters, with a mean height of 38.15 m. Maximum DBH was of 136.2 centimeters, the minimum was 63 cm, the mean DBH value being 101.37 cm. Crown size oscillated between a maximum of 639.32 meters and a minimum of 194.42 m, while mean crown size value was 368.15 m.

7.4 Discussion

7.4.1 Canopy use

Height above sea level is pretty constant in the area in and around the group home range, around the O'Ksiap stream. Heights registered by the GPS recording unit were always around 100 m, never reaching above 150 m. Thus, the group occupied a lowland area in the vicinity of a stream which carried water all year round. The species habitat concurs with what has been noted in other works about the *T. cristatus* group in Indochina as *T. germaini* (*sensu lato*) (which from the geographical location of the localities included both *T. germaini* and *T. margarita*), in areas where they were more commonly found (Moody *et al.,* 2011; Ruggeri & Timmins, 1996; Timmins *et al.,* 2013), although it contrasts with the information provided by Tran (2013) and Hoang *et al.,* (2010), where a *T. annamensis* group, the same species as the group in this study, was found living at around 600 meters above sea level. *T. germaini*, which used to be lumped with *T. margarita*, was found in similar environments (Edwards *et al.,* 2012; Royan, 2010; Starr *et al.,* 2010); another closely related species, *T. cristatus*, was also found in lowland areas in addition to secondary forest in Sumatra and Kalimantan (MacKinnon, 1985). *T. selangorensis* was found in mangrove forest, as well secondary forests and forests close to human habitation (Bernstein, 1968; Furuya, 1962; Southwick & Cadigan, 1972). *T. auratus* has also been observed to live in mountainous areas (Nijman, 2014).

When looking at the way the Annamese silvered langur used the forest canopy, it can be seen that the species preferred to use the high canopy level, from 20 m upwards. The results agree with what has been seen in some Asian colobine species including *Presbytis potenziani* (Fuentes, 1996; Hadi *et al.,* 2012), *Trachypithecus obscurus* (Curtin, 1980; Md-Zain & Chng, 2011), *T. pileatus* (Solanki *et al.,* 2008) as well as some populations of *Presbytis hosei* (Nijman, 2010), *Rhinopithecus bieti* (Xiang *et al.,* 2009) and *Rhinopithecus roxellana* (Li, 2007); this does not however seem to be a particularly common pattern within colobines, not even within the genus *Trachypithecus* (Ampeng & Md-Zain, 2012; Boonratana, 2000; Grueter *et al.,* 2013a; Hadi *et al.,* 2012; Gurmaya, 1986; Ren *et al.,* 2001; Singh *et al.,* 2012; Sushma & Singh, 2006; Zhang *et al.,* 2006; Zhu *et al.,* 2015). This characteristic might prove to be problematic when taking into account the fact that illegal logging in the area targeted large sized trees, which means that animals can find it hard to access areas of their home range or lose them altogether. Interestingly, although low canopy use was low, all age/sex classes except adult females were found in there at least 10% of the time. Furthermore, the study group was found to go down to the ground from time to time, which was most likely due to feeding. Animals were observed to go to the ground whenever they appeared not to detect observers, all while foraging for certain items, or moving across a patch of grassland in order to access a feeding tree. Not only that but they were also seen to move to the ground in order to consume minerals in natural mineral outcrops (Rawson & Luu, 2011). The extent to which this species engages in behavior at ground level is hard to gauge given the fact that they are naturally suspicious whenever they move in the ground, and that they would return to the safety of the canopy whenever they seemed to feel threatened.

When looking at any differences in canopy use by sex, adult males and females did not present any significant differences. When focusing on differences between age classes, it can be seen that infants were more significantly active in the mid canopy than either adults or juveniles. This can have several explanations, but the most probable cause is play. As playing behavior will involve jumping and running, there will be more frequent changes in the canopy tier in which an individual is found. While infants are playing, they will use the mid level canopy layers more often than older age classes which do not engaging in playing behavior as often as infants, thus remaining more fixed in the canopy levels where they are active. Subadults spent the highest amount of time of all age classes in the lower canopy, although it is difficult to know the reasons behind this, but subadults would be more at risk from attacks by predators found in the forest floor. It should also be noted that these trends in canopy use might be affected by the impacts of human activity within the home range. This issue will be further discussed in the following chapter.

7.4.2 Ranging and home range use

It is important to note that there were more data available for the dry season than for the dry, and differences between these might be due to this difference in sampling effort. The results of the two methods for home range size were quite similar. Interestingly enough, while the grid cell method is considered to be conservative when compared to the MCP method (Grueter *et al.,* 2009c), the results obtained in this study by the former method represent a rather larger home range size for the group, with 256.25 ha, compared with 221 ha by the latter method. The same conclusion can be seen when comparing differences in results within seasonal ranges. Nevertheless, it is clear that, to judge by the study group, the home range of the Annamese silvered langur is not only quite large, but also one of the largest within the whole colobine group. In comparison, the recorded home range of a species of the silvered langur group, *T. selangorensis*, was 20 ha (Bernstein, 1968) which is less than 10% of the present study group's home range size.

There is variability between home range sizes of different populations of the same species, however, as it was observed on *S. entellus* (Chhangani & Mohnot, 2006), *S. ajax* (Minhas *et al.,* 2013), *N. larvatus* (Matsuda *et al.*, 2009b), *P. comata* (Ruhiyat, 1983) and *T. francoisi* (Zhou *et al.,* 2007), so it would be interesting to look at the ranges of other populations of the species in the future. Species that present much larger home ranges than *T. margarita* are mainly in the genera *Rhinopithecus* and *Pygathrix* (Guo *et al.,* 2008; Grueter *et al.,* 2008; Kirkpatrick, 1998; Kirkpatrick *et al.,* 1998; Li *et al.,* 2000; Li *et al.,* 2010; Ren *et al.,* 2009; Tan *et al.,* 2007), which present fission-fussion societies with several groups that can aggregate into larger associations, although some *Pygathrix* groups have been observed to present much smaller home ranges than the study group as well (Hoang, 2007; Rawson, 2009). Some range estimates for other species, such as *Semnopithecus ajax* (Minhas *et al.,* 2013) also surpass this size. Other populations of *Nasalis larvatus* and *S.ajax* (Boonratana, 2000; Minhas *et al.,* 2013; Salter *et al.,* 1985) presented the closest home range size to that recorded here, with 220.5, 235 and 270 ha respectively.

When comparing the obtained home range to those of other *Trachypithecus* species, the only species that surpasses *T. margarita* in home range size is *T. crepusculus*, doubling the obtained results with 446 ha (Fan *et al.,* 2015) (Fig.7.13). Thus, *T. margarita* presents a larger home range than even species that have a very similar diet, based on a high amount of seed and fruit (*P. rubicunda*).

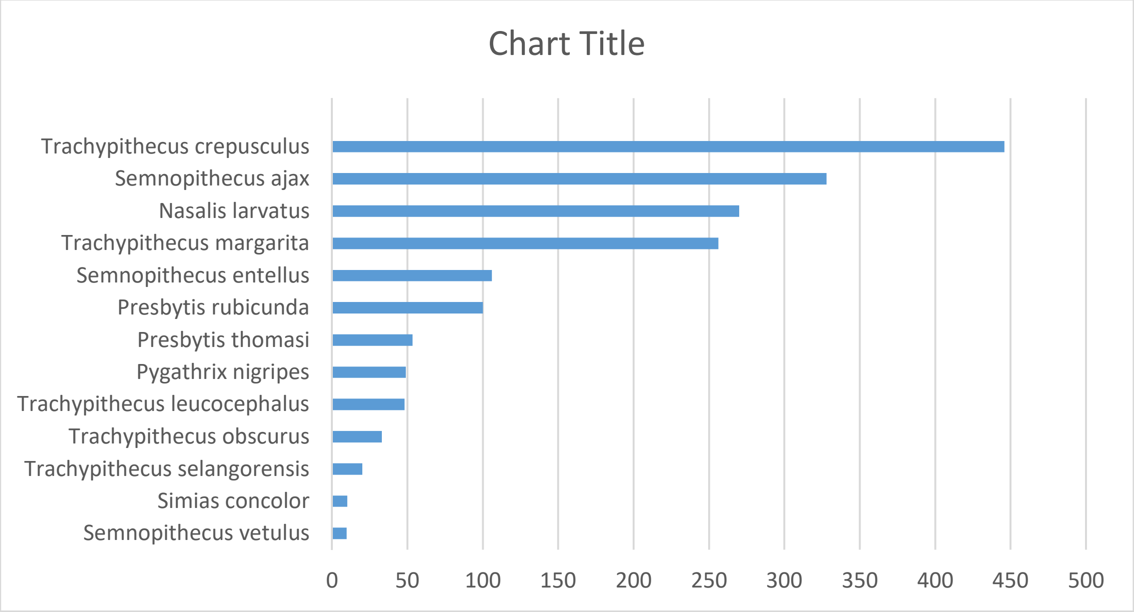

Fig.7.13 *Maximum recorded home range sizes for several species of Asian colobines. Rhinopithecus species are not present so that the comparison between the other species could be appreciated*

When analyzing the way the group used its home range, it can be seen that there was a difference between seasons that goes further than the issue of differing sizes. The home range as a whole was divided into two more or less connected blocks, with langurs moving through the intervening unoccupied cells not being observed. There were five cells with the largest amount of location records, and while not being exactly adjacent, they could be again divided in two more or less distinct blocks of close highly frequented cells, all within the westernmost block of cells, which means the groups uses the westernmost part of its home range more regularly during the whole year. This can be perhaps explained because this area of the home range links with more or less continuous forested areas that extend towards the west, as well as the indication by the local guides of the presence of mineral licks in this area that most likely will be used by the langurs. While the study group itself was never seen engaging in geophagy, the species is known to do it at the study site (Rawson & Luu, 2011), and it has been indicated by different camera traps in several different mineral lick sites. The easternmost portion of the home range, however, is surrounded by farms to the east and south, which suggests a further human encroachment on the habitat, as well as a lack of connectivity, which may impact the way the animals range. This way in which langurs used their habitat could also be explained by seasonal ranging: animals were not detected in this area during the rainy season, so there might not be a lot of preferred foods available in this part of the home range during that season. The previously mentioned lack of connectivity, which added to the low encounter rate during the study show that it is most likely that there was only one single group in the study area. There are no other neighbouring langur groups that could move into the home range area because the surrounding habitats to it cannot sustain them, being savanna woodlands or farms; also, encounter rates would have been much higher if there were several groups of langurs living in the same area.

When looking at home range intensity use by season, the rainy season home range greatly contrasted with the general home range: The easternmost block was not represented, whereas the cells with most ranging locations were clumped together into a large core area. Habitat intensity use was so high in this concentrated area during the rainy season that one cell alone contained more than 25% of all location records for the whole season, which probably means that animals were using very important seasonal resources in that area. On the other hand, the dry season home range followed the total home range more closely, with two main unconnected blocks of cells, but in this case, the cells which presented most location records were found on both blocks of cells, with four on the westernmost portion, and two on the easternmost portion. These six cells could be divided into three separated core areas, which hints that preferred food items might be scarcer and more dependent on time, so animals have to range further than during the rainy season.

This ties with the results obtained in the feeding chapter, where langurs targeted a variety of seeds from food trees were widely distributed throughout the home range

The analysis of the P_i values obtained for each of the two forest categories included in the study shows that, while preferences toward a certain kind of habitat were not very strong during the whole year, there certainly were preferences during each specific season. During the rainy season, Annamese silvered langurs had a slight preference to occupy areas of mixed deciduous forest composition, and were slightly averse to occupy mixed evergreen forest areas. These preferences may be influenced by the fruiting patterns of feeding species that are preferred foods for the species and form part of mixed deciduous formations, but further studies centered on the phenology of food species are needed in order to elucidate this question; many food species recorded in the previous feeding chapter were observed to fruit during the dry season, such as dipterocarps, Fagaceae, *D. oldhamii* or *W. edulis*, while other species found in mixed deciduous forest patches such as *S. cochinchinensis* or *P. dasyrrachis* were observed fruiting during the rainy season. During the dry season there was a switch, with the mixed deciduous being strongly avoided by the langurs.The P_i value for this formation was the strongest of all obtained values, showing that ranging patterns during the dry season will be heavily influenced by the distribution of mixed deciduous patches of forest.

One reason for this strong avoidance could be that there were fewer sources of preferred foods in those patches during the dry season, heavily influenced by the fact that these patches are more strongly affected by the seasons than mixed evergreen patches, and that the quantity and quality of preferred food sources may be greatly reduced. Another important factor is that mixed deciduous formations, as seen previously, are heavily dominated by *Lagerstroemia*, trees that lose their leaf cover during the dry months. Impacts on langurs could be very important: First, given the tendency of the langurs to mostly hide in the canopy, the loss of leaves will mean there will be a massive exposure to the group, both stationary or while moving, thus resulting in an avoidance of these patches due to a high vulnerability. As further support for this, predation by raptors on South and Southeast Asian colobines has been previously observed (Fam & Nijman, 2011; Sunderraj & Johnsingh, 2001). *Trachypithecus* in Malaysia (*T. selangorensis*, *T. obscurus*) have shown signs of distress when raptors approached the group (Bernstein, 1968; Curtin, 1980), as well as other Asian colobine species such as *T. pileatus* (Green, 1981) or *Rhinopithecus bieti* (Cui, 2003; Xiang *et al.,* 2009). If there were no leaves to provide the langurs with cover, they would be prone to being targeted by predators. While adults are too large to be hunted by raptors, juveniles and especially infants might be suitable prey for avian predators. Furthermore, during the course of the study it was noticed that animals went silent and still whenever hovering raptors appeared in the vicinity of the group. This factor could also be an influence on the more common use of mid canopy levels by infant langurs, given that they would be the main targets of aerial predators, and the high canopy is the most likely place in which such an attack would take place.

As noted by Grueter *et al.* (2008), the heterogeneity of the habitat in which the monkeys are found could explain differences in seasonal ranges as the area in which they were found is a mosaic of suitable habitat patches interspersed with non-optimal patches. This seems particulary true for the large dry season home range, given that the central part of the home range is formed by mixed deciduous forest, a formation that, as noted above, is avoided during the dry season. During lean times, food becomes scarce and irregularly distributed, and the animals will have a large home range in order to access to food species (Boonratana, 2000; Erinjery *et al.,* 2015; Minhas *et al.,* 2013). Although some studies find that colobines do not have larger ranges when they consume fruit or flowers (Boonratana, 2000; Matsuda *et al.,* 2009b), others find that they do have larger home ranges whenever these food items are available (Ampeng & Md-Zain, 2012; Grueter *et al.,* 2008; Minhas *et al.,* 2013; Zhou *et al,.* 2011). Silvered langurs were observed to feed on different species and items, and this dietary diversity became more marked during the dry season. It is probable that these langurs take an opportunistic approach to feeding, focusing on the most nutritious available foods, and so move through their home range in search of different dietary items that are scattered and offer food at different times of the year, and always resorting to fallback food items, such as mature leaves, whenever other preferred foods cannot be found. Throughout the study, silvered langurs consumed a large amount of seeds, amounting to more than half of all consumed items, while fruit was also frequently consumed. While during the rainy season langurs incorporated a high amount of fruit in their diet, during the dry season they instead presented a high quantity and diversity of seeds in their diet. Other species in the genus increase their home range size when their diet switches to focus on seeds and fruit (Zhou *et al.,* 2011), so it is very likely the focus on seeds and the enlargement of the home range during the dry season were related.

Another possible explanation for the larger home range size during the dry season (and the strong avoidance of mixed deciduous forest) has to do with the slight selectivity towards mixed deciduous forest patches during the rainy season: *T. margarita* has been observed in other studies to feed on the leaves of *Lagerstroemia calyculata* (Tran, 2013), which was the most dominant species in that particular kind of forest (its IVI value being more than three times that of the next most dominant species), and they most likely do so at the study site as well, even if this was not observed by the researchers. If *T. margarita* fed on the leaves or plant parts of the dominant plant species on the habitat that was selected for and langurs were most frequently found during the rainy season, there would have been no need for the study group to forage as widely as they did during the dry season, when they were looking for seeds. Of course, further studies are needed in order to have a better understanding of the Annamese silvered langur during the rainy season. The inability to assess what species were used as part of the species' diet due to an absence of previous research on the topic prevented any research on the phenology of food species and its impacts on the ranging behavior of langurs, so further studies should focus on the phenology of die species and food items, and how is the ranging affected by them.

Why should a mainly folivorous primate have such a large home range compared to its closest relatives? When we look at comparisons of home ranges in other species it has been argued that a large home range would be the consequence of a low availability of food for the species (Boonratana, 2000; Matsuda *et al.,* 2009b; Singleton & van Schaik, 2001). In the present case, this cannot be tested in the absence of phenological data for the plant species that form part of the species' diet. It is known that the natural habitat of the Annamese silvered langur, though, is subject to a relatively strong seasonal variation. Some areas that are heavily used during a particular season will not be visited due to a lack of preferred foods or even forest cover, such as in mixed deciduous formations. It can be ventured that the distribution of preferred food items, especially knowing that a great proportion of the langur diet during some parts of the year consists in seeds or even fruit, will most probably have a strong influence over ranging behavior and home range size, and will definitely account for such a large home range size. Furthermore, it has been observed that colobine species that eat large quantities of seeds do present much larger home ranges than those species that are more folivorous (Davies *et al.,* 1988; Maisels *et al.,* 1994; Stanford, 1991b). A previous study which was summarized by Nijman (2010) notes that groups of colobines living in forests subject to logging present much larger home range sizes than those that live in unperturbed forests. It is entirely possible that the subject group presents such a large home range because of the influence of habitat degradation caused by logging, but it is not possible to establish this with the present set of data: Further information on feeding habits and response to seasonal food availability as well as information regarding home range sizes for groups in areas where human impact is minimal are necessary in order to not only elucidate if any of these factors have any effect, how much do they contribute to the study species presenting large home ranges, and also to be able to not confound the influence of both factors.

It should be noted that the home range obtained for the study group is most likely underestimated. The graphic representation of the cumulative amount of cells that the group entered during the study (Figure 6) had not reached an asymptote by the end of the study, which means that most likely there are still cells that form part of the group home range that have not yet been registered. It is important to consider that a conservative approach to analyzing the home range was taken, which means that the actual home range might even be larger than observed during the study. A location point far south where a couple of individuals were spotted feeding was removed from the analysis for it being anomalous: the area in which they were found was quite far from the bulk of the home range, so it is unsure if the observed individuals were indeed part of the study group; if they indeed were, this ranging point was an outlier that would skew the analysis. While they were targeting feeding trees, langurs were found adjacent to a track beside which there was a patch of dry deciduous forest formed of thorny bush species, a habitat where these langurs were never spotted before or after this incident, which most likely makes this point the limit of the Annamese silvered langur suitable habitat.

Also, as previously mentioned, it was observed that Annamese silvered langurs regularly engaged in geophagy at mineral licks at the site, implying that these formations are very important resources for the species. Given that the study group was never observed to visit any mineral licks or to consume soil, and no mineral licks were found in the registered home range, it is most likely that the study group home range will englobe areas that include these outcrops, thus implying the home range will be larger than so far known in order to accommodate those areas, as there is a consistency in the species visiting mineral licks, not only in VSSPCA (Rawson & Luu, 2011) but also in other protected areas, such as Prey Lang (Hayes *et al.,* 2015). Furthermore, African colobines have been observed to travel large distances in order to consume particular food items that are rare, as well as to engage in geophagy (Fashing *et al.,* 2007), meaning that these resources have a great influence on the ecology of the species, and thus, will have a great impact on its ranging behaviour.

No data were obtained for daily paths given the methodological issues discussed above. Only one day where the group was found and followed could be considered as a full day follow, so obviously it was impossible to do a proper comparison of overall and seasonal daily paths.

7.4.3 Sleeping tree use

Sleeping trees were both recorded at the inner areas of the home range and at locations that are likely to be on the outer rim of it. Although large, emergent trees with large horizontal branches were always selected by the study group as sleeping sites, this is nevertheless common in most primate species (Anderson, 1984). As mentioned previously, potential predators in the home range include reticulated python (*Malayopython reticulatus*) and probably clouded leopard (*Neofelis nebulosa*), and although leopards (*Panthera pardus*) have not been observed, they are present in other protected areas of Eastern Cambodia, and also be present in more remote areas of VSSPCA.

Although langurs could be subject to predation from these species that have been observed to potentially affect other Southeast Asian species such as gibbons (Phoonjampa *et al.,* 2010; Reichard, 1998), it does not seem that predator avoidance was the main driving factor behind sleeping tree selection as they did not particularly choose trees that were isolated from the surrounding vegetation, while some of the targeted species did not seem very common or widespread in the habitat; also, some of the selected sleeping trees did sport vines attached to them, which would potentially facilitate access by predators. In addition to this, all but one of the species selected by the study group as sleeping trees were recorded as food trees as well, with one of them actually presenting feeding records and thus doubling as a feeding tree, which also points to Annamese silvered langurs sleeping on trees that they feed on, something already observed on other Southeast Asian colobines of the genus *Presbytis* (Ang, 2010).

No sleeping trees were recorded to be in the close vicinity of the stream within the group's home range, even if other Asian primates have been observed to sleep at the fringes of bodies of water (perhaps in order to reduce the risk of predation), including two phylogenetically close species, *T. cristatus* and *T. selangorensis* (Bernard *et al.,* 2011; Brotcorne *et al.,* 2014; Curtin, 1980; Matsuda *et al.,* 2010, 2011; Ramakrishnan & Coss, 2001; Salter *et al.,* 1985). There are two possible reasons for this: either langurs did not indeed suffer from a strong predatory pressure and develop no need to avoid potential nocturnal predators, or the group could only use trees at the fringe of the stream as a successful predator avoidance mechanism during the months where the stream is at its fullest, and no sleeping trees were recorded during the rainy season. It would be of great interest if further studies looked at any changes in sleeping tree use with the seasons, and the location of those relative to the stream.

At the same time, dipterocarps seem to be particularly favoured by langurs, and it has already been mentioned in previous studies (Cheyne *et al.,* 2012; Phoonjampa *et al.,* 2010; Reichard, 1998) that dipterocarps are a group of trees that can afford a better defense from felids, with pythons being an additional nocturnal threat to primates. Also, while langurs were also not particularly noisy nor obvious when they were observed settling on the sleeping trees, which ties in with predator avoidance behavior observed in other species that could be subject to the same predators, such as gibbons (Fan & Jiang, 2008a; Fei *et al.,* 2012; Nelson, unpublished; Reichard, 1998), snub nosed monkeys (Xiang *et al.,* 2010), *T. leucocephalus* (Li *et al.,* 2011) and *T. francoisi* (Wang *et al.,* 2011; Zhou *et al.,* 2009b), they also did not act particularly cautiously either, a pre-sleep behavior that has been observed before in other *Trachypithecus* species (*T. hatinhensis*) (Nguyen, 2006).

It seems the observed results would tie in with what was observed in African colobine species in the genus *Colobus* (Teichroeb *et al.,* 2012; von Hippel, 1998) or other *Trachypithecus* species (Li *et al.,* 2011; Wang *et al.,* 2011; Zhou *et al.,* 2009b), where monkeys slept on food trees in order to have a better access to food, but at the same time exhibited predator avoidance behaviors such as using tall, wide canopy forming trees, choosing sleeping places separated from the main trunk in mid or terminal horizontal branches, and frequently switching sleeping trees. While the group size obtained for the study group and the recorded amount of immature individuals hint that predatorial pressures on Annamese silvered langurs must be small, it might not have been the case historically or in populations that live further inside the conservation area, where predator numbers and activity will most likely be higher than in the study area, due to the lesser intensity of human influence. Further research to elucidate the driving forces behind *T. margarita* sleeping tree choice at VSSPCA should focus on further knowledge on species used as sleeping trees and their phenology. Also of importance should be the availability of plant parts of interest and its influence on ranging behavior. Comparisons of this population to other groups that are living in areas with a larger or lesser amount of human disturbance would be of great interest to look at any differences on predation or hunting pressures. Analysis of parasites in faeces or in and around sleeping trees was not carried out; this would help establish if parasite concentrations would play any role in the choice or avoidance of particular areas or sleeping trees by the study species.

7.5 Summary

The range of *T. margarita* in the study site consisted of a mosaic of lowland mixed deciduous and mixed evergreen forest patches in the vicinity of a stream which carried water all year round. The langurs were found to mainly use the high canopy layers of the forest, 20m high and above, excepting infants, which were more commonly present between 10 and 20m high, probably due to playing and predator avoidance behaviours. They sometimes descended to the ground, with adult females doing this the least.

Total home range size was calculated as 256.25 ha, the largest registered home range for the genus *Trachypithecus* and one of the largest of all colobines, even if the registered dimensions are most likely an underestimate of its true size. Ranging differed between seasons, with the rainy season home range being much smaller in size than the dry season home range. During the rainy season, they had a slight preference towards mixed deciduous forest and a slight avoidance of mixed evergreen forest, while there was some avoidance of mixed deciduous forest during the dry season, probably due to absence of many seasonal food species. The langurs used the westernmost area of the home range more frequently than the easternmost portion, where they were not seen at all during the rainy season. Ranging patterns are most likely related to the availability of preferred food items, many of these being scarce in time, like seeds, which make up a large portion of the diet during the dry season. Further studies should address this by looking at the distribution and the phenology of food species in order to understand their influence in the species ranging behaviour.

Annamese silvered langurs were observed to use tall trees with a large DBH size as sleeping sites. Due to the absence of hunting pressures on the study species and a likely low predatory pressure, at least on langur groups around the study area, it is thought that the driving force behind *T. margarita* sleeping site selection is to enable an easier access to food trees. Further studies would be of interest in order to clarify when and to what extent do food resources influence sleeping site selection, as well as to establish if it is influenced at all by predators or parasite avoidance.

CHAPTER 8

Human impacts

8.1 Introduction

Southeast Asia is not only one of the areas of the world with the highest biodiversity, forming the Indo-Burma Biodiversity Hotspot, but sadly also one of the places in the world where natural habitats and wildlife are most threatened by human activities. Due to fast development in the region in the recent decades, natural resources have been overexploited and many species of animal and plant have suffered huge pressure from human activities that have reduced their populations and sometimes even extirpated them from many parts of their historical range (Critical Ecosystem Partnership Fund, 2012). Traditional views and attitudes towards certain species of plants and animals have encourage illicit traffic of wildlife or their parts, fueling a huge biodiversity crisis that has reached a global scale in the recent years.

When looking at Cambodia it can be argued that despite this it has retained a large portion of its natural habitats and wildlife populations, especially when compared to neighbouring countries where wildlife populations crashed after the Vietnam War. This could be prossibly due to a mixture of several factors that include a low human population density and high isolation of remote areas, as well as an extended civil conflict that lasted into the 21st century and prevented access to the most remote regions of the country, particularly those with large forest formations in the north, northeast and southwest of the country. Thus, Cambodia, while not the country with the highest biodiversity and degree of endemism (Bain & Hurley, 2011; Rawson, 2010), is today the nation in the region with very significant populations of many key endangered species of birds, such as the giant ibis (*Thaumatibis gigantea*) (Keo, 2008), white-shouldered ibis (*Pseudibis davisoni*) (Wright *et al.,* 2012), white-rumped vulture (*Gyps bengalensis*), long-billed vulture (*Gyps tenuirostris*), red-headed vulture *(Sarcogyps calvus*) (Clements *et al.,* 2013), sarus crane (*Grus antygone*) (Archibald *et al.,* 2003); reptiles like the Siamese crocodile (*Crocodylus siamensis*) (Platt *et al.,* 2006; Sam *et al.,* 2015) and Cantor's giant softshell turtle (*Pelochelys cantorii*), and mammals such as the Asian elephant (*Elephas maximus*) (Fernando & Pastorini, 2011), gaur (*Bos gaurus*), wild water buffalo (*Bubalus bubalis*)

(Gray *et al.,* 2012a), banteng (*Bos javanicus*), dhole (*Cuon alpinus*) (Gray *et al.,* 2012b), Irrawaddy dolphin (*Orcaella brevirostris*) (Baird & Beasley, 2005) and black-shanked douc langur (*Pygathrix nigripes*) (Pollard *et al.,* 2007).

All this does not mean that the state of conservation in the country is pristine, as some species present at the turn of the century have been all but extirpated, like the Indochinese tiger (*Panthera tigris*) or the Javan rhinoceros (*Rhinoceros sondaicus*). A further event of similar or even greater importance of late is the extraction of dipterocarp and rosewood tree species destined for the luxury wood market. These trees have been targeted all over the Asia-Pacific region and have been exterminated from most of their range. Cambodia used to be up until very recently one of the last strongholds for rosewood species, but all that has changed in recent times, when forest loss has skyrocketed with Cambodia initially being one of the countries with the highest deforestation rates in the region (Global Witness, 2007, 2015; Hansen *et al.,* 2008, 2013) and eventually holding the top spot (Petersen *et al.,* 2015)

Although Cambodia imposed a ban on the export of wood from national sources, there has been a failure to protect forest stands in the country (Critical Ecosystem Partnership Fund, 2012; Global Witness, 2015; Peter & Pheap, 2015; Titthara, 2014; Wolf, 1996). The Cambodian government allocated certain areas in the country for economic exploitation, called Economic Land Concession Zones, where logging and extractive methods for natural resources were allowed, but although legislation and conservation policies are good on paper (de Lopez, 2002; Peter & Pheap, 2015), logging and extraction of precious wood species has been rampant in areas found outside of the demarcations of concession zones, as well as land clearing for economic purposes. Furthermore, it seems that some government officials actively partake, encourage and benefit from these processes (Global Witness, 2007, 2015; Pye, 2015b; Pye & Titthara, 2014, 2015; Talbott & Brown, 1998; Titthara, 2013) Logs illegally sourced out of protected areas will later be exported to neighbouring countries, by sea or road, which in turn might export them or their products to third countries (de Lopez, 2002; Global Witness, 2015; Pye, 2013; Pye, 2015a, 2015b; Pye & Titthara, 2014, 2015; Titthara, 2014; Wolf, 1996).

Human activities are the main cause of loss of primate species and populations, whether by habitat fragmentation and loss or active hunting, although when looking at different cases, primate species react differently to human disturbance, depending on the severity of those activities and the effect they have on the environment, as well as in the ecological plasticity of the species affected (Heiduck, 2002). Some species experience population losses and reduced fitness as forest fragments keep diminishing (Anderson *et al.,* 2007; Chapman *et al.,* 2000; Chapman *et al.,* 2007; Decker, 1994; Estrada & Coates-Estrada, 1996; Felton *et al.,* 2003; Johns, 1983; Mackinnon, 1974; Menon & Poirier, 1996; Nijman, 2004, 2010; Rosenbaum *et al.,* 1998; Singh *et al.,* 2001; Skorupa, 1985; Umapathy *et al.,* 2011), although some of these populations can recuperate if human pressure abates (Chapman *et al.,* 2007; Johns, 1983; Workman & Le, 2010); other species, however, experience a rise in their population numbers by exploiting the new conditions created after recent logging (Chivers, 1977; Grieser-Johns & Grieser-Johns, 1995; Johns, 1983; Plumptre & Reynolds, 1994; Skorupa, 1985). Some species modify their behavior to adapt to smaller patches of forest (Onderdonk & Chapman, 2000; Riley, 2008; Singh *et al.,* 2001; Umapathy *et al.,* 2011) or to become more inconspicuous and avoid being targeted by hunters (Hicks *et al.,* 2013); even species in the same area will react differently to anthropic pressure (Borgerson, 2015). However, due to the fact that different methods and time scales have been used in different studies, as well as the fact that other anthropic and environmental influences sometimes have not been taken into account, it had been hard to establish a general pattern (Chapman *et al.,* 2006; Johns, 1992).

Loss of canopy species due to illegal logging causes an increase in the production of leaves and other plant parts in the remaining species, so primates whose diet includes species that are not the focus of selective logging can indeed profit from this activity if it is moderated and the animals are able to withstand stress and they do not become exposed to hunting as a result of the disturbance (Chetry *et al.,* 2010; Ganzhorn, 1995; Johns, 1988; Knop *et al.,* 2004). In any case, lack of forested surface has been seen to be associated with a decline in primate densities (Anderson *et al.,* 2007).

The aim of this chapter is to analyse the impact of different variables associated with human logging activity that was carried out in the study group's home range, such as chainsaw numbers, daily length of logging and distance from logging to the study group. I also look at any impacts of logging on the group's socioecology, particularly ranging and habitat use.

8.2 Methods

8.2.1 Study Site and Study Group

This study was carried out in Veun Sai Siem Pang Conservation Area (VSSPCA), Ratanakiri Province, Cambodia, from May 2013 to May 2014, and in the last fortnight of January 2015. An unhabituated group of silvered langurs was tracked in the area and, whenever it was encountered, was followed until dusk or until the researchers lost the group, acknowledging this by determining no activity or signs of presence of silvered langurs in the area after an hour and a half had passed.

8.2.2 Data collection

The study group was tracked in the area five days a week, starting from 5:30 am. Whenever the group was encountered, and from the encounter time onwards until the end of the day or until an hour and 30 minutes passed without any signs of presence whatsoever from the group (indicating the animals had been lost), the group position was recorded every 30 minutes as a GPS point in UTM coordinates using a Garmin 62s GPS unit.

Every time an animal was observed, its age (adult, juvenile, infant) and sex class was noted, as well as the canopy level in which it was found. Canopy levels were measured using a Haglöf Clinometer and then categorized: low (0 to 10m), medium (10 to 20m) high (21m and over), and. The forest type in which the animal is found was also noted (mixed evergreen forest, mixed deciduous forest, dry deciduous forest). The different forest types are described in detail in the methods chapter.

Trees that had been felled by loggers in the area were located once the loggers had left, their position registered by use of a Garmin 62s GPS unit, their species identified with help of different local guides, and the approximate date of felling noted. The kind of habitat where the trees had been felled was also recorded. Location and data collection of logged trees was done after loggers had left because, in the early days of the study, when illegal loggers were approached, I and the local guides accompanying me were not well received and we were forced to leave the area immediately. To prevent a further hostile reaction, I decided to avoid directly confronting loggers.

Each day that any logging activity in the area was detected, the number of chainsaws that were working was recorded. The length of each daily logging episode was measured in hours by noting the hour in which it started and the hour in which it finished, then pooled in different categories depending on each daily length: 0; any minutes up to 2 hours; over 2 hours until 4 hours; over 4 hours up to 6 hours; over 6 hours up to 8 hours; over 8 hours up to 10 hours.

The distance between each ranging point and any logging hotspot where logging activity was carried out in the particular day was also plotted using Google Earth Pro version 7.1.2.2041. Distances obtained were pooled in three different broad categories: 1 to 1000 meters (close distance), over 1000 to 2000 meters (mid distance) and over 2000 meters (far distance).

8.2.3 Data analysis

Registered tree GPS points were plotted on maps using Google Earth Pro version 7.1.2.2041. Thus, logging spots and ranging points were represented and the evolution of both variables over the year could be studied, in order to ascertain any possible influences by logging over the langur's ranging.

In order to establish any influence over the canopy layer use by the whole group and the different sex/age classes by the daily number of chainsaws, daily length of logging activities, and the distance between the closest logging hotspot and the ranging points recorded for the group, χ^2 tests were used. Statistical analysis was performed by using IBM SPSS Statistics 23.

8.3 Results

8.3.1 Logged trees

A total of 89 logged trees were located in the study group home range during the length of this study. Seventy nine trees were logged during 2013, while only 10 were logged during 2014 (Figure 8.1): this difference is due to an increased effort on law enforcement in the area since the beginning of 2014. In regards to differences in logging numbers between the different seasons, 32 trees were cut down during the dry season, while 57 were cut down during the rainy season. The months with the lowest amount of logged trees, zero, were January and April 2014, while the month with the highest count of logged trees was October 2013, with 22 (Figure 8.2).

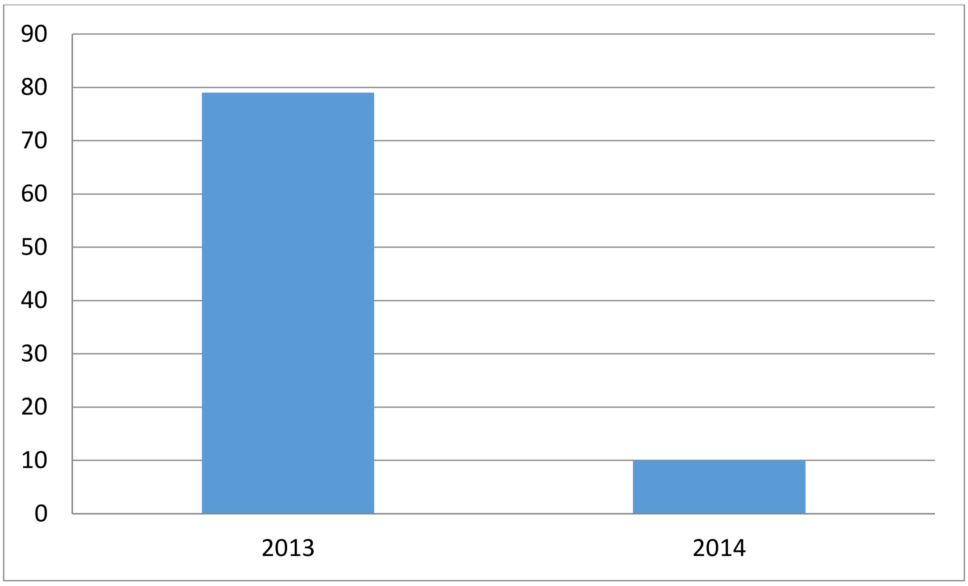

Fig.8.1 *Number of trees logged per year during the study*

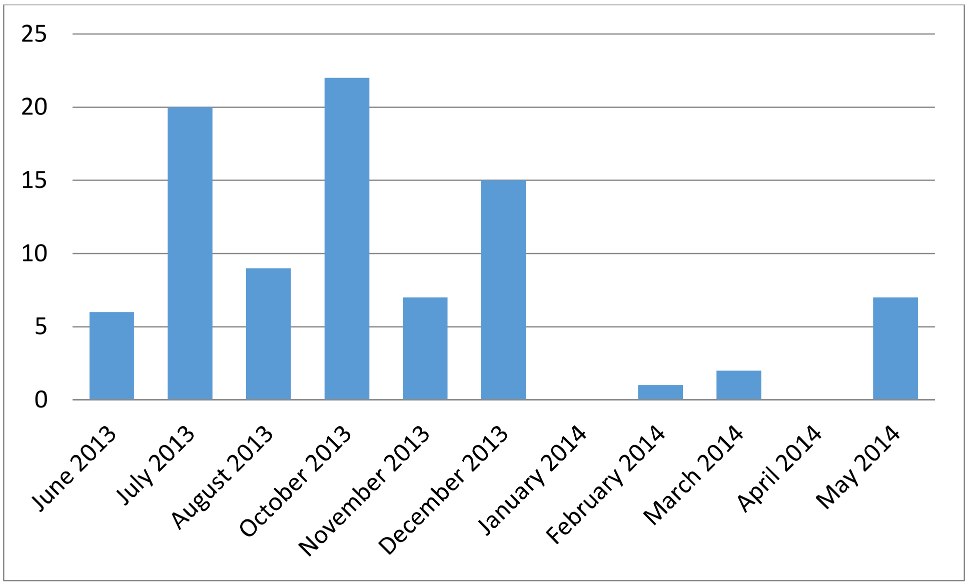

Fig.8.2 *Amount of trees cut down each month during the study*

Trees were targeted all over the langur home range, but while the focus during 2013 was mainly in the western portion of the home range, in 2014 logging was mostly done in the eastern portion of the home range (Figure 8.4)

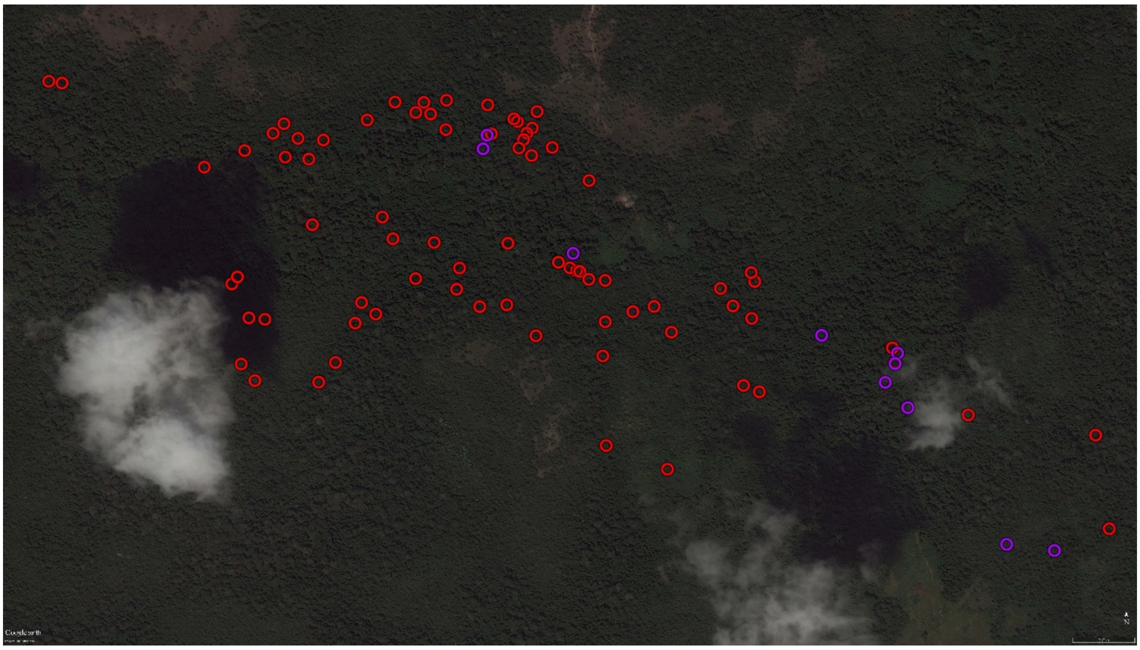

Fig.8.4 *Geographical distribution of logged trees in the langur home range during the study. Red dots represent trees cut down during 2013; purple dots represent trees cut down during 2014*

When looking at species numbers, the Burma padauk (*Pterocarpus macrocarpus*) was the most affected by far, with 71 individuals cut down, which makes 84% of all logged stems. Following it but far behind, are *Dalbergia oliveri* with five trees and *Hopea* sp. with four (Figure 8.5). The number of species targeted for logging during 2013 was four, while five different species were targeted during the first five months of 2014. The tree that was most sought after during 2013 was *P. macrocarpus*: all 71 trees were cut down during that year. The most commonly cut down tree in 2014 was *Lagerstroemia calyculata* with four (Figure 8.6).

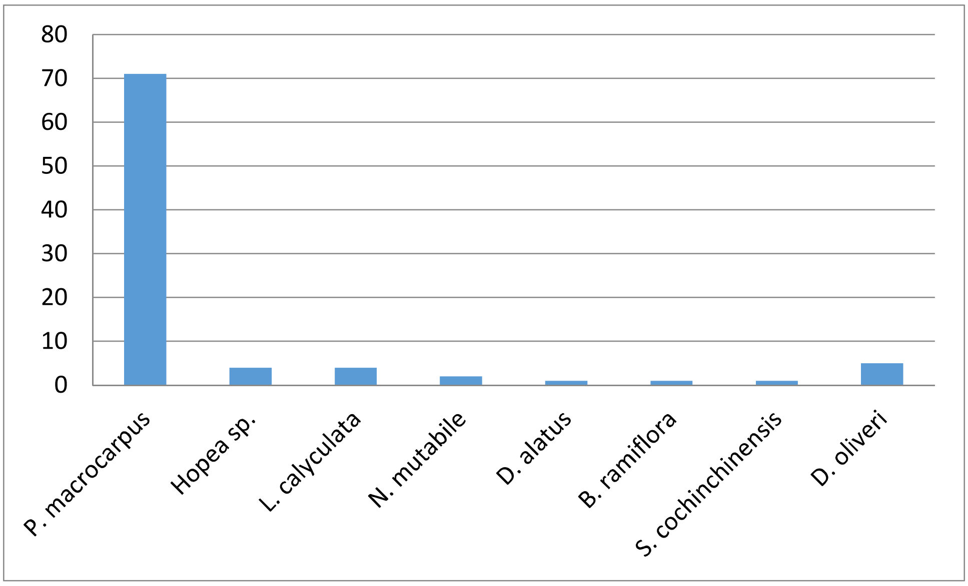

Fig.8.5 *Tree species targeted for logging and numbers in which they were cut down during the study*

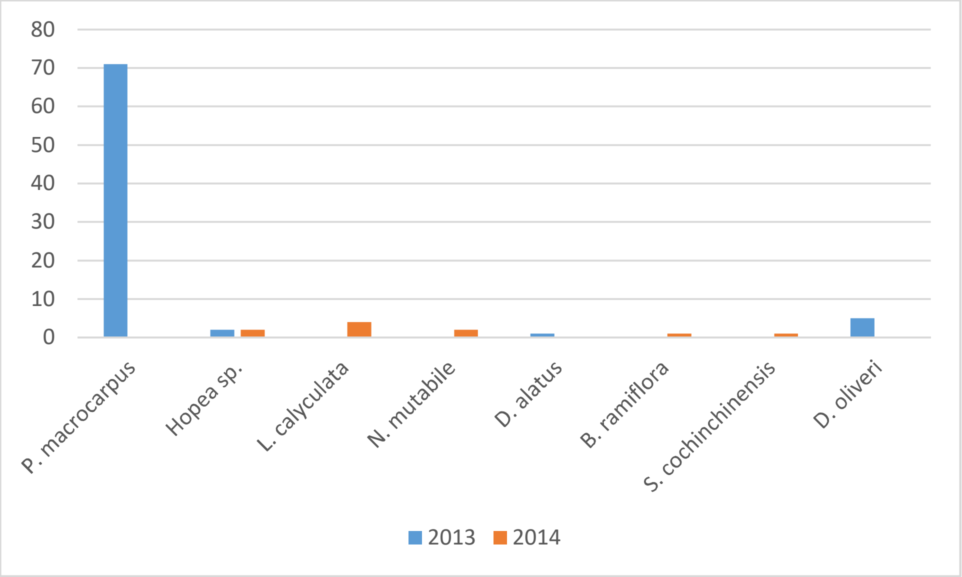

Fig.8.6 *Number of trees per species cut down in each of the years that the study took place*

8.3.2 Logging impacts on ranging and habitat use

When looking at patterns of ranging in regards to the location of logging hotspots, it can be seen that the majority of the northernmost portion of the langur home range, which was heavily used by the group during the 2013 rainy season, was heavily hit by logging activity and was not visited by the group during the first five months of 2014. Forty five trees were cut down in that portion of the home range during 2013 with an area of 60.5 ha, giving just a bit less than a tree per hectare (0.74). Areas in the southern and eastern portions were visited by the group during the whole length of the study (Figure 8.7).

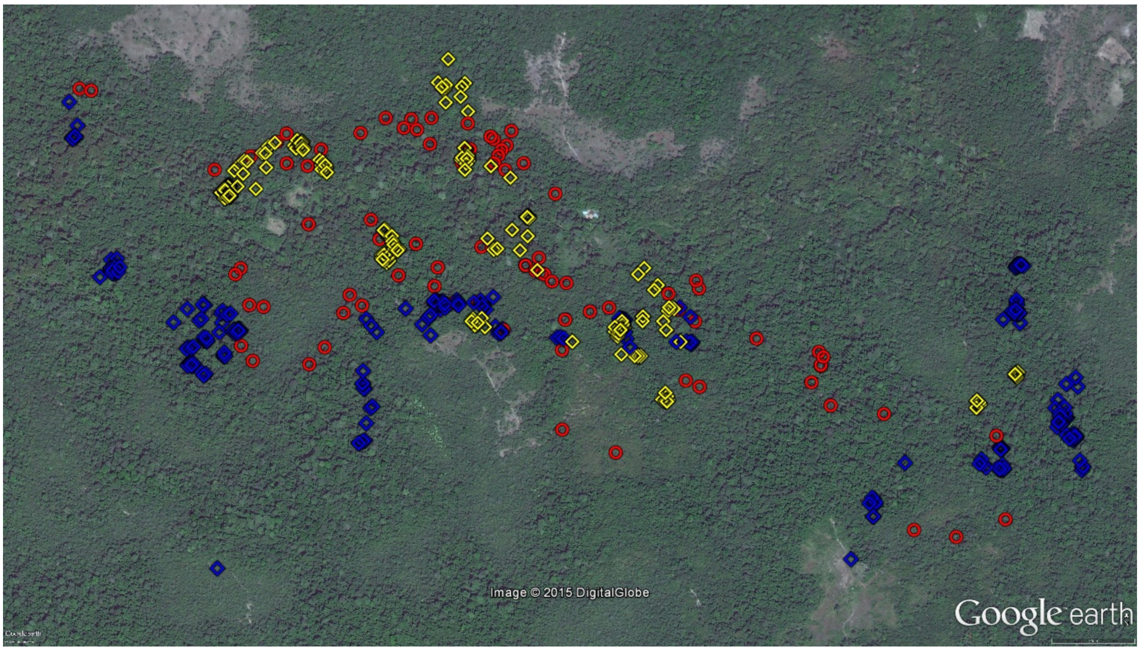

***Fig.8.7** Geographical distribution of langur ranging points and logging hotspots in the home range. Yellow points represent ranging points during 2013; blue points represent ranging points during 2014; red points represent trees cut down*

A total of 147.25 hours of logging were recorded during the study period. In 2013, 105.25 of these occurred (71%), while 42 hours of logging were registered during 2014 (29%) (Figure 8.8). These numbers are comparable given that data were recorded for six months during 2013 and for five months during 2014. Logging activity numbers were recorded for a total of 257 days, 152 during 2013 and 105 during 2014. Seventy seven total days (30%) were recorded with no logging in the area. Most of these (62) were during 2014, making almost 60% of all recorded days of 2014. In 43 days (16%) only one chainsaw was recorded. Again, the majority of these days (37) occurred during 2014, of which they represented 35%. Days with two chainsaws recorded were the most common occurrence, with 132 instances. In this case, however, the vast majority of instances (126) happened during 2013, of which they represented 83% of all instances registered. Days in which three chainsaws were working in the area were the least common with only five instances, all of them happening during 2013 (Figure 8.9).

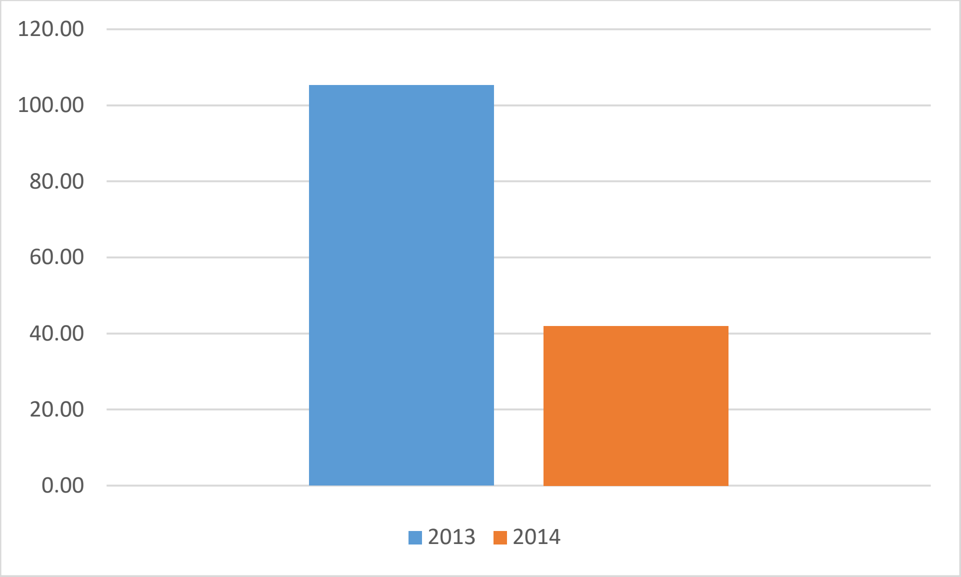

Fig.8.8 *Number of registered hours of logging for each of the years during the study*

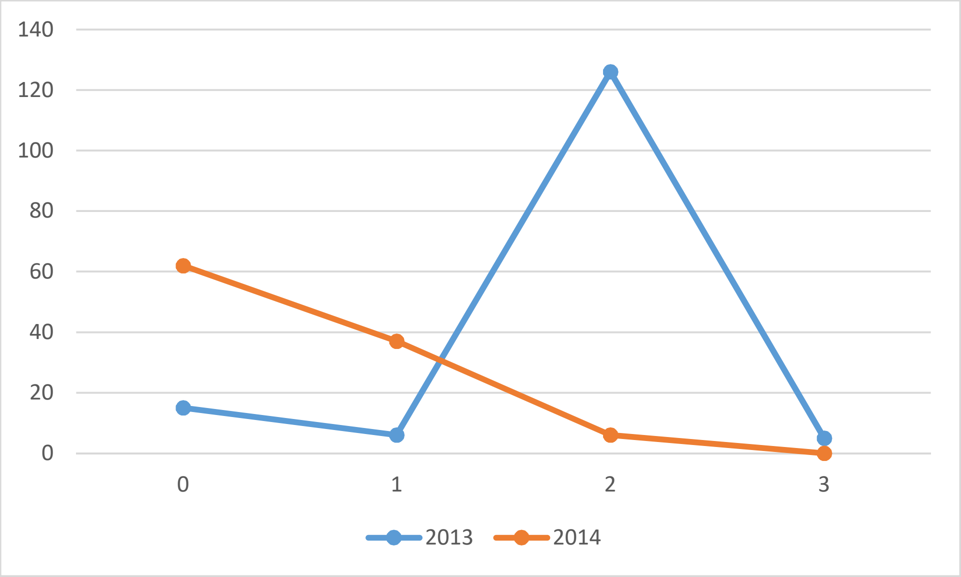

Fig.8.9 *Number of days for each quantity of daily registered chainsaws*

Analysis of the registered data on canopy use by langurs and data on daily logging length, daily chainsaw number and distance of logging hotspots to ranging point correlation, showed a highly significant relationship, as shown by the p-values for all the three χ^2 tests. The relationship between canopy level use and distance of logging hotspots to the group's ranging points was highly significant (χ^2= 138.25, df= 6, p< 0.01). Medium canopy was more commonly used by group members when there was no logging or when it happened more than 2000 meters away from the group, while animals shifted to high canopy layers when logging was closer to the group (Figure 8.10)

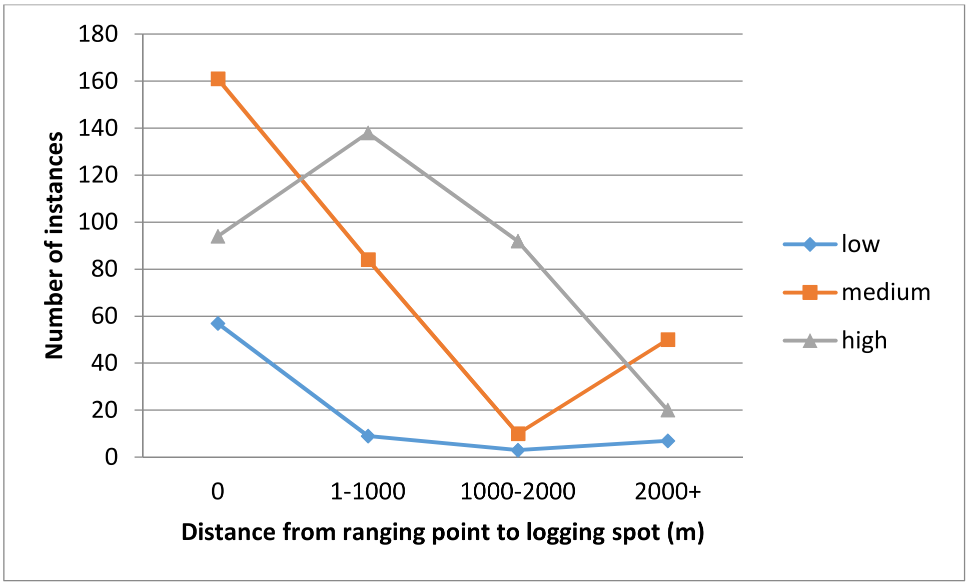

Fig.8.10 *Changes in canopy level use by the group in relation to the distance of logging hotspots to the group*

Table 8.1 *Instances on each of the canopy levels in relation to distance from the group to active logging hotspots*

	low	medium	high
0	57 (18%)	161 (52%)	94 (30%)
1-1000	9 (4%)	84 (36%)	138 (60%)
1000-2000	3 (3%)	10 (10%)	92 (87%)
2000+	7 (9%)	50 (65%)	20 (26%)

There was a highly significant relationship between canopy level use and daily number of chainsaws in the vicinity of the group (χ^2= 85.55, df= 6, p< 0.01). Use of the higher canopy tier by the group increased with the presence of chainsaws (Figure 8.11).

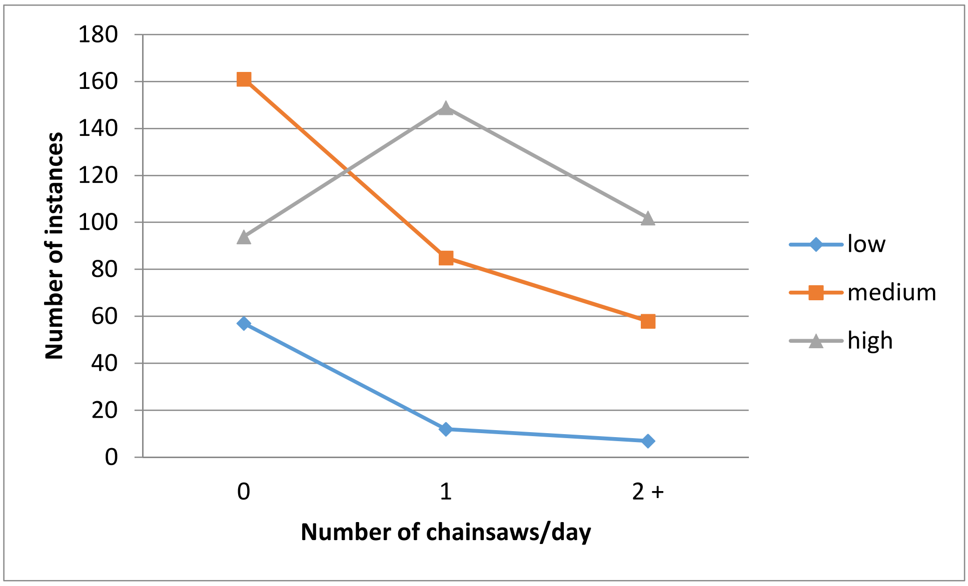

Fig.8.11 *Changes in canopy level use by the group in relation to the daily number of chainsaws active in the area*

Table 8.2 *Instances on each of the canopy levels in relation to daily amount of chainsaws*

	low	medium	high
0	57 (18%)	161 (52%)	94 (30%)
1	12 (5%)	85 (35%)	149 (60%)
2 +	7 (4%)	58 (35%)	102 (61%)

The relationship between canopy level use and the daily amount of hours where logging was taking place in the vicinity of the group was highly significant (χ^2= 154.78, df= 10, p< 0.01). Use of medium canopy by the group was most frequent with no logging, or one or two hours of daily logging. When logging lasted for more than two hours, however, animals were found more frequently in the higher canopy layer (Figure 8.12).

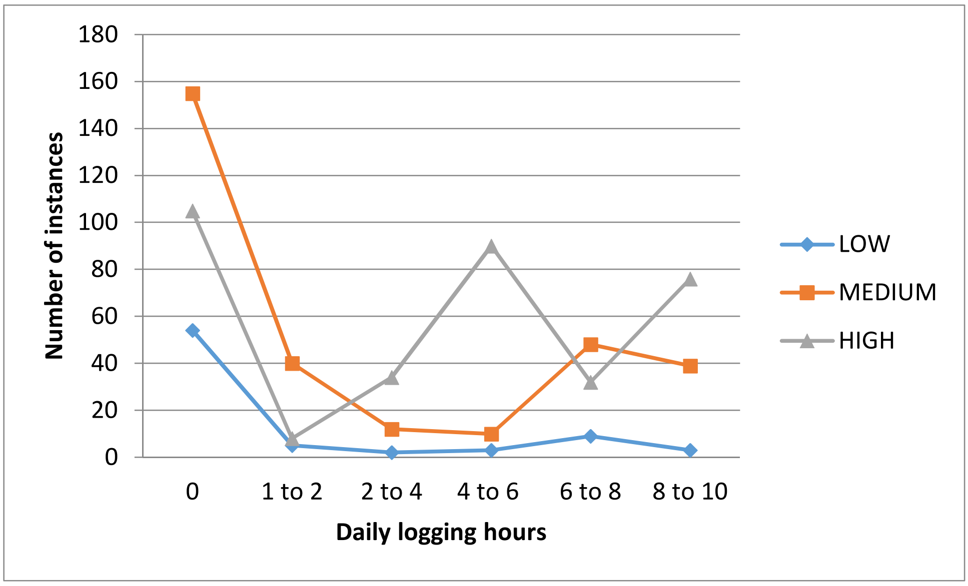

Fig.8.12 *Changes in canopy level use by the group in relation to the daily amount of hours that logging lasts*

Table 8.3 *Instances on each of the canopy levels in relation to daily length of logging (in hours)*

	LOW	MEDIUM	HIGH
0	54 (17%)	155 (49%)	105 (33%)
1 to 2	5 (9%)	40 (75%)	8 (15%)
2 to 4	2 (4%)	12 (25%)	34 (70 %)
4 to 6	3 (3%)	10 (9%)	90 (87%)
6 to 8	9 (10%)	48 (54%)	32 (36%)
8 to 10	3 (3%)	39 (33%)	76 (64%)

8.4 Discussion

8.4.1 Logged trees at VSSPCA

Data show that 2013 was a particularly rough year in the area in regards to logging. Substantially more hours and chainsaw numbers per day were recorded during this year than in the following one. *Pterocarpus macrocarpus* was the most sought after species of tree, due to its value in the international luxury wood market. The fact that this species is able to grow in most kinds of forest, with some stems even found in dry deciduous habitat, meant that logging damage in the area was quite widespread. *P. macrocarpus* was all but extirpated from the area by early 2014, and loggers had already been turning to other species, like the second most logged, *Dalbergia oliveri*. This species is not as widespread and only trees of a very large size are used by loggers, given that only the core of the log will be used, which could be one of the reasons for the difference in number. The observed decline of logging activity numbers in 2014 does not mean that logging will disappear from the area, but probably focus will shift to less valuable but still common species in the area, a trend that has already been flagged (Pye, 2015a).

Candidate species for the next push are species that have already been observed being targeted and are used by the langurs as sources of food and refuge, like *Anisoptera costata*, *Xylia xylocarpa*, several *Hopea* species or *Dipterocarpus alatus*, a species already targeted in other parts of the country by loggers (Global Witness; Peter & Pheap, 2015); given that it is highly used not only by langurs as feeding and sleeping trees (results obtained in chapter six, section 6.3.1, and chapter seven, section 7.3.3), but also by local people as a sustainable income source, destruction of these large trees in the area will not only have a large ecological impact, but also a very harmful effect on the economy and society of local populations. Other species seen to be logged in the area are, surprisingly, fruiting trees, such as *Nephelium melliferum* or *Baccaurea ramiflora*. Wood from these trees is not valuable, but local individuals target them during fruiting season, cutting them down when they are in full fruit in order to pick just some of the fruit and leaving the cut tree and the rest of the fruit to rot. This behavior needs to be immediately addressed and curbed, because it not only greatly disturbs the food chain in the ecosystem, greatly affecting birds, primates and small mammals between others, but it is also highly harmful to local people who also depend on these as an additional resource to feed their families.

Fig.8.13 *Cut down Baccaurea ramiflora. The culprits took only some of the fruit in the tree and left the log and the remaining fruit to rot. The tracks of a truck used by loggers can be seen on the left*

8.4.2 Effects of logging on langurs

During 2014 langurs did not visit areas that were commonly used during the previous year, and that had been under a lot of logging pressure since then. While some of these areas could have been avoided for reasons other than human pressure (see the previous chapter on ranging), this does not explain all group movements. The abandonment of the heavily logged mixed evergreen areas by the study group might have been confounded by the fact that members do not necessarily visit the affected area every year, as non-human factors will impact the habitat and thus influence the behavior and ecology of the group, as it has been observed in other species of colobine (Chapman *et al.,* 2000). However, logging in this particular portion of the home range could actually be considered heavy, with 45 trees logged in 60.5 ha, only somewhat below a tree per hectare. Heavy logging has much larger implications than low intensity logging for the decline in primate populations (Nijman, 2010; Skorupa, 1985). Also, it has to be noted that a large part of the logged area in the home range that was abandoned consisted of mixed evergreen forest, a formation that the group never actively avoids during the whole year, as noted in the previous chapter.

Even without taking into account proper logging activities, avoidance by primate groups of areas in their habitat where human activity was present has been recorded before (Johns, 1983; Johns, 1986), and adaptation to this disturbance by switching ranges from the original range has been recorded in other primates (Singh *et al.,* 2001). Ranging behavior in other colobines has been noted to be modified by the impact of logging activities in the vicinity of the group, including both commercial and small scale logging, sometimes resulting in the complete shift in the home range in order to get away from the logging, thus abandoning the affected area (Grueter *et al.,* 2013b; Guo *et al.,* 2008; Isbell *et al.,* 1990; Johns, 1986; Li *et al.,* 1999; Poirier, 1968a; Tan *et al.,* 2007), although some studies have observed that the home range sizes of particular gibbon species were not particularly affected by logging or human disturbance (Yanuar & Chivers, 2010). It has been observed that other colobine species will avoid areas under logging pressure even if there is plenty of potential food to be found in the area (Li et al., 2000). Also, orangutan densities have been seen to decrease in areas under the same type of logging activity (Felton *et al.,* 2003; Rijksen, 1978).

These results do not mean that the group will not return to the deserted area in the future, especially if there is no further disturbance by logging, since the logging activity there ended once the most valuable tree species were extirpated. It has been observed that colobine groups will return to logged areas after the logging stops and the disturbance ends, meaning these animals have a certain tolerance to the disturbance of their environment (Guo *et al.,* 2008; Leca *et al.,* 2013; Tan *et al.,* 2007). Primates in general and langurs in particular seem to be relatively resilient to forest disturbance if it keeps a low intensity and no further factors are in play (Chivers, 1985; Gupta & Kumar, 1994; Johns & Skorupa, 1987; Nijman, 2010; Plumptre & Reynolds, 1994; Poirier, 1968a; Umapathy & Kumar, 2003; Wich & Sterck, 2010; Workman & Le, 2010; Xiang *et al.,* 2011) and groups belonging to a related species, the Sunda silvered langur (*T. cristatus*) were not only more commonly found in secondary forest in northern Sumatra, but they were also found in areas close to human habitation and cultivation (Rijksen, 1978), which probably indicates a relative tolerance of the taxon to human activities in their vicinity.

The obtained results show that langurs were affected by logging. Animals were more likely to move to higher canopy levels when logging activities were carried out in the vicinity: animals were found mostly in mid canopy when there was no logging, then moved away to the higher tier when logging was close to the group, then reverting to mid canopy if the logging was further than 2000 meters away. Langurs also moved to the high canopy whenever there were chainsaws working in the area. There have been previous studies where it has been noted that chainsaws overtly distressed arboreal colobines found in the vicinity of the logging activity (Li *et al.,* 1999). This same trend is shown when looking at the cumulative number of hours of logging every day, although more data are probably needed to refine these results. Not a lot of studies have addressed the immediate impact of logging on primates; Johns (1986) observed that *Presbytis femoralis (*reported as *melalophos)* in Peninsular Malaysia would move to lower canopy levels after logging had affected their home range. The reason for this discrepancy is that logging eliminated most large sized trees, thus removing the higher canopy layers from the habitat, and as such these strata could not be used by the langurs after the logging, while in the study species' case, there were plenty of tall, canopy forming trees left in the area.

Fig.8.14 *Logs of Pterocarpus macrocarpus left for the truck or cart to pick up and take out of VSSPCA*

Some studies have shown that certain species benefited from forest disturbance due to selective logging, either because of an increase of leaf material and of protein content relative to fiber content in mature leaves exploited by those species, and it has been observed that food quality improves in areas where the canopy disappears, as pioneer species present leaves with a high protein content (Behie *et al.,* 2014). In other cases, they were more flexible in their diet, or plant species used as food were benefited by the conditions resulting from logging (Chivers, 1977; Ganzhorn, 1995; Guo *et al.,* 2008; Hu, 2011; Johns, 1986; Lee *et al.,* 20115; Plumptre & Reynolds, 1994; Skorupa, 1985; Xiang *et al.,* 2011). In any case, it is yet to be seen if the disturbance in the study site would have the same effect for populations of the study species; many of the fallen trees in the study were actually species used either as food items or sleeping trees, and it is possible that the species might not be flexible enough in its diet, a caveat already noted by Johns for other species (1983). Furthermore, the initial benefit can be followed by a decrease in populations as the effects of logging come to be felt as time passes: it has been noted that sometimes the adverse effects on a population from the loss of tree species will only be appreciated after several years have gone by (Decker, 1994; Felton *et al.,* 2003; Nijman, 2010; Struhsaker, 1976). Sometimes the species and the forest where it can be found will only slowly recover, if at all, when decades have passed since logging in the area (Chapman *et al.,* 2000; Okuda *et al.,* 2003). On the other hand, some colobines have been seen to maintain their population number stable even if selective logging has been carried out in their habitat for decades (Guo *et al.,* 2008; Gupta & Kumar, 1994; Salter *et al.,* 1985; Skorupa, 1985; Wich & Sterck, 2010; Xiang *et al.,* 2011).

Although selective logging does not have the same impact as clear cutting or industrialized logging activities, it nevertheless has further impacts, because the felling of large trees as well as clearing in order to access the logged species means that adjacent species that are not targeted but could be important as resources for the species will either be collaterally destroyed, both adults and saplings, or suffer due to the shift of conditions caused by the disturbance (Johns, 1988). It has also been noted that diversity values get reduced, even in selectively logged forests, and do not increase in the short term (Ferry Slik *et al.,* 2008): if particular species of importance to langurs are extirpated from the habitat due to logging, they might not be present again until a large amount of time has passed, maybe even not at all. Thus, the species of choice for the selective logging can have a critical influence to the conservation of *T. margarita*.

Another factor to weigh in is the fact that individuals that engage in illegal selective logging have no training in the procedures and no incentive to maintain the area with a minimal disturbance means that the damage can be much higher than initially perceived (Felton *et al.,* 2003); this issue needs particular attention in the case of this study, given that companies in Cambodia employ untrained villagers to source the wood (Global Witness, 2007; Pye & Titthara, 2014; Titthara, 2014). Additionally, there are further issues: in some cases, managing of a particular forest by limiting the size of harvested trees still led to massive stand damage and loss of the surrounding vegetation (Sist *et al.,* 2003), while in others, what started with selective logging of certain species eventually escalated into clear felling, removing large swaths of potential langur habitat (Sunderraj & Johnsingh, 2001).

In the particular case of the present study species there is reason to be cautious about the degree of impact of logging activities. Two other species of langur (*Presbytis femoralis* and *Trachypithecus obscurus*) that were living in an area in Malaysia where logging was carried out methodically saw infant mortality rise, and low recruitment numbers persisted even 12 years after logging stopped in the area (Grieser-Johns & Grieser-Johns, 1995). It can be stated that, while langurs can be somewhat tolerant to a certain intensity of logging, if this gets out of hand the population will be seriously affected, jeopardizing the conservation efforts. Logging data and numbers in Cambodia also show a worrying trend in the way that once the most valuable tree species have been extirpated from an area, loggers will return to the logged sites and start focusing on the next most valuable species and so on, which means that efforts towards curbing these activities should be stepped up in order to prevent further escalation and constant degradation.

In order to know the full extent of the effects of illegal logging on the behavior and ecology of Annamese silvered langurs it would be of great importance to continue monitoring the study group to see any further changes in their behavior or ecology: it has been noted that definite results on the effects of human disturbance on the primates can only be obtained after considering a long stretch of time (Chapman *et al.,* 2000; Chapman *et al.,* 2006; Decker, 1994; Johns, 1992). Such research would also contribute to the study of human disturbance on natural habitats in Cambodia and its effects on local wildlife.

Removal of big trees will have a strong impact on food availability for the species, thus having more serious repercussions (Heiduck, 2002; Johns & Skorupa, 1987; Li *et al.,* 2003). It has previously been noted that targeted logging of species of great importance to colobines as feeding and sleeping sites will probably lead to a sharp decline in population numbers (Anderson *et al.,* 2007). Furthermore, the lack of large trees will mean a lower connectivity in the habitat which will strongly affect the langurs, because, as seen in previous chapters, they tend to use targeted trees, and move in the high canopy very often. These issues have been observed in other primates in areas affected by logging (Chapman *et al.,* 2000; Felton *et al.,* 2003; Ferrari & Diego, 1995; Johns, 1983; Johns, 1986; Li, 2004; Li *et al.,* 2008; Menon & Poirier, 1996; Ruhiyat, 1983; Umapathy *et al.,* 2011).

Although the consequences of logging in its home range seem grim for the survival of the Annamese silvered langur, already mentioned studies about other primate species show that some primates, and langurs particularly, can be capable of adapting to the new conditions in their habitat (Grieser-Johns & Grieser-Johns, 1995; Gupta & Kumar, 1994; Hu, 2011; Johns & Skorupa, 1987; Knop *et al.,* 2004; Kool, 1993; Marshall *et al.,* 2006; Potts, 2011; Rijksen, 1978; Singh *et al.,* 2001; Skorupa, 1985; Umapathy & Kumar, 2003; Umapathy *et al.,* 2011; Wich & Sterck, 2010; Xiang *et al.,* 2011), The data obtained in the previous chapter referring to the diet composition of the study group show that Annamese silvered langurs are a species that presents a very varied diet, and is able to profit from the different seasonal plant parts available in their habitat. Thus, it is most likely that langurs can rely on a very wide range of food present in their home range in order to balance any detrimental effects on their diet brought about by the targeted logging of species that are used in their diet. Furthermore, and as it was previously discussed in the diet chapter, the specialized digestive anatomy langurs present gives them an adaptive advantage in case preferred food items cannot be obtained, and animals can resort to a folivorous diet in order to survive in a poorer dietary context. Studies on a closely related species, *T. auratus*, mention the fact that the species shows ecological plasticity and exploits plantation species in order to survive in areas where human disturbance is marked (Kool, 1993). If looking at the species' diet composition and anatomical adaptations it can be observed that the study species is able to consume varied plant parts and other resources during the different seasons of the year, and other species also show adaptability towards new conditions brought about by human activity in their vicinity, it is most likely that Annamese silvered langurs are a resilient species in regards to the effects of human disturbance.

All in all, it can be said that the study species has the ability to tolerate human disturbance of their habitat, at least to a sensible extent. Also, there is still plenty of good langur habitat all over VSSPCA, and populations will remain healthy as long as there are enough trees used by the langurs that are able to support them even if some logging has been carried out as it has been pointed out before (Grieser-Johns & Grieser-Johns, 1995; Hu, 2011; Johns & Skorupa, 1987; Knop *et al.,* 2004; Kool, 1993; Marshall *et al.,* 2006; Potts, 2011; Rijksen, 1978; Singh *et al.,* 2001; Skorupa, 1985; Umapathy & Kumar, 2003; Umapathy *et al.,* 2011; Xiang *et al.,* 2011), but illegal logging for export purposes must be brought to a stop, or this status could be compromised. Some populations of primate that recovered after selective logging also did so because their reliance on Dipterocarps, the main target group for logging, was very low (Knop *et al.,* 2004). Langur reliance on these trees, however, is important as both a preferred food resource and sleeping sites, and the total disappearance of this group of trees from the habitat could have potentially irreversible negative effects on langur populations in the area. At the same time, it has been observed that seedlings and saplings of dipterocarps can survive logging episodes and eventually be productive by flushing and fruiting, even if their numbers are smaller at first (Appanah & Manaf, 1994): if langurs could abandon these areas for others where trees have not been logged until the abandoned portions regenerate their dipterocarps or other trees they use as resources until they can feed on them again, their dietary flexibility will pay off. It has also been observed that forests where dipterocarps were common and diverse, logging did not particularly alter the original setup of the forest (Cannon *et al.,* 1998). However, there are two things to bear in mind: the first is that these data have been obtained in lowland rainforests where dipterocarps are the dominant group, so they are not the same habitats as those in VSSPCA and the regeneration dynamics might work completely differently; the second is that langurs are also dependent on other plant families that might not be as able to withstand logging effects as a population as well as dipterocarps, and special care should be taken to study the regeneration dynamics of other families of importance to langur diet, such as Fagaceae, Fabaceae or Apocynaceae. Further studies should look into any differences in langur use of a particular plant species depending on the age of the plant, as well as in regeneration dynamics of the forests in which they are found.

Even if logging is not a pressing issue, it has been noted that cumulative resource extraction, even when only local individuals are involved, can still end in the disappearance of the forest fragments and the loss of primate populations, even if the animals themselves are not targeted (Chapman *et al.,* 2007) or in a drastic decline of the local primate populations (Xiang *et al.,* 2009). Local culture plays a great part in the sustainability of primate populations in the vicinity of human populations and the activities in which they engage, be it hunting (Bismarck, 2010; Borgerson, 2015; Kumar & Solanki, 2008; Marshall *et al.,* 2006; Nijman, 2010; Raemaekers & Chivers, 1980; Stanford, 1988), cattle grazing or agriculture (Chetry *et al.,* 2010; Ellwanger *et al.,* 2015; Estrada & Coates-Estrada, 1996; Singh et al., 2001; Xiang *et al.,* 2009; Xiang *et al.,* 2010), so that primate populations can either persist in the area or disappear due to unsustainable human activities that will directly affect them.

Primates are a popular target for hunting in the region, but consumption of primate species in Cambodia, either for meat or medicine, is not popular or widespread, something that could explain, in addition to general remoteness, the good state of most primate populations in the country. While some primates in VSSPCA are targeted for medicinal uses, langurs are not one of them (Hill, 2011). While one individual was killed and consumed by members of a logging crew in the area, it seems that Annamese silvered langurs are very low on the priority list for hunters. In stark contrast, populations north of the border in Laos are under a higher pressure from hunting and populations are diminishing (Timmins *et al.,* 2013). This means that VSSPCA, in addition to Virachey National Park and Siem Pang Protected Forest, could form the largest stronghold of the species, and the conservation value for the forest would be greatly enhanced.

While some studies (Chapman *et al.,* 2007) argue that funds should not be allocated in maintaining or protecting forest fragments and forest under anthropic influence, the opposite has been argued as well (Lee *et al.,* 2015; Marshall *et al.,* 2006). As seen in the first chapter, forests under human pressure can still present very healthy populations of megafauna as long as pressures do not get out of hand. Studies centered on logging in dipterocarp forests in Malaysia show that most vertebrate species present in a forest will persist or reappear a decade after logging was carried out in an area, and primates and other large bodied vertebrates dependent on the same or similar resources, such as hornbills, will still retain population numbers even after almost three quarters of the forest have been logged (Johns, 1992); woodpecker species could be still found in logged forests, albeit most species had their population numbers reduced (Robinson Styring & Ickes, 2001). Low scale and low intensity logging can be compatible with primate conservation (Chapman *et al.,* 2000; Knop *et al.,* 2004; Marshall *et al.,* 2006; Salter *et al.,* 1985; Skorupa, 1985; Xiang *et al.,* 2011), although good management and control are needed so that intensity is low and sustainability is secured; proximity of logged areas to unexploited or protected areas would be of great help for conservation aims. Of great importance as well, especially in the light of the current global biodiversity crisis spearheaded by countries in the Indo-Burma region, should be the prevention of poaching and hunting activities, which probably will have a much larger impact than selective logging on local wildlife populations once the original habitat is fragmented, as has happened in other regions before (Estrada & Coates-Estrada, 1984; Johns & Skorupa, 1987; Marshall *et al.,* 2006; Nijman, 2004, 2005; Peres, 1997; Raemaekers & Chivers, 1980; Rosenbaum et al., 1998). Sadly, given the current state of affairs and rate of forest loss in Cambodia (Global Witness, 2007, 2015; Hansen *et al.,* 2008, 2013) it is hard to believe that the current state of conservation in the area will be left untouched indefinitely if nothing is done to keep human disturbances in check. While it would be a bad idea to rush to conclusions on studies done during a shorter amount of time, surely that estimated time needed to carry out studies is not something wild areas in the region and communities dependent on their resources can afford at the current rate of development and disturbance.

8.5 Summary

Logging activity in the langur home range area was really strong during 2013, focusing on cutting down mainly *Pterocarpus macrocarpus*, and greatly declined during 2014, when law enforcement efforts carried out by Conservation International and rangers and military police under the supervision of the Cambodian Forestry Administration where heavily incremented. Annamese silvered langurs shifted from medium canopy layers to high canopy layers whenever chainsaws were active in the area, logging activities were between 1 and around 2000 meters from the group, and whenever logging extended in time for several hours. The group also abandoned some areas in the home range, and although logging might not be the only reason, areas of uniform vegetation structure during the year were heavily disturbed. These results do not necessarily mean that animals will not return to abandoned sectors or survive human disturbance: langurs in particular are able to withstand small pressures as long as there are enough plant species left in the area that can provide them with food and refuge, and as long as they are not hunted. While there was no clear cutting of forest in the protected area, and langurs were not hunted for neither meat nor medicine, curbing massive logging activities before they switch to other tree species still common in the area that are also important resources for the langurs, as well as controlling hunting activities is essential to keep the local wildlife populations healthy. A continued monitoring effort on langur populations as well as any logging activities in the area should be carried out and maintained in order to evaluate any further changes in the dynamics shown in this chapter.

CHAPTER 9

Conclusions

9.1 Ecology and habitat composition

After analysis of the botanical composition in the study group's home range, it proved impossible to identify around one third of the recorded stems to taxon. In the case of some of these unidentified stems, local rangers and research assistants were actually able to tell them apart, but had no name for them, even in local languages. A person belonging to the Kavet minority was able to identify some further stems by their Kavet language names, but it was still not possible to find any equivalent for these names either in Lao or Khmer language. Further obstacles towards the identification of many of these unknown stems came from the fact that there are very few experts on the flora of the country, there is no national herbarium, and the few reference works that have been published have been mainly focused on flora with important human applications. In order to maintain as well as to advance further research projects in the country, these issues need to be addressed. Knowledge of the local flora species is the first step to help further gazetting and vegetation studies in protected areas all over the country, support any management plans drafted both in protected areas as well as areas set for exploitation for forestry resources, or advance knowledge on the possible uses of plant parts or compounds with potential medicinal and industrial applications.

A better knowledge on the plant communities will not only greatly advance ecological studies on herbivorous animal species that not only represent a potential source of income through ecotourism, but which also hold key roles in the maintenance of natural habitats, such as primates, large bodied ungulates and elephants. Furthermore, a lack of knowledge in the composition and dynamics of local forest formations has potentially dire consequences when looking at the effects of global warming, and irregular weather patterns caused by it, particularly in a country such as Cambodia, subjected to a highly seasonal input of water resources, on which the country's economy and population have traditionally been strongly dependent of. In addition to this, steps should be taken to improve the training of qualified local botanical experts, as well as further training of local rangers and research assistants

The values obtained for the diversity index of the langur home range show that the whole habitat, while not being the most extremely diverse in its species composition, is also far from being dominated by a particular set of them. While mixed evergreen forests presented a higher number of species than mixed deciduous forest, this was not statistically significant; on the other hand, mixed evergreen forest was significantly more heterogeneous than mixed deciduous forest. Dipterocarps dominated mixed evergreen stands, while *Lagerstroemia calyculata* strongly dominated mixed deciduous patches. Forest diversity was hit in a selectively logged mixed evergreen forest patch, which as a result had lower values than unlogged evergreen forest stands and a reduced structure, with very small numbers of tall, canopy forming trees, but, interestingly, these diversity values did not plummet too low and were similar to those presented by mixed deciduous formations. In addition to that, the presence of a logging track in an evergreen forest habitat does not on itself strongly affect the diversity values of the area, and it was observed that its structure was very similar to those of unlogged mixed evergreen transects. This shows that while some forest formations can be lost by logging activities, the biodiversity importance of these portions of logged forest can still be high, and will further improve if enough time is given for seedlings and saplings to grow and develop. If logging pressures are removed from the area, the biodiversity importance of these portions of logged forest can still be high. When looking at tracts of forest where a wide track has been shaped by the cutting of forest trees and undergrowth, it was observed that the overall diversity of the forest was not dramatically reduced although many of the tall, canopy forming trees were gone from the area, it can be observed that the overall diversity and structure of the forest does not get highly impacted merely by the disturbance of creating a logging track.

There are significant differences in structure and composition of mixed evergreen and mixed deciduous forest. Mixed evergreen forest had a higher amount of stems of smaller height and DBH size, while mixed deciduous forests presented a significantly higher proportion of tall trees and DBH sizes between 50 and 100 cm, as well as over 150 cm. In addition to this, it was found that Evenness Index values were significantly different in the two forest types: mixed evergreen forest presented higher values, which point to a higher number of species and a more heterogeneous habitat composition. Thus, mixed evergreen forests present a large amount of small size and height stems, which form a denser understorey and a more layered canopy, with a high number of species that are unevenly distributed over the ecosystem. Mixed deciduous forests, on the other hand, present a more open understorey, with less small sized and height stems, but a larger amount of tall trees, presenting fewer canopy layers, but a much higher canopy limit.

The dominant species of plant in the forests at VSSPCA were *Diospyros pilosanthera*; *Lagerstroemia calyculata*; a species that was very prevalent in mixed deciduous forest areas; *Dipterocarpus alatus*, a large tree with high economic importance for local villagers; other large wooden trees such as *Irvingia malayana*, *Anisoptera costata, Schoutenia ovata*, *Terminalia triptera*; other species as *Cinnamomum cambodianum*; and trees that produced fruit, very appreciated by villagers in nearby populations as well as the local fauna, such as *Sterculia lychnophora* and *Nephelium melliferum*.

Plant families with the highest importance in the habitat were the Lythraceae, the family to which *L. calyculata* belongs, the dipterocarps, large trees whose wood can fetch very high prices in the luxury wood market in China and Vietnam, Ebenaceae, Irvingiaceae, Malvaceae, Fabaceae, the legume family, on which many species of fauna rely (among other reasons, because of the higher quantities of nitrogen in their plant parts), Sterculiaceae, Lauraceae, Combretaceae, Myrtaceae and Annonaceae. Many of these species and families have a non-extractive importance to local communities, whether as sources of wood for building or coffin construction, plant parts for traditional medicinal use or fruit on which they feed when it is available. These species and family composition differ greatly from those presented by habitats in which other populations of the species have been studied, showing that Annamese silvered langurs are a very ecologically flexible species, and are able to thrive in pristine forest areas as well as forests under pressure of human activities, a characteristic that gives the species a strong advantage for their survival, and will help conservation efforts for them in the region.

While mixed deciduous forests present similar diversity values to those of logged portions of forest, they were not significantly different from the diversity values presented by mixed evergreen forest. Thus, there is no particular reason to suspect that these forest formations, widely extended over eastern Cambodia and northern Vietnam, are the result of logging activities. Mixed deciduous forest patches seem to be very widely present all around Veun Sai Siem Pang Conservation Area, even in remote areas where human influence was pretty much non-existent, meaning they are also found in parts of the protected area that were almost unspoiled until very recent times, and are particularly frequently found adjacent to bodies of water. It could be possible that heavily logged areas of mixed evergreen forest in Indochina could eventually become mixed deciduous forests, but these formations are widespread over parts of Indochina, particularly in regions that used to be considered the hinterlands of their respective countries, where reports stress that these forests are more common in the vicinity of watercourses: it seems that attributing them as a product of human disturbance would be a simplistic, uninformed assumption.

The other posited explanation for the emergence of mixed deciduous forest formations is fire; while perhaps not unlikely, this does not seem to be absolutely true. Mixed deciduous forests at VSSPCA presented a high number of species, and were commonly found adjacent to water as well as closely interspersed with mixed evergreen fragments. While fires could lead to the emergence of mixed deciduous forest patches at VSSPCA, the relatively high diversity values and their close location to water directly contradict fire as the reason behind their formation in many cases, as diversity would diminish after a fire, and formations on areas close to water would be to an extent protected from the effects of fires. Alternating patches of different forest formations imply that fires in the area, would have to be very intense and frequent but not strong enough to affect adjacent evergreen forest fragments. In order to settle these arguments, vegetation cover analysis and soil composition analysis on areas covered by mixed deciduous forest would be invaluable, as well as comparison with other areas covered by evergreen or mixed evergreen forest; further research on the biodiversity composition and the ecosystem dynamics of their plant and animal communities would greatly help towards a better understanding of this barely known forest type.

The inventory of the vertebrate fauna found in the habitat of the study group shows 170 species, which of course is only a minimum amount. Small vertebrates such as amphibians and reptiles, some of them hard to find during stretches of the year, were most likely underrepresented, as well as several small sized animals with life habits that prevent easy or common observation, such as passerines, particularly species that dwell in the forest, where the reduced visibility brought by the thickness of the vegetation, the illumination contrast between lit and dark areas, and the fast speed of the small sized animals prevented many of observed small birds from being identified, and most likely most of them from being detected by the researcher or the local guide. Other groups of birds that probably were underestimated were birds with nocturnal habits such as owls and nightjars, and ground birds belonging to the family Phasianidae, such as partridges and pheasants, where the plumage presented by most individuals helps them go unnoticed on the forest ground. The same goes for small mammal groups such as rodents and small insectivores, whose small size and nocturnal habits largely prevent observation. Most such animals were either detected by camera traps, or their corpses were chanced upon. In any case, this means that a complete inventory would have only been achieved with a proper census effort, using materials and methods focused to that particular end. It is most likely VSSPCA is host to many more vertebrate species than those which are currently known to be found, particularly in remote areas further away from the field camp and closer to Virachey National Park and the international border with Laos.

Even if the number of species registered was an underestimation, several species of vertebrates of conservation interest seem to occur in relatively healthy populations. The Critically Endangered national bird of Cambodia, *Thaumatibis gigantea*, was observed several times during the study. Hornbill species such as *Anthracoceros albirostris* and *Buceros bicornis* seemed to be very common, with individuals observed or heard almost every other day when at the field. Signs of the presence of relatively large bodied carnivorous mammals such as *Cuon alpinus* and *Helarctos malayanus* were observed frequently during the length of the study, particularly the former species, with offspring and large groups found or recorded by camera traps. Signs of the presence of large ungulates were also often observed in the langur home range throughout the study, although in the particular case of *Bos gaurus* their signs disappeared after heavy logging was carried out in the area where they were found. VSSPCA seems to be a key biodiversity spot in regards to primates, with at least 6 resident species, most of them in healthy populations.

Sadly, *Lepus peguensis* and *Manis javanica*, two species which used to be common no great time ago, were never directly observed, nor signs of their presence were noted, and may be absent, at least in areas close to human habitation. All these results show that VSSPCA maintains quite a healthy ecosystem even in areas that are most exposed to human illegal activity, and that communities can bounce back as long as pressure from anthropic influence is kept low. Attention should be given to further wildlife censuses in remote areas further away from human populations, where there will most likely be more species that have not been observed to live in the area, and even more species new to science.

9.2 Morphology and demography

Annamese silvered langurs at VSSPCA showed homogeneity in respect of features deemed taxonomically and phylogenetically important. Individual variability of morphological characters considered to be diagnostic of the species was very low, in contrast to some previous opinions and reports on the species where higher inter-individual variability was observed. All the species defining characters were presented by the majority of the animals that were directly photographed by the researcher or recorded by the camera traps. Further research on the morphological homogeneity of Annamese silvered langurs in other areas would be of interest, as well as areas of possible hybridization between the study species and its close phylogenetical relative, the Indochinese silvered langur *T. germaini*.

With a maximum observed group size of 62 individuals, *T. margarita* seems to present the second largest recorded group size for any species of the genus. The recorded number, however, is most likely an underestimation of the actual number of members of the group, due to the fact that animals were not habituated to human observers, and that some individuals did not use the route undertaken by most group members. While this is a large size, it is likely that this group undergoes fission and fussion, as group counts were not always that large, and two groupings of langurs separated by less than a kilometre were observed on one occasion, while encounter ratios did not seem to indicate that there were several groups present in the study area. There is also the possibility of that maximum size being a construct resulting from the observation of two groups together, but as the subjects all moved as a unit in the same direction to settle in sleeping trees, and the fact that it is hard to make a good estimate on group sizes on most days due to their cryptic habits, it is hard to tell how accurate this possibility is. The group had a multi-male multi-female organization, with several adult males forming part of the group, and subadult individuals of both sexes were recorded moving in lone fashion or groups of two. These large group numbers and the fact that there was a high proportion of juvenile individuals suggests that the study group seemingly was in a good state, with high reproductive rates, meaning that the animals seem to be relatively unaffected by human activities in their vicinity. In order to establish if this group size is common, more census efforts are required for this species over its whole distribution. This would have the benefit of helping establish how endangered the species actually is, and establish which are the areas that are the most likely strongholds for the species. Further research on the dynamics of subadult dispersal would be of interest, in order to better understand these dynamics that have been rarely studied in colobines, particularly in species from mainland Southeast Asia.

T. margarita associated with at least two sympatric species of primate: the pig-tailed macaque (*Macaca leonina*), and the red-shanked douc (*Pygathrix nemaeus*), and, judging by other references, they probably also associated with a third species, the long-tailed macaque (*Macaca fascicularis*), but due to the scarcity of the latter, it would be hard to observe nowadays. Macaques and langurs were observed moving out of large trees in the early morning, meaning that the two species most likely shared sleeping trees. At the time these species were observed to associate, it is known that several species of plant were fruiting, so it is possible that they shared sleeping trees if there were plenty of fruit around for members of both species to feed on. Langurs and doucs were observed feeding together on several trees that served as food for both species. It is possible that these aggregations are facilitated by a high availability of a shared food item. A further instance of langurs and doucs associating was the observation of a juvenile red-shanked douc individual travelling embedded in the silvered langur study group. This opens up the possibility that juvenile doucs dispersing out of their natal groups will travel with silvered langurs to benefit from the protection of the group against possible predators. Evidently, silvered langurs and doucs have a remarkably high tolerance for each other. Further studies and habituation would be of interest to further study the interaction between primate species, and know if they engage in grooming or fighting and with what intensity, and what are the ecological mechanisms behind these associtations, like different species holding separate ecological niches, feeding on different items or species, or at different heights of the forest canopy.

9.4 Feeding and geophagy

Annamese silvered langurs at VSSPCA were observed to feed on 18 different species during the length of the study, 15 of which were positively identified taxonomically. While this is surely an underestimate due to the unhabituation, making the langurs hard to observe when they were not moving through the canopy, a low diversity diet has also been observed in other groups of the same species in Vietnam. Most items which they were observed feeding on were plants, but they were also seen foraging in the nooks of the epiphytic tree fern *Drynaria fortunei*, most likely in order to obtain invertebrate prey, showing that colobines also seasonally feed on invertebrate animal matter, something that was also observed in other Asian colobines from the same and other genera. Trees were the most common growth type that langurs fed on, but vines were reasonably common, and they seemed to have a high seasonal importance, while langurs were rarely observed feeding on shrubs. The height at which langurs were most frequently observed eating was the high canopy. As the actual yearlong diet of the langurs will most likely include more species of plant, further research on the feeding and foraging behaviour of T. margarita at VSSPCA is needed, in order to ascertain how many species do langurs actually target as food at the site, and if the diversity composition of the study species' diet is low, as observed in this study as well as in the one carried out in Vietnam.

T. margarita at VSSPCA were mainly observed to be granivorous, with seeds being more than half their total diet. Leaves were eaten less frequently than seeds and fruit, something not only rarely observed on *Trachypithecus* species, generally considered to present larger proportions of leaves in their diet, but also in opposition to the results obtained on a conspecific group in Vietnam, which fed mainly on leaves. While it is quite likely that the actual proportions of the different plant parts were underestimated, particularly in the case of leaves, seeds can still be seen as a key part of the animals' diet and most likely the most frequently eaten plant part, even if their actual proportions were smaller; it is important to note that differences in diet between the two studied groups could be attributed to the fact that different plant families dominate in each of the respective study sites: Annamese silvered langurs in Vietnam focused on Moraceae, which is the most dominant family in that study site by far, and fed on up to ten different species of *Ficus*, while langurs at VSSPCA were never observed feeding on *Ficus* plants; Moraceae were not particularly dominant at VSSPCA and *Ficus* stems were scarcely found, and when so, they were not fruiting. This might point to a difference in diets berween populations being caused by different habitat conditions, with Ta Kou being subject to a stronger influence of human activities, so that local langur populations would have to adapt to a highly anthropically modified habitat and look for alternative sources of food that might not have initially been their preferred options. Another species that langurs fed on at Ta Kou was *Lagerstroemia calyculata*, and while in VSSPCA there were no observations of feeding on this species either, the species is one of the most dominant ones in the Annamese silvered langur habitat, particularly in mixed deciduous patches of forest, and the study group did spend a considerable amount of time at mixed deciduous forest areas with plenty of *L. calyculata* stems during the whole rainy season, which are the only months of the year in which it presents foliage. All this information and the fact that Annamese silvered langurs are known to feed on *L. calyculata* at Ta Kou hint at the likely use of this species as a food item at VSSPCA. Further research is needed on the species at VSSPCA and other sites, as well as more information on the habitats in which they live will help expand our current knowledge and further understand the composition of the diet of *T. margarita*, and the differences that exist between the different populations of the species over all its distribution.

The dipterocarp *Anisoptera costata* was the species with the highest proportion in the diet, but the fact that this family fruits irregularly and only after several years have passed means that, although langurs consider this species as a preferred food item, they cannot depend on them as a reliable and regular source of food. Other dipterocarps were consumed by langurs during the study and this taxon is quite likely a key food resource to Annamese silvered langurs in the study site. Another group that seems to hold a very important role in the diet of *T. margarita* at VSSPCA for similar reasons are the Fagaceae, a family that was strongly selected for food by langurs, particularly *Lithocarpus elegans*; langurs probably depend on them as a reliable and regular source of new leaves and acorns to feed on them during the year, particularly if other food sources are scarce in a particular season or year. Also of great importance to *T. margarita* were the seeds from the vine *Willughbeia edulis* (Apocynaceae), of which the unripe fruit was targeted. Nonetheless, as vines were not well identified and generally fell under the 12cm of DBH measure that at the beginning of the study was presumed to be the smallest size of interest to langurs as a feeding resource, it would be important to carry out further botanical analysis of the home range habitat in order to quantify the actual amounts of *W. edulis* present in it, with the results also further clarifying the dominance values of the family Apocynaceae that were obtained during the course of the current study. Although the study species appeared to have a granivorous diet, they also fed on the pulp of certain fruit in addition to ingesting the seeds: although Annamese silvered langurs seem to mainly destroy the seeds of most of their food species, affecting their recruitment, in the particular case of *Sindora* *cochinchinensis* they might help its recruitment: the pulp in fruits presents germination retardants, and seeds need to be removed from it in order to germinate; langurs only eat the fruit pulp and discard the seeds, thus enabling their germination. They could play the same role with other plant species, making their relationships with the habitat more complex. Further research on the digestibility and durability of target seeds by analysing langur faeces, as well as on seedling recruitment in plots around food trees or where langurs are more commonly observed defecating will greatly help look at the dynamics of the relationship between both species.

Annamese silvered langurs were observed to be regular visitors to mineral licks, more than any non-primate, herbivorous mammals that frequented the same mineral lick. Comparison to red-shanked doucs was not possible because locals stole a monitoring camera trap at the lick that doucs visited. Most months registered at least one silvered langur visit to mineral licks, but visits were particularly frequent and longer during the dry season, especially in January and February of 2014. There was a strong correlation between the number of individuals that a group presented and the amount of time that the group would spend at the mineral lick. In order to further study the reasons behind geophagy in Annamese silvered langurs, the nutrient proportion in the diet items consumed by silvered langurs should be analysed to look for particular minerals that might be in short availability or secondary compounds that might hinder digestion, as well as the composition of the soil at the mineral licks in order to establish the possible deficiencies or needs of langurs in their diet with regards to their soil consumption.

9.5 Ranging

The Annamese silvered langur habitat consisted of a mosaic of mixed deciduous and mixed evergreen forest areas, in close vicinity to a permanent stream, with adjacent mixed deciduous areas acting as gallery forest which could be inundated for several months at the height of the rainy season. Study group members were shown to favour the higher tiers of the canopy, from 20 meters high upwards. There was no significant difference in canopy use by adult males and females, but juveniles spent significantly more time on the mid strata of the canopy, between 10 and 20 meters. Possible explanations for these differences could be attributed to juveniles engaging in playing behaviours much more frequently than adult individuals, which involve running and jumping around the canopy, and thus would switch between canopy tiers very frequently.

Another possibility is that small sized group members are potential prey to aerial predators: some species of raptor known to be present in the study site have been observed to prey on primates by other researchers. Juvenile individuals were observed to be present more often than other age classes on the low canopy levels, a behaviour that might make them vulnerable to attacks from predators roaming the forest floor or the low canopy.

The home range of the study group was calculated to consist of at least 256 hectares of area, the largest home range recorded for species within the genus *Trachypithecus*, and in the same dimensions as those in other genera such as *Semnopithecus* and *Nasalis*. Even so, this home range size was estimated using the grid cell method, which is the most conservative of the methods that could be applied. Group encounter rates were not particularly high, which means this range will be actually larger. It is known that the species frequently visits mineral licks at the study site and in other areas of its distribution (at least in Cambodia): the group was never observed visiting a mineral lick, so the home range will most likely be larger for this additional reason. Further research on the study group will most likely show new ranging areas that will increase current size. Having said that, areas to the south and east of the group's home range are surrounded by landscapes under heavy anthropic influence: on the east, parts of forest outside the gazetted Conservation Area have been cleared in order to make farms, while areas of forest on the southern edges of the home range are close to human habitation and subject to illegal human activities, with the bordering areas being cut down. On the other hand, the western reaches of the home range are connected to forest that extends westwards. This situation, in addition to the low encounter ratios, further prevents the likelihood of the presence of more than one group in this extension.

Home range size was observed to be larger during the dry season than during the rainy season. Bar the possibility of it being a consequence of differences in sampling effort, one of the most likely reasons for this difference in seasonal home range size would be associated with the diet and the availability of the preferred food items, as many were only seasonally available. As many plants in the mixed evergreen patches of forest that were eaten by langurs developed new leaves and fruit during the dry season and they would generally be found dispersed around the langur home range, langurs foraging for these foodstuffs will have to further move around their habitat during the rainy season; also, as was previously mentioned, *T. margarita* in Vietnam have been observed to feed on *Lagerstroemia calyculata* leaves and langurs were observed to spent a large amount of time in mixed deciduous forests, where *L. calyculata* stems were dominant, which probably means that langurs consumed considerable quantities of leaves and plant parts of this or adjacent species, and might not need to move too far in order to get enough preferred foodstuffs.

Langurs visited the mineral licks more frequently during the dry season, which means that the group would have to move over larger distances in order to return to them. According to local guides, the study group's lick is located somewhere in the forest west of the recorded home range: this location is on the other side of the home range areas where they were observed feeding during the dry season. During the rainy season, there was some avoidance of mixed evergreen forest patches, and a slight preference towards areas of mixed deciduous stands, probably related to the consumption of *L. calyculata* plant parts during the season in which they are available. During the dry season, on the other hand, mixed deciduous forest was strongly avoided by langurs for two possible reasons: a likely seasonal absence of preferred foods, and the absence of canopy cover, which would leave the animals exposed: young individuals in particular would be very vulnerable to aerial predators. Further studies should look at the phenology of plant species in the diet in order to further explain the dynamics behind the langur ranging behaviour, and further explore the langur home range size.

9.6 Human impacts

Illegal logging activities in the langur home range and adjacent areas during 2013 were intense and widespread, although they greatly declined during 2014, probably due to an increase in the intensitiy of law enforcement as well as a shift of the logging activities to areas where the focus species was still present at the time. The main species that was targeted by loggers was *Pterocarpus macrocarpus*, a species that, while never found in great numbers, was regularly found in different forest types around the study area but was virtually extirpated from it before the end of the study. Results show the beginning of a shift in which loggers will turn their attention to the trees in the area with the wood that will attain the next highest value in the luxury wood market after the first choices have already been eradicated. This points to several species of dipterocarps and legumes, like *Dalbergia oliveri*, which looked as the next species to be logged, but also species from the genus *Hopea* or *Xylia xylocarpa*. Even a tree with a vital role in the local economy such as *Dipterocarpus alatus* is threatened by the illegal luxury wood trade.

Species such as *D. alatus* and *Hopea* spp. are known to be food resources of *T. margarita*, and some of them potentially very important for the species, and the progressive removal of these species will have a potentially devastating effect on the ecology of the Annamese silvered langur in the area, as well as with other numerous species of fauna.

Removal of tree coverage can also have a great impact on the local communities, affecting the humidity and water balance close to villages, as well as making much harder the sustainable gathering of natural resources from the forest. Removal of fruit trees strongly harms the local population and wildlife, removing sources of food; the cutting of *D. alatus* trees will have a detrimental effect on the local economy, removing a sustainable and reliable source of income from families. Current efforts on law enforcement in the area should be sustained and increased if possible to prevent illegal activities and maintain low human pressure on the protected area, as well as keeping efforts on education of local communities, particularly youth, with the hope of an eventual change in local sensibilities. This way the ecological assemblages will be maintained as not only an invaluable biodiversity asset, but also a wealth of resources for local people and a provider of fresh water for communities around it.

It was observed that langurs did not return to areas where logging had been particularly intense, and they reacted negatively to the intensity and length of logging during the study: group members mostly moved in the mid canopy tier when there was no logging or it was done at a distance of 2000 meters or further, but as the number of chainsaws increased, the amount of daily hours that logging would last, or the closer logging activities were to the group, animals would incrementally be more frequently found in the highest canopy tier. Although results show that langurs are sensitive to logging activities in their vicinity, other works, as well as observations during this study point to the taxon as a resilient group towards the effects of human activities in their habitat. The fact that the study group was observed to maintain large group numbers and present a large amount of immature individuals during 2014, after logging activities subsided, means that the population had so far coped with human impacts. If logging activities are kept in check, langurs will most likely return to areas that have been heavily affected by the cutting of large trees and they will be able to survive as they are also capable of switching their diet and taking advantage of species and plant parts that other primates or mammals would not be able to feed on, as has been observed in Vietnam in the same species, as well as in other studies on Asian colobines. In any case, law enforcement must be maintained in order to prevent a large disruption of the habitats in the area; the analysis of faecal samples in order to compare cortisol levels to see if there are any differences in them between days when logging in the area was intense and days when ther was no logging would give further information on the response of langurs to human disturbance in their habitat. Further avenues of research should be to look at differences over the course of several years in group size numbers and infant survival and recruitment rates of the study group in particular and other groups in VSSPCA in general, so that the evolution of the population can be observed over time, as many studies have pointed out that the detrimental effects of habitat degradation and fragmentation on a primate population might only be observed after several years have gone by, instead of right after the disturbance has occurred.

References

Abramov, A.V. 2007. Mammal survey on Phu Quoc Island, southern Vietnam. *Mammalia,* 71(1), pp.40-46

Adam, J.H., Mahmud, A.M., Muslim, N.E., Hamid, H.A., Jalaludin, M.A. 2007. Cluster Analysis on Floristic Composition and Forest Structure of Hilly Lowland Forest in Lok Kawi, Sabah State of Malaysia. *International Journal of Botany,* 3(4), pp.351-358

Adams, L., Davis, S.D. 1967. The Internal Anatomy of Home Range. *Journal of Mammalogy,* 48(4), pp.529-536

Agmen, F.L. 2014. *Conservation strategies for Delacour's langur (Trachypithecus delacouri) in Vietnam: Behavioural comparisons and reviewing a release*. PhD Thesis. Australian National University, Canberra, Australia.

Aiba, S., Kitayama, K. 1999. Structure, composition and species diversity in an altitude-substrate matrix of rain forest tree communities on Mount Kinabalu, Borneo. *Plant Ecology,* 140(2), pp.139-157

Albert, A., Savini, T., Huynen, M.C. 2011. Sleeping Site Selection and Presleep Behavior in Wild Pigtail Macaques. *American Journal of Primatology*, 73(12), pp.1222-1230

Amarasinghe, A.A.T., Botejue, W.M.S., Harding, L.E. 2009. Social behaviours of captive *Trachypithecus cristatus* (Mammalia: Cercopithecidae) in the national zoological gardens of Sri Lanka. *Taprobanica,* 1(1), pp.66-73

Ampeng, A., Md-Zain, B.M. 2012. Ranging Patterns of Critically Endangered Colobine, *Presbytis chrysomelas chrysomelas*. *The Scientific World Journal,* 2012, pp.1-7

Anderson, J.R. 1984. Ethology and Ecology of Sleep in Monkeys and. In Rosenblatt, J., Beer, C., Busnel, M.C., Slater, P.J.B. (eds.): *Advances in the Study of Behavior: Volume 14.* London, Academic Press, pp.166-229

Anderson, J.R. 1998. Sleep, Sleeping Sites, and Sleep-Related Activities: Awakening to their Significance. *American Journal of Primatology*, 46(1), pp.63-75

Anderson, J.R., McGrew, W.C. 1984. Guinea Baboons (*Papio papio*) at a Sleeping Site. *American Journal of Primatology*, 6, pp.1-14

Anderson, J., Cowlishaw, G., Rowcliffe, J.M. 2007. Effects of Forest Fragmentation on the Abundance of *Colobus angolensis palliatus* in Kenya's Coastal Forests. *International Journal of Primatology,* 28, pp.637-655

Ang, H.F.A. 2010. *Banded Leaf Monkeys in Singapore: Preliminary Data on Taxonomy, Feeding Ecology, Reproduction, and Population Size*. Masters Thesis. National University of Singapore, Singapore

Ankel-Simons, F. 2007. *Primate Anatomy: An Introduction.* Burlington: Academic Press

Appanah, S. 1993. Mass flowering in dipterocarp forests in the aseasonal tropics. *Journal of Biosciences*, 18(4), pp.457-474

Appanah, S., Manaf, M.R.A. 1994. Fruiting and seedling survival of dipterocarps in a logged forest. *Journal of Tropical Forest Science,* 6(3), pp.215-222

Appanah, S., Gentry, A.H., LaFrankie, J.V. 1993. Liana diversity and species richness of Malaysian rain forests. *Journal of Tropical Forest Science,* 6(2), pp.116-123

Aquino, R., Encarnación, F. 1986. Characteristics and Use of Sleeping Sites in *Aotus* (Cebidae: Primates) in the Amazon Lowlands of Peru. *American Journal of Primatology*, 11(4), pp.319-331

Archibald, G.W., Gopi Sundar, K.S., Barzen, J. 2003. A Review of the Three Subspecies of Sarus Cranes *Grus antigone*. *Journal of Ecological Society,* 16, pp. 5-15

Ashton, E.C., Macintosh, D.J. 2002. Preliminary assessment of the plant diversity and community ecology of the Sematan mangrove forest, Sarawak, Malaysia. *Forest Ecology and Management,* 166(1-3), pp.111-129

Averyanov, L.V, Phan, K.L., Nguyen, T.H., Harder, D.K. 2003. Phytogeographic review of Vietnam and Adjacent Areas of Eastern Indochina. *Komarovia,* 3, pp.1-83

Aziz, M.A., Feeroz, M.M. 2009. Utilization of forest flora by Phayre's Leaf-Monkey *Trachypithecus phayrei* (Primates: Cercopithecidae) in semi-evergreen forests of Bangladesh. *Journal of Threatened Taxa*, 1(5), pp.257-262

Bain, R.H., Hurley, M.M. 2005. A Biogeographic Synthesis of the Amphibians and Reptiles of Indochina. *Bulletin of the American Museum of Natural History,* 360, pp.1-138

Baird, I.G., Dearden, P. 2003. Biodiversity Conservation and Resource Tenure Regimes: A Case Study from Northeast Cambodia. *Environmental management*, 32(5), pp.541-550

Baird, I.G., Beasley, I.L. 2005. Irrawaddy dolphin *Orcaella brevirostris* in the Cambodian Mekong River, an initial survey. *Oryx,* 39 (3), pp.301-310

Baker, P.J., Bunyavejchewin, S., Oliver, C.D., Ashton, P.S. 2005. Disturbance history and historical stand dynamics of a seasonal tropical forest in western Thailand. *Ecological Monographs,* 75(3), pp.317-343

Baldwin, L.A., Kavanagh, M., Teleki, G. 1975. Field Research on Langurs and Proboscis Monkeys: An Historical, Geographical, and Bibliographical Listing. *Primates,* 16(3), pp.351-363

Barnes, R.F.W., Tapper, S.C., Williams, J. 1983. Use of Pastures by Brown Hares. *Journal of Applied Ecology*, 20(1), pp.179-185

Barnett, A.A., Shaw, P., Spironello, W.R., MacLarnon, A., Ross, C. 2012. Sleeping site selection by golden-backed uacaris, *Cacajao melanocephalus ouakary* (Pitheciidae), in Amazonian flooded forests. *Primates*, 53(3), pp.273-285

Bartlett, T.Q. 2009. Seasonal Home Range Use and Defendability in White-Handed Gibbons (*Hylobates lar*) in Khao Yai National Park, Thailand. In Lappan, S., Whittaker, D.J. (eds.): *The Gibbons: New Perspectives on Small Ape Socioecology and Population Biology.* New York: Springer, pp.265-275

Bates, B.C. 1970. Territorial behavior in primates: A review of recent field studies. *Primates*, 11(3), pp.271-284

Bauchop, T., Martucci, R.W. 1968. Ruminant-Like Digestion of the Langur Monkey. *Science,* 161(3842), pp.698-700

Behie, A.M., Kutz, S., Pavelka, M.S. 2014. Cascading Effects of Climate Change: Do Hurricane-damaged Forests Increase Risk of Exposure to Parasites? *Biotropica*, 46(1), pp.25-31

Bernard, H., Matsuda, I., Hanya, G., Ahmad, A.H. 2011. Characteristics of Night Sleeping Trees of Proboscis Monkeys (*Nasalis larvatus*) in Sabah, Malaysia. *International Journal of Primatology*, 32(1), pp.259-267

Bernstein, I.S. 1968. The Lutong of Kuala Selangor. *Behaviour*, 32(1), pp.1-16

Bicca-Marques, J.C. 2003. How do Howler Monkeys Cope with Habitat Fragmentation? In Marsh, L.K. (ed.): *Primates in Fragments: Ecology and Conservation.* New York: Springer, pp.283-303

Birdlife International Cambodia Programme. 2012. *The Biodiversity of the Proposed Western Siem Pang Protected Forest Stung Treng Province, Cambodia*. Birdlife International Cambodia Programme, Phnom Penh, Cambodia

Bismarck, M. 2010. Proboscis monkey (*Nasalis larvatus*): Bio-ecology and Conservation. In Gursky-Doyen, S., Supriatna, J. (eds.): *Indonesian Primates.* Springer, pp.217-234

Biswas, J., Das, N., Borah, D.K., Sangma, A., Ray, P.C., Das, J. 2009. *Status and distribution of least known primate species: Slow Loris and Capped Langur in the Protected Areas of Assam, India and its feeding ecology, Final Report*. Primate Research Center NE India: Guwahati, India.

Blair, M.E., Sterling, E., Hurley, M. 2011. Taxonomy and Conservation of Vietnam’s Primates: A Review. *American Journal of Primatology,* 73, pp.1093-1106

Blanc, L., Maury-Lechon, G., Pascal, J.P. 2000. Floristic Composition and Natural Regeneration in the Forests of Cat Tien National Park, Vietnam: An Analysis of the Succesional Trends. *Journal of Biogeography,* 27 (1), pp.141-157

Blasco, F., Bellan, M.F., Aizpuru, M. 1996. A vegetation map of tropical continental Asia at scale 1:5 million. *Journal of Vegetation Science,* 7, pp.623-634

Boonratana, R. 2000. Ranging Behavior of Proboscis Monkeys (*Nasalis larvatus*) in the Lower Kinabatangan, Northern Borneo. *International Journal of Primatology*, 21(3), pp.497-518

Borries, C. 1997. Infanticide in seasonally breeding multimale groups of Hanuman langurs (*Presbytis entellus*) in Ramnagar, South Nepal. *Behavioral Ecology and Sociobiology,* 41, pp.139-150

Borries, C., Larney, E., Derby, A.M., Koenig, A. 2004. Temporary Absence and Dispersal in Phayre's Leaf Monkeys (*Trachypithecus phayrei*). *Folia Primatologica,* 75(1), pp.27-30

Borries, C., Larney, E., Lu, A., Ossi, K., Koenig, A. 2008. Costs of group size: lower developmental and reproductive rates in larger groups of leaf monkeys. *Behavioral Ecology,* 19(6), pp.1186-1191

Borries, C., Lu, A., Ossi-Luppo, K., Larney, E., Koenig, A. 2011. Primate Life Histories and Dietary Adaptations: A Comparison of Asian Colobines and Macaques. *American Journal of Physical Anthropology,* 144(2), pp.286-299

Borgerson, C. 2015. The Effects of Illegal Hunting and Habitat on Two Sympatric Endangered Primates. *International Journal of Primatology,* 36, pp.74-93

Brotcorne, F., Maslarov, C., Nengah Wandia, I., Fuentes, A., Beudels-Jamar, R.C., Huynen, M.C. 2014. The role of anthropic, ecological, and social factors in sleeping site choice by long-tailed Macaques (*Macaca fascicularis*). *International Journal of Primatology*, 76(12), pp.1140-1150

Brandon-Jones, D. 2004. A taxonomic revision of the langurs and leaf monkeys (Primates: Colobinae) of South Asia. *Zoos' Print Journal,* 19(8), pp.1552-1594

Brandon-Jones, D., Eudey, A.A., Geissmann, T., Groves, C.P., Melnick, D.J., Morales, J.C., Shekelle, M., Stewart, C.B. 2004. Asian Primate Classification. *International Journal of Primatology,* 25(1), pp.97-164

Bunyavejchewin, S. 1999. Structure and dynamics in seasonal dry evergreen forest in northeastern Thailand. *Journal of Vegetation Science,* 10 (6), pp.787-792

Bunyavejchewin, S., LaFrankie, J.V., Baker, P.J., Kanzaki, M., Ashton, P.S., Yamakura, T. 2003. Spatial distribution patterns of the dominant canopy dipterocarp species in a seasonal dry evergreen forest in western Thailand. *Forest Ecology and Management*, 175(1), pp.87-101

Cannon, C.H., Peart, D.R., Leighton, M. 1998. Tree Species Diversity in Commercially Logged Bornean Rainforest. *Science,* 281 (5381), pp.1367-1368

Campbell, I.C., Poole, C., Giesen, W., Valbo-Jorgensen, J. 2006. Species diversity and ecology of Tonle Sap Great Lake, Cambodia. *Aquatic Sciences,* 68(3), pp.355-373

Caton, J.M. 1999. Digestive Strategy of the Asian Colobine Genus *Trachypithecus*. *Primates,* 40(2), pp.311-325

Chapman, C. 1988. Patterns of Foraging and Habitat Use by Three Species of Neotropical Primates. *Primates*, 29 (2), pp.177-194

Chapman, C.A. 1989. Spider monkey sleeping sites: use and availability. *International Journal of Primatology*, 18(1), pp.53-60

Chapman, C.A., Chapman, L.J. 2002. Foraging challenges of red colobus monkeys: influence of nutrients and secondary compounds. *Comparative Biochemistry and Physiology Part A*, 133, pp.861-875

Chapman, C.A., Chapman, L.J., MacLaughlin, R.L. 1989. Multiple central space foraging by spider monkeys: travel consequences of using many sleeping sites. *Oecologia*, 79(4), pp.506-511

Chapman, C.A., Balcomb, S.R., Gillespie, T.R., Skorupa, J.P., Struhsaker, T.T. 2000. Long-Term Effects of Logging on African Primate Communities: A 28-Year Comparison from Kibale National Park, Uganda. *Conservation Biology,* 14(1), pp.207-217

Chapman, C.A., Chapman, L.J., Gillespie, T.R. 2002. Scale Issues in the Study of Primate Foraging: Red Colobus of Kibale National Park. *American Journal of Physical Anthropology*, 117, pp.349-363

Chapman, C.A., Chapman, L.J., Rode, K.D., Hauck, E.M., McDowell, L.R. 2003. Variation in the Nutritional Value of Primate Foods: Among Trees, Time Periods, and Areas. *International Journal of Primatology*, 24(2), pp.317-333

Chapman, C.A., Wasserman, M.D., Gillespie, T.R. 2006. Behavioral Patterns of Colobus in Logged and Unlogged Forests: The Conservation Value of Harvested Forests. In Newton-Fisher, N.E., Notman, H., Patterson, J.D., Reynolds, V. (eds.): *Primates of Western Uganda.* New York: Springer, pp.373-390

Chapman, C.A., Naughton-Treves, L., Lawes, M.J., Wasserman, M.D., Gillespie, T.R. 2007. Population Declines of Colobus in Western Uganda and Conservation Value of Forest Fragments. *International Journal of Primatology,* 28, pp.513-528

Chetry, D., Chetry, R., Ghosh, K., Bhattacharjee, P.C. 2010. Status and Conservation of Golden Langur in Chakrashila Wildlife Sanctuary, Assam, India. *Primate Conservation,* 25, pp.81-86

Cheyne, S.M., Höing, A., Rinear, J., Sheeran, L.K. 2012. Sleeping Site Selection by Agile Gibbons: The Influence of Tree Stability, Fruit Availability and Predation Risk. *Folia Primatologica*, 83(3-6), pp.299-311

Chhangani, A.K., Mohnot, S.M. 2006. Ranging Behaviour of Hanuman Langurs (*Semnopithecus entellus*) in Three Different Habitats. *Primate Conservation*, 21, pp.171-177

Chivers, D.J. 1977. The lesser apes. In HSH Prince Rainier, Bourne, G.H. (eds.): *Primate Conservation.* New York: Academic Press, pp.539-598

Chivers, D.J. 1985. Southeast Asian Primates. In Benirschke, K. (ed.): *Primates: The Road to Self-Sustaining Populations.* New York: Springer, pp.127-152

Chivers, D.J., Hladik, C.M. 1980. Morphology of the Gastrointestinal Tract in Primates: Comparisons with Other Mammals in Relation to Diet. *Journal of Morphology*, 166(3), pp.337-386

Chopra, G., Bhoombak, M.B., Kumar, P. 2012. Selection and Shifting of Sleeping Sites by Hanuman Langurs in Morni Hills of Haryana, India. *Zoo's Print*, 27(5), pp. 19-23

Clements, T., Gilbert, M., Rainey, H.J., Cuthbert, R., Eames, J.C., Pech, B., Seng, T., Song, C., Tan, S. 2013. Vultures in Cambodia: population, threats and conservation. *Bird Conservation International*, 23(1), pp. 7-24

Clutton-Brock, T.H. 1975. Ranging behaviour of red colobus (*Colobus badius tephrosceles*) in the Gombe National Park. *Animal Behaviour*, 23(3), pp. 706-722

Clutton-Brock, T.H. 1977. Some Aspects of Intraspecific Variation in Feeding and Ranging Behaviour in Primates. In Clutton-Brock, T.H. (ed.): *Primate Ecology: Studies of feeding and ranging behaviour in lemurs, monkeys and apes.* London: Academic Press, pp.539-556

Clutton-Brock, T.H., Harvey, P.H. 1977. Species Differences in Feeding and Ranging Behaviour in Primates. In Clutton-Brock, T.H. (ed.): *Primate Ecology: Studies of feeding and ranging behaviour in lemurs, monkeys and apes.* London: Academic Press, pp.557-579

Clutton-Brock, T.H., Lukas, D. 2012. The evolution of social philopatry and dispersal in female mammals. *Molecular Ecology*, 21, pp.472-492

Coe, M.J. 1983. Primates: their niche structure and habitats. In Chivers, D.J., Wood, B.A., Bilsborough, A. (edS.): *Food Acquisition and Processing in Primates.* New York: Springer, pp.1-353

Corlett, R.T. 1987. The Phenology of *Ficus fistulosa* in Singapore. *Biotropica*, 19(2), pp.122-124

Corlett, R.T. 2004. Flower visitors and pollination in the Oriental (Indomalayan) Region. *Biological Reviews*, 79(3), pp.497-532

Cottam, G., Curtis, J.T. 1956. The Use of Distance Measures in Phytosociological Sampling. *Ecology*, 37(3), pp.451-460

Coudrat, C.N.Z., Rodgers, L.D., Nekaris, K.A.I. 2011. Abundance of primates reveals Samkos Wildlife Sanctuary, Cardamom Mountains, Cambodia, as a priority area for conservation. *Oryx,* 45(3), pp.427-434

Coudrat, C.N.Z., Nekaris, K.A.I. 2013. Modelling Niche Differentiation of Co-Existing, Elusive and Morphologically Similar Species: A Case Study of Four Macaque Species in Nakai –Nam Theun National Protected Area, Laos. *Animals,* 3(1), pp.45-62

Cox, C.B. 2001. The biogeographic regions reconsidered. *Journal of Biogeography,* 28(4), pp.511-523

Critical Ecosystem Partnership Fund. 2012. *Ecosystem Profile: Indo-Burma Biodiversity Hotspot*. Final version, October 2012. Downloaded July 13, 2015 from http://www.cepf.net/Documents/final.indoburma_indochina.ep.pdf.

Cui, L.W. 2003. A Note on an Interaction between *Rinopithecus bieti* and a Buzzard at Baima Snow Mountain. *Folia Primatologica*, 74, pp.51-53

Cui, L.W., Quan, R.C., Xiao, W. 2006. Sleeping sites of black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) at Baima Snow Mountain, China. *Journal of Zoology*, 270, pp.192-198

Cui, L.W., Li, Y.C., Ma, C., Scott, M.B., Li, J.F., He, X.Y., Li, D.H., Sun, J., Sun, W.M., Xiao, W. 2015. Distribution and conservation status of Shortridge's capped langurs *Trachypithecus shortridgei* in China. *Oryx,* pp.1-10

Curtin, S.H. 1980. Dusky and banded leaf monkeys. In Chivers, D.J. (ed.): *Malayan Forest Primates: Ten Years' Study in Tropical Rain Forest.* New York: Springer, pp.107-145

Damstra, K.S.J., Richardson, S., Reeler, B. 1996. Sinchronized fruiting between trees of *Ficus thonningii* in seasonally dry habitats. *Journal of Biogeography*, 23(4), pp.495-500

Das, I. 2010. *A Field Guide to the Reptiles of South-East Asia*. London: New Holland Publishers

Dasilva, G.L. 2003. The Western Black-And-White Colobus as a Low-Energy Strategist: Activity Budgets, Energy Expenditure and Energy Intake. *Journal of Animal Ecology*, 61(1), pp.79-91

Davies, G. 1991. Seed-Eating by Red Leaf Monkeys (*Presbytis rubicunda*) in Dipterocarp Forest of Northern Borneo. *International Journal of Primatology*, 12(2), pp.119-144

Davies, A.G., Baillie, I.C. 1988. Soil-Eating by Red Leaf Monkeys (*Presbytis rubicunda*) in Sabah, Northern Borneo. *Biotropica*, 20(3), pp.252-258

Davies, A.G., Bennett, E.L., Waterman, P.G. 1988. Food selection by two South-east Asian colobine monkeys (*Presbytis rubicunda* and *Presbytis melalophos*) in relation to plant chemistry. *Biological Journal of the Linnean Society*, 34(1), pp.33-56

Davies, A.G., Oates, J.F., Dasilva, G.L. 1999. Patterns of Frugivory in Three West African Colobine Monkeys. *International Journal of Primatology*, 20(3), pp.327-357

Day, R.T., Elwood, R.W. 1999. Sleeping Site Selection by the Golden-handed Tamarin *Saguinus midas midas*: The Role of Predation Risk, Proximity to Fedding Sites, and Territorial Defence. *Ethology*, 105(12), pp.1035-1051

Decker, B.S. 1994. Effects of Habitat Disturbance on the Behavioral Ecology and Demographics of the Tana River Red Colobus (*Colobus badius rufomitratus*). *International Journal of Primatology,* 15(5)*,* pp.703-737

DeJong, T.M. 1975. A Comparison of Three Diversity Indices Based on Their Components of Richness and Evenness. *Oikos,* 26 (2)*,* pp.222-227

Dela, J.D.S. 2007. Seasonal Food Use Strategies of *Semnopithecus vetulus nestor*, at Panadura and Piliyandala, Sri Lanka. *International Journal of Primatology*, 28(3), pp.607-626

Delson, E. 1975. Evolutionary History of the Cercopithecidae. In Szalay, F.S. (ed.): *Approaches to Primate Paleobiology: Contributions to Primatology, vol. 5.* Basel: Karger, pp.167-217

Denise, T.S.H., Ali, F., Kutty, S.N., Meier, R. 2008. The need for specifying species concepts: How many species of silvered langurs (*Trachypithecus cristatus* group) should be recognized? *Molecular Phylogenetics and Evolution,* 49, pp.688-689 di Bitetti, M.S. 2001. Home-range use by the tufted capuchin monkey (*Cebus apella nigritus*) in a subtropical rainforest of Argentina. *Journal of Zoology*, 253(1), pp.33-45

di Bitetti, M.S., Luengos Vidal, M.S., Baldovino, M.C., Benesovsky, V. 2010. Sleeping Site Preferences in Tufted Capuchin Monkeys (*Cebus apella nigritus*). *American Journal of Primatology*, 50(4), pp.257-274

Ding, W., Zhao, Q.K. 2004. *Rhinopithecus bieti* at Tacheng, Yunnan: Diet and Daytime Activities. *International Journal of Primatology*, 25(3), pp.583-598

Disotell, T.R. 2000. The molecular systematics of the Cercopithecoidea. In Whitehead, P.F., Jolly, C.J. (eds.): *Old World Monkeys.* Cambridge: Cambridge University Press, pp.29-56

Dy Phon, P. 2000. *Plants Used in Cambodia*. Imprimerie Olympic, Phnom Penh, Cambodia

Duarte, M.H.L., Young, R.J. 2011. Sleeping Site Selection by Urban Marmosets (*Cebus apella nigritus*) Under Conditions of Exceptionally High Predator Density. *International Journal of Primatology*, 32(2), pp.329-334

Eakins, A. 2010. *Ontogeny of Positional Behavior in Captive Silvered Langurs (Trachypithecus cristatus).* Senior Honors Thesis. Ohio State University, Columbus, USA

Eang, H.K. 2015. Vegetation. In Hayes, B., Eang, H.K., Neang, T., Furey, N., Chhin, S., Holden, J., Hun, S., Phen, S., La, P., Simpson, V. *Biodiversity Assessment of Prey Lang: Kratie, Kampong Thom, Stung Treng and Preah Vihear Provinces*. Conservation International Greater Mekong, Phnom Penh, Cambodia

Edwards, S., Allison, J., Cheetham, S. 2012. Short Communication: Recent mammal records from the Oddar Meanchey portion of the Kulen-Promtep Wildlife Sanctuary, Northern Cambodia. *Cambodian Journal of Natural History,* 2012(1), pp.8-12

Ehlers Smith, D.A., Husson, S.J., Ehlers Smith, Y.C., Harrison, M.E. 2013. Feeding Ecology of Red Langurs in Sabangau Tropical Peat-Swamp Forest, Indonesian Borneo: Extreme Granivory in a Non-Masting Forest. *American Journal of Primatology*, 75, pp.848-859

Ellwanger, A.L., Riley, E.P., Niu, K.F., Tan, C.L. 2015. Local People's Knowledge and Attitudes Matter for the Future Conservation of the Endangered Guizhou Snub-Nosed Monkey (*Rhinopithecus brelichi*) in Fanjingshan National Nature Reserve, China. *International Journal of Primatology,* 36*,* pp.33-54

Erinjery, J.J., Kavana, T.S., Singh, M.. 2015. Food resources, distribution and seasonal variations in ranging in lion-tailed macaques, *Macaca silenus*, in the Western Ghats, India. *Primates,* 56, pp.45-54

Estrada, A., Coates-Estrada, R. 1984. Some Observations on the Present Distribution and Conservation of *Alouatta* and *Ateles* in Southern Mexico. *American Journal of Primatology,* 7*,* pp.133-137

Estrada, A., Coates-Estrada, R. 1996. Tropical Rain Forest Fragmentation and Wild Populations of Primates at Los Tuxtlas, Mexico. *International Journal of Primatology,* 17(5)*,* pp.759-783

Fam, S.D., Nijman, V. 2011. *Spizaetus* hawk-eagles as predators of arboreal colobines. *Primates*, 52, pp.105-110

Fan, P.F., Jiang, X.L. 2008a. Sleeping Sites, Sleeping Trees, and Sleep-related Behaviors of Black Crested Gibbons (*Nomascus concolor jingdongensis*) at Mt. Wuliang, Central Yunnan, China. *American Journal of Primatology*, 70(2), pp.153-160

Fan, P.F., Jiang, X.L. 2008b. Effects of Food and Topography on Ranging Behavior of Black Crested Gibbon (*Nomascus concolor jingdongensis*) in Wuliang Mountain, Yunnan, China. *American Journal of Primatology*, 70(9), pp.871-878

Fan, P.F., Garber, P., Ma, C., Ren, G.P., Liu, C.M., Chen, X.Y., Yang, J.X. 2015. High Dietary Diversity Supports Large Group Size in Indo-Chinese Grey Langurs in Wuliangshan, Yunnan, China. *American Journal of Primatology,* 77(5), pp. 479-491

Fashing, P.J. 2001a. Feeding Ecology of Guerezas in the Kakamega Forest, Kenya: The Importance of Moraceae Fruit in Their Diet. *International Journal of Primatology*, 22(4), pp.579-609

Fashing, P.J. 2001b. Male and female strategies during intergroup encounters in guerezas (*Colobus guereza*): evidence for resource defense mediated through males and a comparison with other primates. *Behavioral Ecology and Sociobiology*, 50(3), pp.219-230

Fashing, P.J., Dierenfeld, D.S., Mowry, C.B. 2007. Influence of Plant and Soil Chemistry on Food Selection, Ranging Patterns, and Biomass of *Colobus guereza* in Kakamega Forest, Kenya. *International Journal of Primatology*, 28(3), pp.673-703

Fei, P.F., Scott, M.B., Zhang, W., Ma, C.Y., Xiang, Z.F., Fan, P.F. 2012. Sleeping Tree Selection of Cao Vit Gibbon (*Nomascus nasutus*) Living in Degraded Karst Forest in Banliang, Jingxi, China. *American Journal of Primatology*, 74(11), pp.998-1005

Felton, A.M., Engström, L.M., Felton, A., Knott, C.D. 2003. Orangutan population density, forest structure and fruit availability in hand-logged and unlogged peat swamp forests in West Kalimantan, Indonesia. *Biological Conservation,* 114, pp. 91-101

Felton, A.M., Felton, A., Lindenmayer, D.B., Foley, W.J. 2009. Nutritional goals of wild primates. *Functional Ecology*, 23(1), pp.70-78

Fernando, P., Pastorini, J. 2011. Range-wide Status of Asian Elephants. *Gajah*, 35, pp.15-20

Ferrari, S.F., Diego, V.H. 1995. Habitat fragmentation and primate conservation in the Atlantic Forest of eastern Minas Gerais, Brazil. *Oryx,* 29 (3), pp.192-196

Ferry Slik, J.W., Verburg, R.W., Kessler, P.J.A. 2008. Effects of fire and selective logging on the tree species composition of lowland dipterocarps forest in East Kalimantan, Indonesia. *Biodiversity and Conservation,* 11(1), pp.85-98

Ferry Slik, J.W., Bernard, C.S., van Beek, M., Breman, F.C., Eichhorn, K.A.O. 2008. Tree diversity, composition, forest structure and aboveground biomass dynamics after single and repeated fire in a Bornean rain forest. *Oecologia,* 158, pp.579-588

Fleagle, J.G. 1977. Locomotor Behavior and Muscular Anatomy of Sympatric Malaysian Leaf-Monkeys (*Presbytis obscura* and *Presbytis melalophos*). *American Journal of Physical Anthropology,* 46, pp.297-308

Fleagle, J.G. 1998. Old World Monkeys. In Fleagle, J.G. (ed.): *Primate Adaptation and Evolution.* New York: Academic Press, pp.185-233

Fooden, J. 1996. Zoogeography of Vietnamese Primates. *International Journal of Primatology,* 17(5), pp.845-899

Francis, C.M. 2008. *A Field Guide to the Mammals of South-East Asia.* London: New Holland Publishers

Frechette, J.L. 2014. *Constructing and experimentally testing the impacts of animal generated dispersal kernels in a Northeastern Cambodian fruiting tree*. PhD Thesis. University of Florida, Gainesville, USA.

Fuentes, A. 1996. Feeding and Ranging in the Mentawai Island Langur (*Presbytis potenziani*). *International Journal of Primatology,* 17(1), pp.525-547

Furuya, Y. 1962. The Social Life of Silvered Leaf Monkeys. *Primates*, 3(2), pp.41-60

Ganzhorn, J.U. 1995. Low-Level Forest Disturbance Effects on Primary Production, Leaf Chemistry and Lemur Populations. *Ecology,* 76(7)*,* pp.2084-2096

Ghollasimood, S., Faridah-Hanum, I., Nazre, M., Kamziah, A.K. 2012. Abundance and Distribution of Climbers in a Coastal Hill Forest in Perak, Malaysia. *Journal of Agricultural Science,* 4(5), pp.245-254

Gibson, L., Koenig, A. 2012. Neighboring groups and habitat edges modulate use in Phayre's leaf monkeys (*Trachypithecus phayrei crepusculus*). *Behavioral Ecology and Sociobiology*, 66, pp.633-643

Gittins, S.P., Raemaekers, J.J. 1980. Siamang, Lar, and Agile Gibbons. In Chivers, D.J. (ed.): *Malayan Forest Primates: Ten Years' Study in Tropical Rain Forest*. New York: Springer, pp.63-105

Global Witness. 2007. *Cambodia's family trees: Illegal logging and the stripping of public assets by Cambodia's elite*. Downloaded July 13, 2015, from http://www.globalwitness.org/.../**cambodias_family_trees**_low_res.pdf

Global Witness. 2015. *The cost of luxury: Cambodia's illegal trade in precious wood with China*. Downloaded September 7, 2015, from http://www.globalwitness.org/documents/17847/globalwitnessthecostofluxurypressreleaseenglish6feb15.pdf

Goes, F. 2013. *The Birds of Cambodia: An Annotated Checklist*. Phnom Penh: Centre for Biodiversity Conservation.

Goodman, S.M. 1987. Predation by the Grey Leaf Monkey (*Presbytis hosei*) on the Contents of a Bird's Nest at Mt. Kinabalu Park, Sabah. *Primates*, 30(1), pp.127-128

Grant, J.W.A., Chapman, C.A., Richardson, K.S. 1992. Defended versus undefended home range size of carnivores, ungulates and primates. *Behavioral Ecology and Sociobiology*, 31(3), pp.149-161

Gray, T.N.E, Phan, C. 2011. Habitat preferences and activity patterns of the larger mammal community in Phnom Prich Wildlife Sanctuary, Cambodia. *The Raffles Bulletin of Zoology,* 59(2), pp.311-318

Gray, T.N.E., Ou, R., Huy, K., Pin, C., Maxwell, A.L. 2012a. The status of large mammals in eastern Cambodia: a review of camera trapping data 1999-2007. *Cambodian Journal of Natural History,* 2012 (1), pp.42-55

Gray, T.N.E., Prum, S., Pin, C., Phan, C. 2012b. Distance sampling reveals Cambodia's Eastern Plains Landscape supports the largest global population of the Endangered banteng *Bos javanicus*. *Oryx,* 46 (4), pp.563-566

Green, K.M. 1981. Preliminary Observations on the Ecology and Behavior of the Capped Langur, *Presbytis pileatus*, in the Madhupur Forest of Bangladesh. I. Characteristics of Range Use. *International Journal of Primatology*, 2(2), pp.131-151

Grieser-Johns, A., Grieser-Johns, B. 1995. Tropical forest primates and logging: long-term coexistence? *Oryx,* 29(3), pp. 205-211

Groves, C.P. 2007. Speciation and Biogeography of Vietnam's Primates. *Vietnamese Journal of Primatology,* 1(1), pp.27-40

Grueter, C.C., Li, D.Y., van Schaik, C.P., Ren, B.P., Long, Y.C., Wei, F.W. 2008. Ranging of *Rhinopithecus bieti* in Samage Forest, China. I. Characteristics of Range Use. *International Journal of Primatology*, 29, pp.1121-1145

Grueter, C.C., Li, D.Y., Ren, B.P., Wei, F.W., van Schaik, C.P. 2009a. Dietary Profile of *Rhinopithecus bieti* and Its Socioecological Implications. *International Journal of Primatology*, 30(4), pp.601-624

Grueter, C.C., Li, D.Y., Ren, B.P., Wei, F.W. 2009b. Choice of analytical method can have dramatic effects on primate home range estimates. *Primates*, 50, pp.81-84

Grueter, C.C., Li, D.Y., Ren, B.P., Li, M. 2013a. Substrate use and postural behaviour in free-ranging snub-nosed monkeys (*Rhinopithecus bieti*) in Yunnan. *Integrative Zoology*, 24, pp.125-135

Grueter, C.C., Li, D.Y., Ren, B.P., Li, M. 2013b. Overwintering strategy of Yunnan snub-nosed monkeys: adjustments in activity scheduling and foraging patterns. *Primates*, 54, pp.125-135

Guo, S.T., Li, B.G., Watanabe, K. 2007. Diet and activity budget of *Rhinopithecus roxellana* in the Qinling Mountains, China. *Primates*, 48(4), pp.268-276

Guo, S.T., Ji, W.H., Li, B.G., Li, M. 2008. Response of a Group of Sichuan Snub-Nosed Monkeys to Commercial Logging in the Qinling Mountains, China. *Conservation Biology,* 22(4), pp.1055-1064

Gupta, A.K., Kumar, A. 1994. Feeding ecology and conservation of Phayre's leaf monkey *Presbytis phayrei* in Northeast India. *Biological Conservation,* 69(3), pp.301-306

Gurmaya, K.J., 1986. Ecology and Behavior of *Presbytis thomasi* in Northern Sumatra. *Primates*, 27(2), pp.151-172

Ha, T.L., Nguyen, T.T., Tran, H.V., Ho, T.M. 2007. Activity budget of grey-shanked douc langurs (*Pygathrix cinerea*) in Kon Ka Kinh National Park, Vietnam. *Vietnamese Journal of Primatology,* 4, pp.27-39

Hadi, S., Ziegler, T., Waltert, M., Hodges, J.K. 2009. Tree diversity and forest structure in northern Siberut, Mentawai islands, Indonesia. *Tropical Ecology,* 50(2), pp.315-327

Hadi, S., Ziegler, T., Waltert, M., Syamsuri, F., Mühlenger, M., Hodges, J.K. 2012. Habitat Use and Trophic Niche Overlap of Two Sympatric Colobines, *Presbytis potenziani* and *Simias concolor*, on Siberut Island, Indonesia. *International Journal of Primatology*, 33, pp.218-232

Hamilton, W.J., III. 1982. Baboon sleeping site preferences and relationship to primate grouping patterns. *American Journal of Primatology*, 3, pp.41-53

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J.R.G. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science,* 342(850), pp.133-139

Hansen, M.C., Stehman, S.V., Potapov, P.V., Loveland, T.R., Townshend, J.R.G., de Fries, R.S., Pittman, K.W., Arunarwati, B., Stolle, F., Steininger, M.K., Carroll, M., DiMicelli, C. 2008. Humid tropical forest clearing from 2000 to 2005 quantified by using multitemporal and multiresolution remotely sensed data. *Proceedings of the National Academy of Sciences,* 105(27), pp.9439-9444

Hanya, G., Bernard, H. 2012. Fallback Foods of Red Leaf Monkeys (*Presbytis rubicunda*) in Danum Valley, Borneo. *International Journal of Primatology*, 33(2), pp.322-337

Harding, L.E. 2010. *Trachypithecus cristatus* (Primates: Cercopithecidae). *Mammalian Species,* 42(862), pp.149-165

Harding, L.E. 2011. Red morph of silvered lutung (*Trachypithecus cristatus*) rediscovered in Borneo, Malaysia. *Taprobanica,* 3(1), pp.47-48

Harris, T.R. 2006. Between-Group Contest Competition for Food in a Highly Folivorous Population of Black and White Colobus Monkeys (*Colobus guereza*). *Behavioral Ecology and Sociobiology*, 61(2), pp.317-329

Harris, T.R., Chapman, C.A. 2007. Variation in diet and ranging of black and white colobus monkeys in Kibale National Park, Uganda. *Primates*, 48(3), pp.208-221

Harrison, T., Krigbaum, J., Manser, J. 2006. Primate Biogeography and Ecology on the Sunda Shelf Islands: A Paleontological and Zooarcheological Perspective. In Lehman, S.M., Fleagle, J.G. (eds.): *Primate Biogeography: Progress and Prospects.* New York: Springer, pp.331-372

Hassel-Finnegan, H., Borries, C., Zhao, Q., Phiapalath, P., Koenig, A. 2013. Southeast Asian primate communities: the effects of ecology and Pleisthocene refuges on species richness. *Integrative Zoology*, 8, pp.417-426

Haus, T., Vogt, M., Forster, B. 2009. Observations on the Hatinh langurs (*Trachypithecus hatinhensis*) during point and line transect sampling in the Phong Na – Ke Bang National Park, Central Vietnam. *Vietnamese Journal of Primatology,* 3, pp.17-27

Hausfater, G., Meade, B.J., 1982. Alternation of Sleeping Groves by Yellow Baboons (*Papio cynocephalus*) as a Strategy for Parasite Avoidance. *Primates*, 23(2), pp.287-297

Hayes, B., Mould, A., Eang, H.K., Hartmann, T., Kha, H., Calame, T., Boughey, K., Yon, T. *A Biodiversity Assessment of Phnom Kulen National Park, with Recommendations for Management*. The Rufford Foundation. Retrieved 23 February, 2016 from www.rufford.org/files/11488-1%20Detailed%20Final%20Report_0.pdf

Hayne, D.W. 1949. Calculation of Size of Home Range. *Journal of Mammalogy,* 30(1), pp.1-18

He, F.L., Legendre, P., LaFrankie, J.V. 1996. Spatial pattern of diversity in a tropical rain forest in Malaysia. *Journal of Biogeography,* 8(1), pp.57-74

He, F.L., Legendre, P., LaFrankie, J.V. 1997. Distribution Patterns of Tree Species in a Malaysian Tropical Rain Forest. *Journal of Vegetation Science,* 23(1), pp.105-114

Heiduck, S. 2002. The use of disturbed and undisturbed forest by masked titi monkeys *Callicebus personatus melanochir* is proportional to food availability. *Oryx,* 36(2), pp.133-139

Hemingway, C.A., Bynum, N. 2005. The influence of seasonality on primate diet and ranging. In Brockman, D.K., van Schaik, C.P. (eds.): *Seasonality in Primates: Studies on Living and Extinct Human and Non-Human Primates.* Cambridge, Cambridge University Press, pp.57-104

Hicks, T.C., Roessingh, P., Menken, S.B.J. 2013. Impact of Humans on Long-Distance Communication Behaviour of Eastern Chimpanzees (*Pan troglodytes schweinfurthii*) in the Northern Democratic Republic of the Congo. *Folia Primatologica,* 84, pp.135-156

Hiramatsu, R., Kanzaki, M., Toriyama, J., Kaneko, T., Okuda, Y., Ohta, S., Khorn, S., Pith, P., Lim, S., Pol, S., Ito, E., Araki, M. 2007. Open Woodland Patches in an Evergreen Forest of Kampong Thom, Cambodia: Correlation of Structure and Composition with Microtopography. In Sawada, H., Araki, M., Chappell, N.A., LaFrankie, J.V., Shimizu, A. (eds.): *Forest Environments in the Mekong River Basin.* New York: Springer, pp.222-231

Hoang, M.D. 2003. New record of the silver langur in Kien Luong District, Kien Giang Province, Vietnam. *Asian Primates,* 8(3-4), pp.22-25

Hoang, M.D. 2007. *Ecology and Conservation Status of the black-shanked douc (Pygathrix nigripes) in Nui Chua and Phuoc Binh National Parks, Ninh Thuan Province, Vietnam.* PhD Thesis. University of Queensland, Brisbane, Australia

Hoang, M.D., Baxter, G.S., Page, M.J. 2009. Diet of *Pygathrix nigripes* in Southern Vietnam. *International Journal of Primatology*, 30(1), pp.15-28

Hoang, M.D., Tran, B.V., Covert, H.H., Luu, H.T., Tran, Q.T. 2010. Conservation status of primates in Ta Kou Nature Reserve. In Nadler, T., Rawson, B.M., Thinh, V.N. (eds.): *Conservation of Primates in Indochina.* Hanoi: Frankfurt Zoological Society and Conservation International, pp.91-98

Hoang, M.D., Covert, H.H., Roos, C., Nadler, T. 2012. A note on phenotypical and genetic differences of silvered langurs in Indochina (*Trachypithecus germaini* and *T. margarita*). *Vietnamese Journal of Primatology,* 2(1), pp.47-54

Holmes, T.D, Bergstrom, M.L., Fedigan, M.L. 2011. Sleeping Site Selection by White-faced Capuchins (*Papio cynocephalus*) in the Area de Conservación Guanacaste, Costa Rica. *Ecological and Environmental Anthropology*, 6, pp.1-9

Hrdy, S.B. 1974. Male-Male Competition and Infanticide Among the Langurs (*Presbytis entellus*) of Abu, Rajasthan. *Folia Primatologica,* 22, pp.19-58

Hu, G. 2011. Dietary Breadth and Resource Use of François' Langur in a Seasonal and Disturbed Habitat. *American Journal of Primatology,* 73*,* pp.1176-1187

Hubrecht, R.C. 1985. Home-range size and use and territorial behaviour in the common marmoset, *Callithrix jacchus jacchus*, at the Tapacura field station, Recife, Brazil. *International Journal of Primatology*, 6(5), pp.533-550

Ingicco, T., Balzeau, A., Callou, C., Fitriana, Y.S. 2011. Brief Communication: A Cranial Morphometric Assessment of the Taxonomic Affinities of *Trachypithecus auratus* (E. Geoffroy, 1812 Primates: Colobinae) With a Reassessment of the *T. auratus* Type Specimen. *American Journal of Physical Anthropology,* 146, pp.306-312

Inthakoun, L., Delang, C.O. 2008. *Lao Flora a checklist of plants found in Lao PDR with scientific and vernacular names*. Lulu Press, Morrisville, NC, USA

Iseborn, T., Rogers, L.D., Rawson, B., Nekaris, K.A.I. 2012. Sightings of Common Palm Civets *Paradoxurus hermaphroditus* and of other civet species at Phnom Samkos Wildlife Sanctuary and Veun Sai-Siem Pang Conservation Area, Cambodia. *Small Carnivore Conservation,* 46, pp.26-29

Isbell, L.A., Young, T.P. 2002. Ecological models of female social relationships in primates: similarities, disparities and some directions for future clarity. *Behaviour*, 139(2), pp.177-202

Isbell, L.A., Cheney, D.L., Seyfarth, R.M. 1990. Costs and Benefits of Home Range Shifts among Vervet Monkeys (*Cercopithecus aethiops*) in Amboseli National Park, Kenya. *Behavioral Ecology and Sociobiology,* 27(5)*,* pp.351-358

Ith, S., Csorba, G., Bates, P.J.J., Furey, N.M. 2011. Confirmation of seven bat species for Cambodia. *Cambodian Journal of Natural History,* 2011(2), pp.93-103

Iwamoto, T., Mori, A., Kawai, M., Bekele, A. 1996. Anti-predator behavior of gelada baboons. *Primates,* 37 (4), pp.389-397

Jacobs, J. 1974. Quantitative Measurement of Food Selection: A Modification of the Forage Ratio and Ivlev's Electivity Index. *Oecologia* , 14(4), pp.413-417

Jin, T., Wang, D.Z., Zhao, Q., Yin, L.J., Qin, D.G., Ran, W.Z., Pan, W.S. 2009a. Reproductive Parameters of Wild *Trachypithecus leucocephalus*: Seasonality, Infant Mortality and Interbirth Interval. *American Journal of Primatology,* 71, pp.558-566

Jin, T., Wang, D.Z., Zhao, Q., Yin, L.J., Qin, D.G., Ran, W.Z., Pan, W.S. 2009b. Social Organization of White-Headed Langurs (*Trachypithecus leucocephalus*) in the Nongguan Karst Hills, Guangxi, China. *American Journal of Primatology,* 71, pp.206-213

Johns, A.D. 1983. Tropical forest primates and logging: can they coexist? *Oryx,* 17, pp. 114-118

Johns, A.D. 1986. Effects of Selective Logging on the Behavioral Ecology of West Malaysian Primates. *Ecology,* 67(3)*,* pp.684-694

Johns, A.D. 1988. Effects of "Selective" Timber Extraction on Rain Forest Structure and Composition and Some Consequences for Frugivores and Folivores. *Biotropica,* 20(1), pp. 31-37

Johns, A.D. 1992. Vertebrate Responses to Selective Logging: Implications for the Design of Logging Systems. *Philosophical Transactions of the Royal Society of London B,* 335, pp. 437-442

Johns, A.D., Skorupa, J.P. 1987. Responses of Rain-Forest Primates to Habitat Disturbance: A Review. *International Journal of Primatology,* 8(2)*,* pp.157-191

José-Domínguez, J.M., Asensio, N., García García, C.M., Huynen, M.C., Savini, T. 2015. Exploring the Multiple Functions of Sleeping Sites in Northern Pigtailed Macaques (*Macaca leonina*). *International Journal of Primatology*, 36(5), pp.931-949

Kao, D., Iida, S. 2006. Structural characteristics of logged evergreen forests in Preah Vihear, Cambodia, 3 years after logging. *Forest Ecology and Management,* 225(1-3), pp.62-73

Kannan, R., James, D.A. 1999. Fruiting Phenology and the Conservation of the Great Pied Hornbill (*Buceros bicornis*) in the Western Ghats of Southern India. *Biotropica*, 31(1), pp. 167-177

Karanth, K.P. 2010. Molecular systematics and conservation of the langurs and leaf monkeys of South Asia. *Journal of Genetics,* 89(4), pp.393-399

Karanth, K.P., Singh, L., Collura, R.V., Stewart, C.B. 2006. Molecular phylogeny and biogeography of langurs and leaf monkeys of South Asia (Primates: Colobinae). *Molecular Phylogenetics and Evolution,* 46, pp.683-694

Kaul, R.B. Evolution and Reproductive Biology of Inflorescences in *Lithocarpus*, *Castanopsis*, *Castanea*, and *Quercus* (Fagaceae). *Annals of the Missouri Botanical Garden*, 73(2), pp. 284-296

Kaul, R.B., Abbe, E.C., Abbe, L.B. Reproductive Phenology of the Oak Family (Fagaceae) in the Lowland Rain Forests of Borneo. *Biotropica*, 18(1), pp. 51-55

Kenyon, M., Chivers, D., Vo, T.B. 2010. Home range size and density of yellow-cheeked gibbons in different forest types within Cat Tien National Park, Vietnam. In Nadler, T., Rawson, B.M., Thinh, V.N. (eds.): *Conservation of Primates in Indochina.* Hanoi: Frankfurt Zoological Society and Conservation International, pp.197-209

Keo, O. 2008. *Ecology and conservation of Giant Ibis in Cambodia.* PhD Thesis. University of East Anglia, Norwich, United Kingdom

Kessler, M., Kessler, P.J.A., Robbert Gradstein, S., Bach, K., Schmull, M., Pitopang, R. 2005. Tree diversity in primary forest and different land use systems in Central Sulawesi, Indonesia. *Biodiversity and Conservation,* 14(3), pp.547-560

Khem, R.D., Chou, S. 2013. Experiences from the field: lessons learned in the implementation of integrated conservation and development projects: Cambodia. 15: Virachey National Park. In Sunderland, T.C.H., Sayer, J., Hoang, M.H. (eds.): *Evidence-based Conservation: Lessons from the Lower Mekong.* Oxford: Routledge, pp.-216-223

Kirkpatrick, R.C. 1998. Ecology and Behavior in Snub-nosed and Douc Langurs. In Jablonski, N.G. (ed.): *The Natural History of the Doucs and the Snub-nosed Monkeys.* Singapore: World Scientific Publishing, pp.155-190

Kirkpatrick, R.C., Long, Y.C., Zhong, T., Xiao, L. 1998. Social Organization and Range Use in the Yunnan Snub-Nosed Monkey *Rhinopithecus bieti*. *International Journal of Primatology*, 19(1), pp.13-51

Kirkpatrick, R.C., Zhou, R.J., Dierenfeld, E.S., Zhou, H.W. 2001. Digestion of Selected Foods by Yunnan Snub-Nosed Monkey *Rhinopithecus bieti* (Colobinae). *American Journal of Physical Anthropology*, 114, pp. 156-162

Knop, E., Ward, P.I., Wich, S.A. 2004. A comparison of orang-utan density in a logged and unlogged forest on Sumatra. *Biological Conservation,* 120, pp. 183-188

Kochummen, K.M., LaFrankie, J.V., Manokaran, M. 1990. Floristic composition of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. *Journal of Tropical Forest Science,* 3(1), pp.1-13

Koenig, A., Borries, C. 2001. Socioecology of Hanuman Langurs: The Story of Their Success. *Evolutionary Anthropology*, 10(4), pp. 117-152

Koenig, A., Borries, C., Suarez, S., Kreetiyutanont, Prabnasuk, J. 2004a. Socio-ecology of Phayre's leaf monkeys (*Trachypithecus phayrei*) at Phu Khieo Wildlife Sanctuary. *Journal of Wildlife in Thailand*, 12(1), pp. 150-163

Koenig, A., Larney, E., Lu, A., Borries, C. 2004b. Agonistic Behavior and Dominance Relationships in Female Phayre's Leaf Monkeys – Preliminary Results. *American Journal of Primatology*, 64(3), pp. 351-357

Koenig, A., Borries, C. 2012. Social Organization and Male Residence Pattern in Phayre's Leaf Monkeys. In Kappeler, P.M., Watts, D.P. (eds.): *Long-Term Field Studies of Primates.* Berlin: Springer, pp.215-236

Koenig, A., Scarry, C.J., Wheeler, B.C., Borries, C. 2013. Variation in grouping patterns, mating systems and social structure: what socio-ecological models attempt to explain. *Phylosophycal Transactons of the Royal Society B*, 368(1618)

Kool, K.M. 1992. Food selection by the silver leaf monkey, *Trachypithecus auratus sondaicus*, in relation to plant chemistry. *Oecologia*, 90(4), pp. 527-533

Kool, K.M. 1993. The Diet and Feeding Behavior of the Silver Leaf Monkey (*Trachypithecus auratus sondaicus*) in Indonesia. *International Journal of Primatology*, 14(5), pp. 667-700

Korstjens, A.H., Schippers, E.P. 2003. Dispersal Patterns Among Olive Colobus in Tai National Park. *International Journal of Primatology,* 24(3), pp.515-539

Kowalewski, M., Zunino, G.E. 2005. The Parasite Behavior Hypothesis and the Use of Sleeping Sites by Black Howler Monkeys (*Alouatta caraya*) in a Discontinuous Forest. *Neotropical Primates,* 13(1), pp.22-26

Koyabu, D.B., Endo, H. 2010. Craniodental Mechanics and Diet in Asian Colobines: Morphological Evidence of Mature Seed Predation and Sclerocarpy. *American Journal of Physical Anthropology*, 142(1), pp. 137-148

Krishnamani, R., Mahaney, W.C. 2000. Geophagy among primates: adaptive significance and ecological consequences. *Animal Behaviour*, 59(5), pp. 899-915

Kumar, A., Solanki, G.S. 2008. Population Status and Conservation of Capped Langurs (*Trachypithecus pileatus*) in and around Pakke Wildlife Sanctuary, Arunachal Pradesh, India. *Primate Conservation,* 23, pp.97-105

Lambert, F. 1990. Some Notes on Fig-eating by Arboreal Mammals in Malaysia. *Primates*, 31(3), pp. 453-458

Lambert, F.R., Marshall, A.G. 1991. Keystone Characteristics of a Bird-dispersed Ficus in a Malaysian Lowland Rain Forest. *Journal of Ecology*, 79(3), pp. 793-809

Lambert, J.E. 1998. Primate Digestion: Interactions Among Anatomy, Physiology, and Feeding Ecology. *Evolutionary Anthropology*, 7(1), pp. 8-20

Lamotte, S., Gajaseni, J., Malaisse, F. 1999. Structure diversity in three forest types of north-eastern Thailand (Sakaerat Reserve, Pak Tong Chai). *Biotechnology, Agronomy, Society and Environment,* 2(2), pp.192-202

Le, K.Q., Nguyen, A.D., Vu, A.T., Wright, B.B., Covert, H.H. 2007. Diet of the Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) in the Khau Ca area, Ha Giang Province, Northeastern Vientam. *Vietnamese Journal of Primatology*, 1, pp.75-83

Le, K.Q., Nguyen, V.K. 2010. Preliminary survey on primates in Phu Quoc National Park, Kien Giang Province, Vietnam. In Nadler, T., Rawson, B.M., Thinh, V.N. (eds.): *Conservation of Primates in Indochina.* Hanoi: Frankfurt Zoological Society and Conservation International, pp.99-106

Leca, J.B., Gunst, N., Rompis, A., Soma, G., Arta Putra, I.G.A., Nengah Wandia, I. 2013. Population Density and Abundance of Ebony Leaf Monkey (*Trachypithecus auratus*) in West Bali National Park, Indonesia. *Primate Conservation,* 26(1), pp.133-144

Lee, D.C., Powell, V.J., Lindsell, J.A. 2015. The Conservation Value of Degraded Forests for Agile Gibbons *Hylobates agilis*. *American Journal of Primatology,* 77*,* pp.76-85

Li, B.G., Ren, B.P., Gao, Y.F. 1999. A Change in the Summer Home Range of Sichuan Snub-Nosed Monkeys in Yuhuangmiao, Qinling Mountains. *Folia Primatologica,* 70*,* pp.269-273

Li, B.G., Chen, C., Ji, W.H., Ren, B.P. 2000. Seasonal Home Range Changes of the Sichuan Snub-Nosed Monkey (*Rhinopithecus roxellana*) in the Qinling Mountains of China. *Folia Primatologica*, 71, pp.375-386

Li, D.Y., Grueter, C.C., Ren, B.P., Zhou, Q.H., Li, M., Peng, Z.S., Wei, F.W. 2006. Characteristics of night-time sleeping places selected by golden monkeys (*Rhinopithecus bieti*) in the Samage Forest, Baima Snow Mountain Reserve, China. Use of Land Cover Types and Altitudes. *Integrative Zoology*, 1, pp.141-152

Li, D.Y., Grueter, C.C., Ren, B.P., Long, Y.C., Li, M., Peng, Z.S., Wei, F.W. 2008. Ranging of *Rhinopithecus bieti* in the Samage Forest, China. II. Use of Land Cover Types and Altitudes. *International Journal of Primatology*, 29, pp.1147-1173

Li, D.Y., Ren, B.P., Grueter, C.C., Li, B.G., Li, M. 2010. Nocturnal Sleeping Habits of the Yunnan Snub-Nosed Monkey in Xiangguquing, China. *American Journal of Primatology*, 72(12), pp.1092-1099

Li, D.Y., Zhou, Q.H., Tang, X.P., Huang, H.L., Huang, C.M. 2011. Sleeping site use of the white-headed langur *Trachypithecus leucocephalus*: The role of predation risk, territorial defense, and proximity to feeding sites. *Current Zoology*, 57(3), pp.260-268

Li, D.Y., Yuan, P.S., Krzton, A., Huang, C.M., Zhou, Q.H. 2015. Dietary adaptation of white-headed langurs in a fragmented limestone habitat. *Mammalia*, de Gruyter, March 2015 http://www.degruyter.com.virtual.anu.edu.au/view/j/mamm.ahead-of-print/mammalia-2014-0152/mammalia-2014-0152.xml?rskey=LiqKa8&result=5. 22 January 2016

Li, Y.B., Ding, P., Huang, C.M., Lu, S.Y. 2015. Total tannin content of foods of François Langur in Fusui, Guangxi, China: Preliminary study. *Acta Ecologica Sinica*, 35(1), pp.16-22

Li, Y.C., He, X.Y., Ma, C., Sun, J., Li, D.H., Xiao, W., Cui, L.W. 2015. Social organization of the Shortridge's langur (*Trachypithecus shortridgei*) at Dulongjiang Valley in Yunnan, China. *Zoological Research,* 36(1), pp.1-11

Li, Y.K., Jiang, Z.G., Li, C.W., Grueter, C.C. 2010. Effects of Seasonal Folivory and Frugivory on Ranging Patterns in *Rhinopithecus roxellana*. *International Journal of Primatology,* 31, pp.609-626

Li, Y.M. 2004. The effect of forest clear-cutting on habitat use in Sichuan snub-nosed monkey (*Rhinopithecus roxellana*) in Shennongja Nature Reserve, China. *Primates,* 45*,* pp.69-72

Li, Y.M. 2006. Seasonal Variation in Diet and Food Availability in a Group of Sichuan Snub-Nosed Monkeys in Shennongja Nature Reserve, China. *American Journal of Primatology*, 68(3), pp.217-233

Li, Y.M., 2007. Terrestriality and tree stratum use in a group of Sichuan snub-nosed monkeys. *Primates*, 48, pp.197-207

Li, Z.Y., Wei, Y., Rogers, E. 2003. Food Choice in White-headed Langurs in Fusui, China. *International Journal of Primatology*, 24(6), pp.1189-1205

Li, Z.Y., Rogers, E. 2004. Social Organization of White-Headed Langurs *Trachypithecus leucocephalus* in Fusui, China. *Folia Primatologica,* 75(2), pp.97-100

Li, Z.Y., Rogers, M.E. 2005. Habitat Quality and Range Use of White-headed Langurs in Fusui, China. *Folia Primatologica*, 76, pp.185-195

Li, Z.Y., Rogers, E. 2006. Food Items Consumed by White-headed Langurs in Fusui, China. *International Journal of Primatology*, 27(6), pp.1551-1567

Liedigk, R., Thinh, V.N., Nadler, T., Walter, L., Roos, C. 2009. Evolutionary history and phylogenetic position of the Indochinese grey langur (*Trachypithecus crepusculus*). *Vietnamese Journal of Primatology,* 3, pp.1-8

Lippold, L.K., Thanh, V.N. 1998. Primate Conservation in Vietnam. In Jablonski, N.G. (ed.): *The Natural History of the Doucs and Snub-nosed Monkeys.* Singapore: World Scientific Publishing, pp.293-300

Liu, X.C., Stanford, C.B., Yang, J.Y., Yao, H., Li, Y.M. 2013. Foods Eaten by the Sichuan Snub-Nosed Monkey (*Rhinopithecus roxellana*) in Shennongja National Nature Reserve, China, in Relation to Nutritional Chemistry. *American Journal of Primatology*, 75(8), pp.860-871

Liu, Z.H., Zhao, Q.K. 2004. Sleeping Sites of *Rhinopithecus bieti* at Mr. Fuhe, Yunnan. *Primates*, 45(4), pp.241-248

Lu, A., Borries, C., Czekala, N.M., Beehner, J.C. 2010. Reproductive characteristics of wild female Phayre's leaf monkeys. *American Journal of Primatology,* 72(12), pp.1073-1081

Lu, A., Borries, C., Gustison, M.L., Larney, E., Koenig, A. 2016. Age and reproductive status influence dominance in wild female Phayre's leaf monkeys. *Animal Behaviour,* 117, pp.145-153

Ma, C., Luo, Z.H., Liu, C.M., Orkin, J.D., Xiao, W., Fan, P.F. 2015. Population and Conservation Status of Indo-Chinese Grey Langurs (*Trachypithecus crepusculus*) in the Wuliang Mountains, Jingdong, Yunnan, China. *International Journal of Primatology,* 36(4), pp. 749-763

Mackinnon, J. 1974. The behavior and ecology of wild orang-utans (*Pongo pygmaeus*). *Animal Behaviour,* 22, pp. 3-74

MacKinnon, K. 1985. The Conservation Status of Nonhuman Primates in Indonesia. In Benirschke, K. (ed.): *Primates: The Road to Self-Sustaining Populations.* New York: Springer, pp.99-126

Maisels, F., Gautier-Hion, A., Gautier, J.P. 1994. Diets of Two Sympatric Colobines in Zaire: More Evidence on Seed-Eating in Forests on Poor Soils. *International Journal of Primatology*, 15(5), pp.681-701

Malone, N., Purnama, A.R., Wedana, M., Fuentes, A. 2003. Assessment of the sale of primates at Indonesian bird markets. *Asian Primates,* 8(1-2), pp.7-11

Manson, J.H., Wrangham, R.W. 1991. Intergroup Aggression in Chimpanzees and Humans. *Current Anthropology*, 32(4), pp.369-390

Marod, D., Kutintara, U., Yarwudhi, C., Tanaka, H., Nakashisuka, T. 1999. Structural dynamics of a natural mixed deciduous forest in western Thailand. *Journal of Vegetation Science,* 10(6), pp.777-786

Marshall, A.J., Nardiyono, Engström, L.M., Pamungkas, B., Palapa, J., Meijaard, E., Stanley, S.A. 2006. The blowgun is mightier than the chainsaw in determining population density of Bornean Orangutans (*Pongo pygmaeus morio*) in the forests of East Kalimantan. *Biological Conservation,* 129, pp. 566-578

Matsuda, I., Tuuga, A., Higashi, S. 2009a. The Feeding Ecology and Activity Budget of Proboscis Monkeys. *American Journal of Primatology*, 71, pp.478-492

Matsuda, I., Tuuga, A., Higashi, S. 2009b. Ranging Behavior of Proboscis Monkeys in a Riverine Forest with Special Reference to Ranging in Inland Forest. *International Journal of Primatology*, 30, pp.313-325

Matsuda, I., Tuuga, A., Higashi, S. 2010. Effects of water level on sleeping-site selection and inter-group association in proboscis monkeys: why do they sleep alone inland on flooded days? *Ecological Research*, 25(2), pp.475-482

Matsuda, I., Tuuga, A., Bernard, H. 2011. Riverine refuging by proboscis monkeys (*Nasalis larvatus*) and sympatric primates: Implications for adaptive benefits of the riverine habitat. *Mammalian Biology,* 76, pp.165-171

Matsuda, I., Tuuga, A., Bernard, H., Sugau, J., Hanya, G. 2013. Leaf Selection by Two Bornean Colobine Monkeys in Relation to Plant Chemistry and Abundance. *Scientific Reports*, 3(1873), pp.1-6

Matsuda, I., Ancrenaz, M., Akiyama, Y., Tuuga, A., Majalap, N., Bernard, H. 2015. Natural licks are required for large terrestrial mammals in a degraded riparian forest, Sabah, Borneo, Malaysia. *Ecological Research*, 30(1), pp.191-195

Maxwell, J.F. 2009. Vegetation and vascular flora of the Mekong River, Kratie and Stung Treng Provinces, Cambodia. *Maejo International Journal of Science and Technology,* 3(1), pp.143-211

McKey, D.B., Gartlan, J.S., Waterman, P.G., Choo, G.M. 1981. Food Selection by black colobus monkeys in relation to plant chemistry. *Biological Journal of the Linnean Society*, 16(2), pp.115-146

Md. Zain, B.M., Morales, J.C., Hasan, M.N., Abdul, J., Lakim, M., Supriatna, J., Melnick, D.J. 2008. Is *Presbytis* a monophyletic genus: inferences through mitochondrial DNA sequences. *Asian Primate Journal,* 1(1), pp.26-36

Md-Zain, B.M., Ch'ng, C.E. 2011. The Activity Patterns of a Group of Cantor's Dusky Leaf Monkeys (*Trachypithecus obscurus halonifer*). *International Journal of Zoological Research,* 7(1), pp.59-67

Medhi, R., Chetry, D., Bhattacharjee, P.C., Patiri, B.N. 2004. Status of *Trachypithecus geei* in a Rubber Plantation in Western Assam, India. *International Journal of Primatology,* 25(6), pp.1331-1337

Medway, L. 1970. Breeding of the Silvered Leaf Monkey, *Presbytis cristata*, in Malaya. *Journal of Mammalogy,* 51(3), pp.630-632

Medway, L.F.L.S. 1972. Phenology of a tropical rain forest in Malaya. *Biological Journal of the Linnean Society*, 4(2), pp.117-142

Meijaard, E., Groves, C.P. 2006. The Geography of Mammals and Rivers in Mainland Southeast Asia. In Lehman, S.M., Fleagle, J.G. (eds.): *Primate Biogeography: Progress and Prospects.* New York: Springer, pp.305-329

Mendes Pontes, A.R.M., Soares, M.L. 2005. Sleeping sites of common marmosets (*Callithrix jacchus*) in defaunated urban forest fragments: a strategy to maximize food intake. *Journal of Zoology,* 266(1), pp.55-63

Menon, S., Poirier, F.E. 1996. Lion-Tailed Macaques (*Macaca silenus*) in a Disturbed Forest Fragment: Activity Patterns and Time Budget. *International Journal of Primatology,* 17(6), pp.969-985

Milton, K. 1998. Physiological Ecology of Howlers (*Alouatta*): Energetic and Digestive Considerations and Comparison with the Colobinae. *International Journal of Primatology*, 19(3), pp.513-548

Milton, K., May, M.L. 1976. Body weight, diet and home range area in primates. *Nature,* 259(5543), pp.459-462

Milton, K., Windsor, D.M., Morrison, D.W., Estribi, M.A. 1982. Fruiting Phenologies of Two Neotropical *Ficus* Species. *Ecology*, 63(3), pp.752-762

Minhas, R.A., Ahmed, K.B., Awan, M.S., Dar, N.I. 2010a. Social Organization and Reproductive Biology of Himalayan grey langurs (*Semnopithecus entellus ajex*) in Machiara National Park, Azad Kashmir, Pakistan. *Pakistan Journal of Zoology,* 42(2), pp.143-156

Minhas, R.A., Ahmed, K.B., Awan, M.S., Dar, N.I. 2010b. Habitat Utilization and Feeding Biology of Himalayan Grey Langur (*Semnopithecus entellus ajex*) in Machiara National Park, Azad Jammu and Kashmir, Pakistan. *Zoological Research,* 31(2), pp.177-188

Minhas, R.A., Ali, U., Awan, M.S., Ahmed, K.B., Khan, M.N., Dar, N.I., Qamar, Q.Z., Ali, H., Grueter, C.C., Tsuji, Y. 2013. Ranging and foraging of Himalayan grey langurs (*Semnopithecus ajax*) in Machiara National Park, Pakistan. *Primates,* 54, pp.147-152

Mishra, M., Chaturvedi S.K., Upadhayay, M.K. 2012. Selection of Sleeping Sites by Hanuman Langurs in Chitrakoot Forest Range of Madhya Pradesh, India. *International Journal of Science and Research,* 3(11), pp.2669-2672

Mitani, J.C., Rodman, P.S. 1979. Territoriality: The Relation of Ranging Pattern and Home Range Size to Defendability, with an Analysis of Territoriality Among Primate Species. *Behavioral Ecology and Sociobiology*, 5(3), pp.241-251

Mittermeier, R.A., Turner, W.R., Larsen, F.W., Brooks, T.M., Gascon, C. 2011. Global Biodiversity Conservation: The Critical Role of Hotspots. In Zachos, F.E., Habel, J.C. (eds.): *Biodiversity Hotspots: Distribution and Protection of Conservation Priority Areas.* Berlin: Springer, pp.305-329

Moody, J.E., An, D., Coudrat, C.N.Z., Evans, T., Gray, T., Maltby, M., Men, S., Nut, M.H., O'Kelly, H., Pech, B., Phan, C., Pollard, E., Rainey, H.J., Rawson, B.M., Rours, V., Song, C., Tan, S., Thong, S. 2011. A summary of the conservation status, taxonomic assignment and distribution of the Indochinese silvered langur *Trachypithecus germaini* (*sensu lato*) in Cambodia. *Asian Primates Journal,* 2(1), pp.21-28

Moore, R.S., Nekaris, K.A.I., Eschmann, C. 2010. Habitat use by western purple-faced langurs *Trachypithecus vetulus nestor* (Colobinae) in a fragmented suburban landscape. *Endangered Species Journal,* 12, pp. 227-234

Murai, T. 2004. Social behaviors of all-male proboscis monkeys when joined by females. *Ecological Research,* 19(4), pp.451-454

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature,* 403, pp.853-858

Nadler, T. 2009. Observations of Lao langurs (*Trachypithecus [laotum] laotum*) and black langurs (*Trachypithecus [laotum] hatinhensis* morph *ebenus*) in Khammouane Province, Laos and remarks to their systematic position. *Vietnamese Journal of Primatology,* 3, pp.9-15

Nadler, T. 2010. Color variation in Hatinh langurs (*Trachypithecus [laotum] hatinhensis*). *Vietnamese Journal of Primatology,* 4, pp.13-18

Nadler, T., Brockman, D. 2014. Annamese silvered langur (*Trachypithecus margarita*). In Nadler, T., Brockman, D. (ed.): *Primates of Vietnam.* Cuc Phuong National Park: Endangered Primate Rescue Center, pp.129-131

Nadler, T., Thanh, V.N., Streicher, U. 2007. Conservation Status of Vietnamese Primates. *Vietnamese Journal of Primatology,* 1(1), pp.7-26

Nadler, T., Timmins, R.J., Richardson, M. 2008. *Trachypithecus germaini*. The IUCN Red List of Threatened Species. Version 2014.2. www.iucnredlist.org . Downloaded on 06 November 2014.

Nakagawa, M., Nakashizuka, T. 2004. Relationships between physical and chemical characteristics of dipterocarp seeds. *Seed Science Research*, 14(4), pp.363-369

Neang, T., Chhin, S., Kris, M., Hun, S. 2011. First records of two reptile species (Gekkonidae: *Hemidactylus garnotii* Dumeril & Bibron, 1836; Viperidae: *Ovophis convictus* Stoliczka, 1870) from Cambodia. *Cambodian Journal of Natural History,* 2011(2), pp.86-92

Neumann, M., Starlinger, F. 2001. The significance of different indices for stand structure and diversity in forests. *Forest Ecology and Management,* 29, pp.91-106

Newbery, D.M., Campbell, E.J.F., Lee, Y.F., Ridsdale, C.E., Still, M.J. 1992. Primary Lowland Dipterocarp Forest at Danum Valley, Sabah, Malaysia: Structure, Relative Abundance and Family Composition. *Phylosophical Transactions of the Royal Society B,* 335(1275), pp.341-356

Newton, P. 1992. Feeding and Ranging Patterns of Forest Hanuman Langurs (*Presbytis entellus*). *International Journal of Primatology,* 13(3), pp.245-285

Nguyen, M.H. 2006. Some Observations on the Hatinh langur, *Trachypithecus laotum hatinhensis* (Dao, 1970), in North Central Vietnam. *Primate Conservation,* 26, pp.149-154

Nguyen, N.T., Harder, D.K. 1996. Diversity of the Flora of Fan Si Pan, the Highest Mountain in Vietnam. *Annals of the Missouri Botanical Garden,* 83(3), pp.404-408

Nguyen, N.T. 1997. The vegetation of Cucphuong National Park, Vietnam. *Cambodian SIDA, Contributions to Botany,* 17(4), pp.719-759

Nguyen, T.T., Ha, T.L., Bui, V.T., Tran, H.V., Nguyen, A.T. 2012. The feeding behavior and phytochemical food content of grey-shanked douc langurs (*Pygathrix cinerea*) at Kon Ka Kinh National Park, Vietnam. *Vietnamese Journal of Primatology*, 2(1), pp.25-35

Nijboer, J., Clauss, M., Olsthoorn, M., Noordermeer, W., Huisman, T.R., Verheyen, C., van der Kuilen, H., Streich, W.J., Beynen, A.C. 2006. Effect of diet on the feces quality in Javan langur (*Trachypithecus auratus auratus*). *Journal of Zoo and Wildlife Medicine,* 37(3), pp.366-372

Nijboer, J., Clauss, M., van de Put, K., van der Kuilen, J., Woutersee, H., Beynen, A.C. 2007. Influence of two different diets on fluid and particle retention time Javan langur (*Trachypithecus auratus auratus*). *Der Zoologische Garten,* 77(1), pp.36-46

Nijman, V. 1998. A faunal survey of the Dieng Mountains, Central Java, Indonesia: distribution and conservation of primate taxa. *Oryx,* 32(2), pp.145-156

Nijman, V. 2000. Geographic distribution of ebony leaf monkey *Trachypithecus auratus* (E. Geoffroy Saint-Hilaire, 1812) (Mammalia: Primates: Cercopithecinae). *Contributions to Zoology,* 69(3), pp.157-177

Nijman, V. 2004. Effects of habitat disturbance and hunting on the density and biomass of the endemic Hose's leaf monkey *Presbytis hosei* (Thomas, 1889) (Mammalia: Primates: Cercopithecidae) in East Borneo. *Contributions to Zoology,* 73 (4), pp. 283-291

Nijman, V. 2005. Decline of the endemic Hose's langur *Presbytis hosei* in Kayan Mentarang National Park, East Borneo. *Oryx,* 39(2), pp. 1-4

Nijman, V. 2010. Ecology and Conservation of the Hose's Langur Group (Colobinae: *Presbytis hosei*, *P. canicrus*, *P. sabana*): A Review. In Gursky-Doyen, S., Supriatna, J. (eds.): *Indonesian Primates.* Springer, pp.269-284

Nijman, V. 2014. Distribution and Ecology of the Most Tropical of the High-Elevation Montane Colobines: the Ebony Langur on Java. In Grow, N.B., Gursky-Doyen, S., Krzton, A. (eds.): *High Altitude Primates.* New York: Springer, pp.115-132

Nijman, V., Meijaard, E. 2008. *Trachypithecus cristatus*. The IUCN Red List of Threatened Species 2008. Downloaded on 19 September, 2015.

Nijman, V., Supriatna, J. 2008. *Trachypithecus auratus*. The IUCN Red List of Threatened Species 2008. Downloaded on 19 September, 2015.

Nisbett, R.A., Ciochon, R.L. 1993. Primates in Northern Viet Nam: A Review of the Ecology and Conservation Status of Extant Species, with Notes on Pleistocene Localities. *International Journal of Primatology,* 14(5), pp.765-795

Nowak, R.M. 1999. *Walker's Primates of the World.* Baltimore: The Johns Hopkins University Press

Oates, J.F. 1977. The Guereza and Its Food. In Clutton-Brock, T.H. (ed.): *Primate Ecology: Studies of feeding and ranging behaviour in lemurs, monkeys and apes.* London: Academic Press, pp.275-321

Oates, J.F. 1978. Water Plant and Soil Consumption by Guereza Monkeys, (*Procolobus verus*): a Relationship with Minerals and Toxins in the Diet? *Biotropica*, 10(4), pp.241-253

Oates, J.F. 1988. The Diet of the Olive Colobus Monkey, *Procolobus verus*, in Sierra Leone. *International Journal of Primatology*, 9(5), pp.457-478

Oates, J.F., Waterman, P.G., Choo, G.M. 1980. Food Selection by the South Indian Leaf-Monkey, *Presbytis johnii*, in Relation to Leaf Chemistry. *Oecologia*, 45(1), pp.45-56

Okuda, T., Suzuki, M., Adachi, N., Quah, E.S., Hussein, N.A., Manokaran, N. 2003. Effects of selective logging on canopy and stand structure and tree species composition in a lowland dipterocarp forest in peninsular Malaysia. *Forest Ecology and Management,* 175*,* pp.297--320

Onderdonk, D.A., Chapman, C.A. 2000. Coping with Forest Fragmentation: The Primates of Kibale National Park. *International Journal of Primatology,* 21(4)*,* pp.587-611

Osterholz, M., Walter, L., Roos, C. 2008. Phylogenetic position of the langur genera *Semnopithecus* and *Trachypithecus* among Asian colobines, and genus affiliations of their species groups. *BMC Evolutionary Biology,* 8(58)

Pages, G., Lloyd, E., Suarez, S.A. 2004. The Impact of Geophagy on Ranging Behaviour in Phayre's Leaf Monkeys (*Trachypithecus phayrei*). *Folia Primatologica,* 76(6), pp.342-346

Peet, R.K. 1974. The measurement of Species Diversity. *Annual Review of Ecology and Systematics,* 5, pp.285-307

Peres, C.A. 1997. Effects of Habitat Quality and Hunting Pressure on Arboreal Folivore Densities in Neotropical Forests: A Case Study of Howler Monkeys (*Alouatta* spp.). *Folia Primatologica,* 68, pp.199-222

Peter, Z., Pheap, A. 2015, August 1. (Un)protected Areas. *The Cambodia Daily.* Retrieved 7 September, 2015 from http://www.cambodiadaily.com

Petersen, R., Sizer, N., Hansen, M., Potapov, P., Thau, D. 2015, September 2. Satellites Uncover 5 Surprising Hotspots for Tree Cover Loss. Retrieved 4 September, 2015 from http://www.wri.org/

Phiapalath, P., Suwanwaree, P. 2010. Time budget and activity of red-shanked douc langurs (*Pygathrix nemaeus*) in Hin Namno National Protected Area, Lao PDR. In Nadler, T., Rawson, B.M., Thinh, V.N. (eds.): *Conservation of Primates in Indochina.* Hanoi: Frankfurt Zoological Society and Conservation International, pp.171-178

Phiapalath, P., Borries, C., Suwanwaree, P. 2011. Seasonality of Group Size, Feeding, and Breeding in Wild Red-Shanked Douc Langurs (Lao PDR). *American Journal of Primatology*, 73(10), pp.1134-1144

Phoonjampa, R., Koenig, A., Borries, C., Gale, G.A., Savini, T. 2010. Selection of sleeping trees in pileated gibbons (*Hylobates pileatus*). *American Journal of Primatology,* 72(7), pp.617-625

Phuong, V.T. 2007. Forest Environment of Vietnam: Features of Forest Vegetation and Soils. In Sawada, H., Araki, M., Chappell, N.A., LaFrankie, J.V., Shimizu, A. (eds.): *Forest Environments in the Mekong River Basin.* New York: Springer, pp.189-200

Pin, C., Phan, C., Prum, S., Gray, T.N.E. 2013. Structure and composition of deciduous dipterocarp forest in the Eastern Plains Landscape, Cambodia. *Cambodian Journal of Natural History,* 2013(1), pp.27-34

Platt, S.G., Heng, S., Long, K., Stuart, B.L., Walston, J. 2006. *Crocodylus siamensis* along the Sre Ambel River, Southern Cambodia: Habitat, Nesting and Conservation. *Herpetological Natural History,* 9(2), pp.183-188

Plumptre, A.J. 1996. Changes following 60 years of selective timber harvesting in the Budongo Forest Reserve, Uganda. *Forest Ecology and Management,* 89 (1-3), pp.101-113

Plumptre, A.J., Reynolds, V. 1994. The Effect of Selective Logging on the Primate Populations in the Budongo Forest Reserve, Uganda. *Journal of Applied Ecology,* 31(4), pp.631-641

Poirier, F.E. 1968a. Analysis of a Nilgiri Langur (*Presbytis johnii*) Home Range Change. *Primates,* 9 (1), pp.29-43

Poirier, F.E. 1968b. Nilgiri Langur (*Presbytis johnii*) Territorial Behavior. *Primates,* 11 (4), pp.351-364

Pollard, E., Clements, T., Nut, M.H., Sok, K., Rawson, B.M. 2007. *Status and Conservation of Globally Threatened Primates in the Seima Biodiversity Conservation Area, Cambodia*. Wildlife Conservation Society, Phnom Penh, Cambodia

Potts, K.B. 2011. The Long-term Effect of Timber Harvesting on the Resource Base of Chimpanzees in Kibale National Park, Uganda. *Biotropica,* 43(2)*,* pp.256-264

Pye, D. 2013, December 26. Chainsaws stayed busy in last year. *Phnom Penh Post.* Retrieved 7 September, 2015 from http://www.phnompenhpost.com/

Pye, D. 2015a, April 7. Timber by the numbers. *Phnom Penh Post.* Retrieved 7 September, 2015 from http://www.phnompenhpost.com/

Pye, D. 2015b, June 23. Logging's roots deep. *Phnom Penh Post.* Retrieved 7 September, 2015 from http://www.phnompenhpost.com/

Pye, D., Titthara, M. 2014, October 10. The calculus of logging. *Phnom Penh Post.* Retrieved 7 September, 2015 from http://www.phnompenhpost.com/

Pye, D., Titthara, M. 2015, February 6. The 'timber gangsters'. *Phnom Penh Post.* Retrieved 7 September, 2015 from http://www.phnompenhpost.com/

Qi, X.G., Li, B.G., Garber, P.A., Ji, W.H., Watanabe, K. 2009. Social dynamics of the golden snub-nosed monkey (*Rhinopithecus roxellana*): female transfer and one-male unit succession. *American Journal of Primatology,* 71(8), pp.670-679

Qin, X.S., Zhang, R.J., Xing, F.W. 2012. A Study on the Flora and Vegetation of Cat Dua Island, Northeastern Vietnam. *Pakistan Journal of Botany,* 44(4), pp.1229-1232

Rabinowitz, A.R., Walker, S.R. 1993. The carnivore community in a dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Journal of Tropical Ecology* , 7 (01), pp.37-47

Raemaekers, J.J., Chivers, D.J. 1980. Socio-ecology of Malayan forest primates. In Chivers, D.J. (ed.): *Malayan Forest Primates: Ten Years' Study in Tropical Rain Forest.* New York: Springer, pp.279-316

Ramachandran, K.K., Joseph, G.K. 2001. Feeding Ecology of Nilgiri Langur (*Trachypithecus johnii*) in Silent Valley National Park, Kerala, India. *Indian Forester*, 127(10), pp.1155-1164

Ramakrishnan, U., Coss, R.G. 2001. Strategies Used by Bonnet Macaques (*Macaca radiata*) to Reduce Predation Risk While Sleeping. *Primates,* 42(3), pp.193-206

Rawson, B.M. 2009. *The socio-ecology of the black-shanked douc (Pygathrix nigripes) in Mondulkiri Province, Cambodia*. PhD Thesis. Australian National University, Canberra, Australia

Rawson, B.M. 2010. The status of Cambodian primates. In Nadler, T., Rawson, B.M., Thinh, V.N. (eds.): *Conservation of Primates in Indochina.* Hanoi: Frankfurt Zoological Society and Conservation International, pp.17-329

Rawson, B.M., Roos, C. 2008. A new primate species record for Cambodia: *Pygathrix nemaeus*. *Cambodian Journal of Natural History,* 2008(1), pp.7-11

Rawson, B.M., Luu, T.B. 2011. Preliminary observations of geophagy amongst Cambodia's Colobinae. *Vietnamese Journal of Primatology,* 29, pp.173-182

Rawson, B.M., Insua-Cao, P., Nguyen M.H., Van N.T., Hoang M.D., Mahood, S., Geissmann, T., Roos, C. 2011. *The Conservation Status of Gibbons in Vietnam.* Fauna & Flora International/Conservation International, Hanoi, Vietnam

Reichard, U. 1998. Sleeping Sites, Sleeping Places, and Presleep Behavior of Gibbons (*Hylobates lar*). *American Journal of Primatology*, 46(1), pp. 35-62

Ren, B.P., Zhang, S.Y., Wang, L.X., Liang, B., Li, B.G. 2001. Vertical Distribution of Different Age-Sex Classes in a Foraging Group of Sichuan Golden Monkeys (*Rhinopithecus roxellana*). *Folia Primatologica,* 72, pp.96-99

Ren, B.P., Li, M., Long, Y.C, Wu, R.D., Wei, F.W. 2009. Home range and seasonality of Yunnan snub-nosed monkeys. *Integrative Zoology,* 4, pp.162-171

Ren, B.P., Li, D.Y., Liu, Z.J., Li, B.G., Wei, F.W., Li, M. 2010. First evidence of prey capture and meat eating by wild Yunnan snub-nosed monkeys *Rhinopithecus bieti* in Yunnan, China. *Current Zoology*, 56 (2), pp.227-231

Rijksen, H.D. 1978. *A fieldstudy on Sumatran orang utans (Pongo pygmaeus abelii Lesson 1827): Ecology, behaviour and conservation*. PhD Thesis. Agricultural University, Wageningen, the Netherlands.

Riley, E.P. 2008. Ranging Patterns and Habitat Use of Sulawesi Tonkean Macaques (*Macaca tonkeana*) in a Human-Modified Habitat. *American Journal of Primatology,* 70, pp.670-679

Robinson Styring, A., Ickes, K. 2001. Woodpecker abundance in a logged (40 years ago) vs. unlogged lowland dipterocarp forest in Peninsular Malaysia. *Journal of Tropical Ecology,* 17(2)*,* pp.261-268

Robson, C. 2010. *New Holland Field Guide to the Birds of South-East Asia*. London: New Holland Publishers

Rodgers, L.D., Nekaris, K.A.I. 2011. Behaviour and habitat use of the Bengal slow loris *Nycticebus bengalensis* in the dry dipterocarp forests of Phnom Samkos Wildlife Sanctuary, Cambodia. *Cambodian Journal of Natural History,* 2011(2), pp.92-103

Roos, C., Thanh, V.N., Walter, L., Nadler, T. 2007. Molecular Systematics of Indochinese Primates. *Vietnamese Journal of Primatology,* 1(1), pp.41-53

Roos, C., Nadler, T., Walter, L. 2008. Mitochondrial phylogeny, taxonomy and biogeography of the silvered langur species group (*Trachypithecus cristatus*). *Molecular Phylogenetics and Evolution,* 47, pp.629-636

Roos, C., Zinner, D., Kubatko, L.S., Schwarz, C., Yang, M.Y., Meyer, D., Nash, S.D., Xing, J.C., Batzer, M.A., Brameier, M., Leendertz, F.H., Ziegler, T., Perwitasari-Farajallah, D., Nadler, T., Walter, L., Osterholz, M. 2011. Nuclear versus mitochondrial DNA: evidence of hybridization in colobine monkeys. *BMC Evolutionary Biology*, 11(1), pp.77-90

Roos, C., Boonratana, R., Supriatna, J., Fellowes, J.R., Rylands, A.B., Mittermeier, R.A. 2013. An updated taxonomy of primates in Vietnam, Laos, Cambodia and China. *Vietnamese Journal of Primatology,* 2(2), pp.13-26

Roos, C., Boonratana, R., Supriatna, J., Fellowes, J.R., Groves, C.P., Nash, S.D., Rylands, A.B., Mittermeier, R.A. 2014. An updated taxonomy and conservation status review of Asian primates. *Asian Primates Journal,* 4(1), pp.2-38

Rosenbaum, B., O'Brien, T.G., Kinnaird, M., Supriatna, J. 1998. Population Densities of Sulawesi Crested Black Macaques (*Macaca nigra*) on Bacan and Sulawesi, Indonesia: Effects of Habitat Disturbance and Hunting. *American Journal of Primatology, 77,* pp.76-85

Rowe, N. 1996. *The Pictorial Guide to the Living Primates.* Hong Kong: Pogonias Press

Rosenblum, L.L., Supriatna, J., Hasan, M.N., Melnick, D.J. 1997. High Mitochondrial DNA Diversity with Little Structure Within and Among Leaf Monkey Populations (*Trachypithecus cristatus* and *Trachypithecus auratus*). *International Journal of Primatology,* 18(6), pp.1005-1028

Roy, D., Ashokkumar, M., Desai, A.A. 2012 Foraging Ecology of Nilgiri Langur (*Trachypithecus johnii*) in Parimbikulam Tiger Reserve, Kerala, India. *Asian Journal of Conservation Biology*, 1 (2), pp.92-102

Royan, A. 2010. Short Communication: Significant mammal records from Botum-Sakor National Park, Southwest Cambodia. *Cambodian Journal of Natural History,* 2010(1), pp.22-26

Rudran, R., Dayananda, H.G.S.K., Jayamanne, D.D., Sirimanne, D.G.R. 1988. Food Habits and Habitat Use Patterns of Sri Lanka's Western Purple-faced Langur. *Primate Conservation*, 27, pp.99-108

Ruggeri, N., Timmins, R.J. 1996. An initial summary of diurnal primate status in Laos. *Asian Primates,* 5(3-4), pp.1-3

Ruhiyat, Y. 1983. Socio-ecological Study of *Presbytis aygula* in West Java. *Primates*, 24(3), pp.344-359

Rundel, P.W. 1999. *Forest Habitats and Flora in Laos PDR, Cambodia and Vietnam*. World Wide Fund for Nature, Hanoi, Vietnam

Sakai, S. 2002. General flowering in lowland mixed dipterocarp forests of South-east Asia. *Biological Journal of the Linnean Society*, 75(2), pp.233-247

Salter, R.E., MacKenzie, N.A., Nightingale, N., Aken, K.M., P. Chai, P.K. 1985. Habitat Use, Ranging Behaviour, and Food Habits of the Proboscis Monkey, *Nasalis larvatus* (van Wurmb), in Sarawak. *Primates*, 26 (4), pp.436-451

Sam, H., Hor, L., Nhek, R., Sorn, P., Heng, S., Simpson, B., Starr, A., Brook, S., Frechette, J.L., Daltry, J.C. 2015. Status, distribution and ecology of the Siamese crocodile *Crocodylus siamensis* in Cambodia. *Cambodian Journal of Natural History,* 2015(2), pp.153-164

Sayers, K. 2014. On folivory, competition and intelligence: generalism, overgeneralizations, and models of primate evolution. *Primates*, 54(2), pp.111-124

Sayers, K., Norconk, M.A. 2008. Himalayan *Semnopithecus entellus* at Langtang National Park, Nepal: Diet, Activity Patterns, and Resources. *International Journal of Primatology*, 29(2), pp.509-530

Schmidt, L.H. 2007. *Tropical Forest Seed.* Berlin, Heidelberg: Springer

Schneider, I., Tielen, I.H.M., Rode, J., Levelink, P., Schrudde, D. 2010. Behavioral Observations and Notes on the Vertical Ranging Pattern of the Critically Endangered Cat Ba Langur (*Trachypithecus poliocephalus poliocephalus*) in Vietnam. *Primate Conservation,* 25, pp.111-117

Schreier, A., Swedell, L. 2008. Use of palm trees as a sleeping site for hamadryas baboons (*Papio hamadryas hamadryas*) in Ethiopia. *American Journal of Primatology*, 70(2), pp.107-113

Shelmidine, N., Borries, C., Koenig, A. 2007. Genital Swellings in Silvered Langurs: What Do They Indicate? *American Journal of Primatology,* 69, pp.519-532

Shelmidine, N., Borries, C., McCann, C. 2009. Patterns of Reproduction in Malayan Silvered Leaf Monkeys at the Bronx Zoo. *American Journal of Primatology,* 71, pp.852-859

Shelmidine, N., McAloose, D., McCann, C. 2013. Survival Patterns and Mortality in the North American Population of Silvered Leaf Monkeys (*Trachypithecus cristatus*). *Zoo Biology,* 32, pp.177-188

Sicotte, P., Teichroeb, J.A., Vayro, J.V., Fox, S.A., Badescu, I., Wikberg, E.C. 2015. The Influence of Male Takeovers on Female Dispersal in *Colobus*. *American Journal of Primatology,* 71(8), pp.670-679

Singh, M., Singh, M., Kumara, H.N., Kumar, M.A., D'Souza, L. 1997. Inter- and intra-specific associations of Non-human Primates in Anaimalai Hills, South India. *Mammalia,* 61(1), pp.17-28

Singh, M., Kumara, H.N., Kumar, M.A., Sharma, A.K. 2001. Behavioural Responses of Lion-Tailed Macaques (*Macaca silenus*) to a Changing Habitat in a Tropical Rain Forest Fragment in the Western Ghats, India. *Folia Primatologica,* 72, pp.278-291

Singleton, I., van Schaik, C.P. 2001. Orangutan Home Range Size and Its Determinants in a Sumatran Swamp Forest. *International Journal of Primatology,* 22(6), pp.877-911

Sist, P., Fimbel, R., Sheil, D., Nasi, R., Chevallier, M.H. 2003. Towars sustainable management of mixed dipterocarp forests of South-east Asia: moving beyond minimum diameter cutting limits. *Environmental Conservation,* 30(4), pp.364-374

Skorupa, J.P. 1985. Responses of Rainforest Primates to Selective Logging in Kibale Forest, Uganda: A Summary Report. In Benirschke, K. (ed.): *Primates: The Road to Self-Sustaining Populations.* New York: Springer, pp.57-70

Snaith, T.V., Chapman, C.A. 2007. Primate Group Size and Interpreting Socioecological Models: Do Folivores Really Play by Different Rules? *Evolutionary Anthropology*, 16(3), pp. 94-106

Solanki, G.S., Kumar, A., Sharma, B.K. 2008. Feeding Ecology of *Trachypithecus pileatus* in India. *International Journal of Primatology,* 29, pp.173-182

Southwick, C.S., Cadigan, F.C. 1972. Population Studies of Malaysian Primates. *Primates,* 13(1), pp.1-18

Souza-Alves, J.P., Fontes, I.P., Ferrari, S.F. 2011. Use of sleeping sites by a titi group (*Callicebus coimbrai*) in the Brazilian Atlantic Forest. *Primates,* 52(2), pp.155-161

Srivastava, A. 1991. Insectivory and Its Significance to Langur Diets. *Primates*, 32(2), pp.237-241

Stanford, C.B. 1988. Ecology of the Capped Langur and Phayre's Leaf Monkey in Bangladesh. *Primate Conservation*, 9, pp.125-128

Stanford, C.B. 1991a. Social Dynamics of Intergroup Encounters in the Capped Langur (*Presbytis pileata*). *American Journal of Primatology,* 25, pp.35-47

Stanford, C.B. 1991b. The Diet of the Capped Langur (*Presbytis pileata*) in a Moist Deciduous Forest in Bangladesh. *International Journal of Primatology*, 12(3), pp.199-216

Starr, C. 2010. *The Conservation and Ecology of the Pygmy Slow Loris (Nycticebus pygmaeus) in Eastern Cambodia*. PhD Thesis. University of Queensland, Brisbane, Australia

Starr, A.T., Sam, H., Lun, D. 2010. Short Communication: New records of threatened mammals in Southwest Cambodia. *Cambodian Journal of Natural History,* 2010(2), pp.94-96

Steenbeek, R. 1999. Tenure related changes in wild Thomas' langurs I: Between-group interactions. *Behaviour,* 136(5), pp.595-625

Steenbeek, R., van Schaik, C.P. 2001. Competition and group size in Thomas's langurs (*Presbytis thomasi*): the folivore paradox revisited. *Behavioral Ecology and Sociobiology,* 49(2), pp.100-110

Steenbeek, R., Piek, R.C., van Buul, M., van Hoof, J.A.R.A.M. 1999. Vigilance in wild Thomas' langurs (*Presbytis thomasi*): the importance of infanticide risk. *Behavioral Ecology and Sociobiology,* 45, pp.137-150

Sterck, E.H.M., Watts, D.P., van Schaik, C.P. 1997. The evolution of female social relationships in nonhuman primates. *Behavioral Ecology and Sociobiology*, 41(5), pp.291-309

Sterck, E.H.M., Willems, E.P., van Hooff J.A.R.A.M., Wich, S.A. 2005. Female dispersal, inbreeding avoidance and mate choice in Thomas langurs (*Presbytis thomasi*). *Behaviour,* 142(7), pp.845-868

Sterck, E.H.M., 2012. The Behavioral Ecology of Colobine Monkeys. In Mitani, J.C., Call, J., Kappeler, P.M., Palombit, R.A., Silk, J.B. (eds.): *The Evolution of Primate Societies.* Chicago: The University of Chicago Press, pp.65-90

Sterling, E.J., Hurley, M.M., Le, D.M. 2006. *Vietnam: A Natural History*. New Haven, Yale University Press

Sterner, K.N, Raaum, R.L., Zhang, Y.P., Stewart, C.B., Disotell, C.R. 2006. Mitochondrial data support an odd-nosed colobine clade. *Molecular Phylogenetics and Evolution,* 40, pp.1-7

Streicher, U. 2004. *Aspects of Ecology and Conservation of the Pygmy Loris (Nycticebus pygmaeus) in Vietnam.* PhD Thesis. Ludwig-Maximillians University, Munich, Germany

Streicher, U. 2009. Diet and feeding behavior of pygmy lorises (*Nycticebus pygmaeus*) in Vietnam. *Vietnamese Journal of Primatology,* 3, pp.37-44

Struhsaker, T.T. 1976. A Further Decline in Numbers of Amboseli Vervet Monkeys. *Biotropica,* 8(3), pp.211-214

Suarez, S.A. 2013. Diet of Phayre's Leaf-Monkey in the Phu Khieo Wildlife Sanctuary, Thailand. *Asian Primates Journal*, 3(1), pp.2-12

Sugardjito, J. 1983. Selecting Nest-sites of Sumatran Orang-utans, *Pongo pygmaeus abelii* in the Gunung Leuser National Park, Indonesia. *Primates,* 24(4), pp.467-474

Sunderraj, S.F.W., Johnsingh, A.J.T. 2001. Impact of biotic disturbances on Nilgiri langur habitat, demography and group dynamics. *Current Science,* 80(3)*,* pp.428-436

Supriatna, J., Barita, O.M., Endang, S. 1986. Group Composition, Home Range, and Diet of The Maroon Leaf Monkey (*Presbytis rubicunda*) at Tanjung Putting Reserve, Central Kalimantang, Indonesia. *Primates,* 27(2), pp.185-190

Sushma, H.S., Singh, M. 2006. Resource partitioning and interspecific interactions among sympatric rainforest arboreal mammals of the Western Ghats, India. *Behavioral Ecology*, 17 (3), pp.479-490

Suzuki, K., Nagai, H., Hayama, S., Tamate, H. 1985. Anatomical and Histological Observations of the Stomach of François' Leaf Monkeys (*Presbytis francoisi*). *Primates*, 26(1), pp.99-103

Takasaki, H. 2007. Troop Size, Habitat Quality, and Home Range Area in Japanese Macaques. *Behavioral Ecology and Sociobiology*, 9(4), pp.277-281

Talbott, K., Brown, M. 1998. Forest Plunder in Southeast Asia: An Environmental Security Nexus in Burma and Cambodia. *Environmental Change and Security Project Report,* 4(1)*,* pp.53-60

Tan, C.L., Guo, S.T., Li, B.G. 2007. Population Structure and Ranging Patterns of *Rhinopithecus roxellana* in Zhouzhi National Nature Reserve, Shaanxi, China. *International Journal of Primatology*, 28, pp.577-591

Tani, A., Ito, E., Kanzaki, M., Ohta, S., Khorn, S., Pith, P., Tith, B., Pol, S., Lim, S. 2007. Principal Forest Types of Three Regions of Cambodia: Kampong Thom, Kratie, and Mondolkiri. In Sawada, H., Araki, M., Chappell, N.A., LaFrankie, J.V., Shimizu, A. (eds.): *Forest Environments in the Mekong River Basin.* New York: Springer, pp. 201-213

Teichroeb, J.A., Wikberg, E.C., Sicotte, P. 2009. Female dispersal patterns in six groups of ursine colobus (*Colobus vellerosus*): infanticide avoidance is important. *Behaviour*, 146, pp.551-582

Teichroeb, J.A., Holmes, T.D., Sicotte, P. 2012. Use of sleeping trees by ursine colobus monkeys (*Colobus vellerosus*) demonstrates the importance of nearby food. *Primates,* 53(3), pp. 287-296

Tenaza, R., Tilson, R.L. 1983. Human Predation and Kloss's Gibbon (*Hylobates klossii*) Sleeping Trees in Siberut Island, Indonesia. *American Journal of Primatology*, 8(4), pp.299-308

Theilade, I., Schmidt, L., Chhang, P., McDonald, A. 2011. Evergreen swamp forest in Cambodia: floristic composition, ecological characteristics, and conservation status. *Nordic Journal of Botany,* 29(1), pp. 71-80

Thoeun, H.C. 2015. Observed and projected changes in temperature and rainfall in Cambodia. *Weather and Climate Extremes,* 7, pp. 61-71

Timmins, R.J., Steinmetz, R., Poulsen, M.K., Evans, T.D., Duckworth, J.W., Boonratana, R. 2013. The Indochinese Silvered Leaf Monkey *Trachypithecus germaini* (*sensu lato*) in Lao PDR. *International Primate Conservaton,* 26, pp.75-87

Titthara, M. 2013, December 20. Memories of a land unspoiled. *Phnom Penh Post.* Retrieved 7 September, 2015 from http://www.phnompenhpost.com/

Titthara, M. 2014, April 10. A logging free-for-all. *Phnom Penh Post.* Retrieved 7 September, 2015 from http://www.phnompenhpost.com/

Tran, V.B. 2013. *Feeding ecology of the Annamese silvered langur (Trachypithecus margarita Elliot, 1909) at Takou mountain, Takou Nature Reserve, Binh Thuan Province*. Master Thesis. National University, Ho Chi Minh, Vietnam.

Tran, V.C., Nguyen, T.T., Do, T.T.H., Cao, C.K., Tran, H.Q., Vu, T.L., Tran, V.D., Sato, T. 2013. Relationship between aboveground biomass and measures of structure and species diversity in tropical forests of Vietnam. *Forest Ecology and Management,* 310, pp. 213-218

Trang, T.T.T. 2009. *Spacial distribution and historical dynamics of threatened conifers on the Dalat Plateau, Vietnam*. Masters Thesis. University of Missouri, Columbia, USA.

Tsuji, Y. 2011. Sleeping-site preferences of wild Japanese macaques (*Macaca fuscata*): the importance of nonpredatory factors. *Journal of Mammalogy*, 92(6), pp.1261-1269

Tsuji, Y., Nguyen, V.M., Kitamura, S., Nguyen, H.V., Hamada, Y. 2013. Seed dispersal by rhesus macaques (*Macaca mulatta*) in Son Tra Nature Reserve, central Vietnam: A preliminary report. *Vietnamese Journal of Primatology,* 2(2), pp.65-73

Tsuji, Y., Widayati, K.A., Hadi, I., Suryobroto, B., Watanabe, K. 2013. Identification of individual adult female Javan lutungs (*Trachypithecus auratus sondaicus*) by using patterns of dark pigmentation in the pubic area. *Primates,* 54, pp.27-31

Tutin, C.E.G., Parnell, R.J., White, L.J.T., Fernandez, M. 1995. Nest Building by Lowland Gorillas in the Lopé Reserve, Gabon: Environmental Influences and Implications for Censusing. *International Journal of Primatology*, 16(1), pp.53-76

Tutin, C.E.G., Parnell, R.J., White, F. 1996. Protecting seeds from primates: examples from *Diospyros* spp. in the Lopé Reserve, Gabon. *Journal of Tropical Ecology*, 12(3), pp.371-384

Umapathy, G., Kumar, A. 2003. Impacts of forest fragmentation on lion-tailed macaque and Nilgiri langur in Western Ghats, South India. In Marsh, L.K. (ed.): *Primates in Fragments: Ecology and Conservation.* New York: Springer, pp.163-189

Umapathy, G., Hussain, S., Shivaji, S. 2011. Impact of Habitat Fragmentation on the Demography of Lion-tailed Macaque (*Macaca silenus*) Populations in the Rainforests of Anamalai Hills, Western Ghats, India. *International Journal of Primatology,* 32, pp.889-900

Unanthanna, W.M.J.R.K.W., Wickramasinghe, S. 2010. *Population distribution, threats and conservation status of Semnopithecus priam thersites at Mihintale Sanctuary, Sri Lanka*. Proceedings of the 15th International Forestry and Environment Symposium, 26-27 November, 2010. University of Sri Jayewardenepura, Sri Jayewardenepura Kotte, Sri Lanka

Van N.T., Mootnick, A.R., Vu N.T.., Nadler, T., Roos, C. 2010. A new species of crested gibbon, from the central Annamite mountain range. *Vietnamese Journal of Primatology,* 4, pp. 1-12

van Schaik, C.P., Assink, P.R., Salafsky, N. 1992. Territorial Behavior in Southeast Asian Langurs: Resource Defense or Mate Defense? *American Journal of Primatology,* 26, pp.233-242

Vandercone, R.P., Dinadh, C., Wijethunga, G., Ranawana, K., Rasmussen, D.T. 2012. Dietary Diversity and Food Selection in Hanuman Langurs (*Semnopithecus entellus*) and Purple-Faced Langurs (*Trachypithecus vetulus*) in the Kaludiyapokuna Forest Reserve in the Dry Zone of Sri Lanka. *International Journal of Primatology*, 33(6), pp.1382-1405

Verburg, R., van Eijk-Bos, C. 2010. Effects of selective logging on tree diversity, composition and plant functional type patterns in a Bornean rain forest. *Journal of Vegetation Science,* 14(1), pp. 99-110

von Hippel, F.A. 1998. Use of Sleeping Trees by Black and White Colobus Monkeys (*Colobus guereza*) in the Kakamega Forest, Kenya. *American Journal of Primatology*, 45(3), pp.225-311

Wada, K., Ichiki, Y. 1980. Seasonal Home Range Use by Japanese Monkeys in the Snowy Shiga Heights. *Primates,* 21(4), pp.468-483

Wahungu, G.M. 2001. Common use of sleeping sites by two primate species in Tana River, Kenya. *African Journal of Ecology,* 39(1), pp.18-23

Wang, S.L., Luo, Y., Cui, G.F. 2011. Sleeping site selection of François's langur (*Trachypithecus francoisi*) in two habitats in Mayanghe National Natural Reserve, Guizhou, China. *Primates,* 52(1), pp.51-60

Wangchuk, T., Inouye, D.W., Hare, M.P. 2008. The Emergence of an Endangered Species: Evolution and Phylogeny of the *Trachypithecus geei* of Bhutan. *Journal of Genetics,* 89(4), pp.393-399

Wasserman, M.D., Chapman, C.A. 2003. Determinants of colobine monkey abundance: the importance of food energy, protein and fibre content. *Journal of Animal Ecology*, 72(4), pp.650-659

Waterman, P.G., Ross, J.A.M., Bennett, E.L., Davies, A.G. 1988. A comparison of the floristics and leaf chemistry of the tree flora in two Malaysian rain forests and the influence of leaf chemistry on populations of colobine monkeys in the Old World. *Biological Journal of the Linnaean Society*, 34(1), pp.1-32

Webb, C.O. 2005. *Vegetation mapping in Phnom Samkos and Phnom Aural wildlife sanctuaries, Cardamom mountains, Cambodia*. Fauna & Flora International, Phnom Penh, Cambodia

Weitzel, V., Groves, C.P. 1985. The Nomenclature and Taxonomy of the Colobine Monkeys of Java. *International Journal of Primatology,* 6(4), pp.399-409

White, E.C., Dikangadissi, J.T., Dimoto, E., Karesh, W.B., Kock, M.D., Abiaga, N.O., Starkey, R., Ukizintambara, T., White, L.J.T., Abernethy, K. 2010. Home-range Use by a Large Horde of Wild *Mandrillus sphinx*. *International Journal of Primatology,* 31(4), pp.627-645

Whitten, A.J. 1982. Home range use by Kloss gibbons (*Hylobates klossi*) on Siberut Island, Indonesia. *Animal Behaviour,* 30, pp.182-198

Wich, S.A., Sterck, E.H.M. 2010. Thomas Langurs: Ecology, Sexual Conflict and Social Dynamics. In Gursky-Doyen, S., Supriatna, J. (eds.): *Indonesian Primates.* Springer, pp.285-308

Williams, L. 1965. *Vegetation of Southeast Asia Studies of Forest Types 1963-1965*. Agricultural Research Service, U.S. Department of Agriculture, Washington, USA

Witte, A. 2011. *Grooming Dynamics Among Captive African (Colobus angolensis) and Asian (Trachypithecus cristatus) Colobines*. Senior Honors Thesis. Ohio State University, Columbus, USA

Wojciechowski, F., Nguyen, H.C. 2013. The status of Delacours' langur (*Trachypithecus hatinhensis*) in the planned extension area of Van Long Nature Reserve. *Vietnamese Journal of Primatology,* 2(2), pp.37-47

Wolf, K.E., Fleagle, J.G. 1977. Adult Male Replacement in a Group of Silvered Leaf-monkeys (*Presbytis cristata*) at Kuala Selangor, Malaysia. *Primates,* 18 (4), pp.949-955

Wolf, H.A. 1996. Deforestation in Cambodia and Malaysia: the case for an international legal solution. *Pacific Rim Law and Policy Journal,* 5(2), pp. 429-455

Workman, C. 1977. Primate Conservation in Vietnam: Toward a Holistic Environmental Narrative. *American Anthropologist,* 106 (2), pp.346-352

Workman, C. 2010. Diet of the Delacour's Langur (*Trachypithecus delacouri*) in Van Long Nature Reserve, Vietnam. *American Journal of Primatology*, 72(4), pp.317-324

Workman, C., Le, V.D. 2010. Seasonal effects on feeding selection by Delacour's langur (*Trachypithecus delacouri*) in Van Long Nature Reserve, Vietnam. In Nadler, T., Rawson, B.M., Thinh, V.N. (eds.): *Conservation of Primates in Indochina.* Hanoi: Frankfurt Zoological Society and Conservation International, pp.143-156

Workman, C., Schmitt, D. 2012. Positional Behavior of Delacour's langurs (*Trachypithecus delacouri*) in Northern Vietnam. *International Journal of Primatology,* 33 (1), pp.19-37

Wright, B.W., Willis, M.S. 2012. Relationships Between Diet and Dentition of Asian Leaf Monkeys. *American Journal of Physical Anthropology*, 148(2), pp. 262-275

Wright, B.W., Ulibarri, L., O'Brien, J., Sadler, B., Prodhan, R., Covert, H.H., Nadler, T. 2008. It's Tough Out There: Variation in the Toughness of Ingested Leaves and Feeding Behavior Among Four Colobiae in Vietnam. *International Journal of Primatology*, 29(6), pp.1455-1466

Wright, H.L., Collar, N.J., Lake, I.R., Net, N., Rours, V., Sok, K., Sum, P., Dolman, P.M. 2012. First census of the white-shouldered ibis *Pseudibis davisoni* reveals roost-site mismatch with Cambodia's protected areas. *Oryx*, 46(2), pp. 236-239

Xiang, Z.F., Huo, S., Xiao, W., Quan, R.C., Grueter, C.C. 2007. Diet and Feeding Behavior of *Rhinopithecus bieti* at Xiaochangdu, Tibet: Adaptations to a Marginal Enivornment. *American Journal of Primatology*, 69(10), pp.1141-1158

Xiang, Z.F., Huo, S., Xiao, W., Quan, R.C., Grueter, C.C. 2009. Terrestrial behavior and use of forest strata in a group of black-and-white snub-nosed monkeys *Rhinopithecus bieti* at Xiaochangdu, Tibet. *Current Zoology,* 55(3), pp.180-187

Xiang, Z.F., Nie, S.G, Lei, X.P., Chang, Z.F., Wei, F.W., Li, M. 2009. Current status and conservation of the gray snub-nosed monkey *Rhinopithecus brelichi* (Colobinae) in Guizhou, China. *Biological Conservation,* 142, pp.469-476

Xiang, Z.F., Huo, S., Xiao, W., Cui, L.W. 2010. Positive influence of traditional culture and socioeconomic activity on conservation: A case study from the black-and-white snub-nosed monkey (*Rhinopithecus bieti*) in Tibet. *Current Zoology,* 55(3), pp.180-187

Xiang, Z.F., Nie, S.G., Chang, Z.F., Wei, F.W., Li, M. 2010. Sleeping Sites of *Rhinopithecus brelichi* at Yangaoping, Guizhou. *International Journal of Primatology,* 72(12), pp.59-71

Xiang, Z.F., Huo, S., Xiao, W. 2011. Habitat Selection of Black-and-White Snub-Nosed Monkey (*Rhinopithecus bieti*) in Tibet: Implications for Species Conservation. *American Journal of Primatology,* 73, pp.347-355

Xiang, Z.F., Liang, W.B., Nie, S.B., Li, M. 2012. Diet and Feeding Behavior of *Rhinopithecus brelichi* at Yangaoping, Guizhou. *American Journal of Primatology*, 74(6), pp.551-560

Xie, D.M., Lu, J.Q., Sichilima, A., Wang, Li, B.S. 2012. Patterns of habitat selection and use by *Macaca mulatta tcheliensis* in winter and early spring in temperate forest, Jiyuan, China. *Biologia,* 67(1), pp.234-239

Yang, S.J. 2003. Altitudinal Ranging of *Rhinopithecus bieti* at Jinsichang, Lijiang, China. *Folia Primatologica*, 74, pp.88-91

Yang, S.J., Zhao, Q.K. 2001. Bamboo Leaf-Based Diet of *Rhinopithecus bieti* at Lijiang, China. *Folia Primatologica*, 72(2), pp.92-95

Yanuar, A., Chivers, D.J. 2010. Impact of Forest Fragmentation on Ranging and Home Range of Siamang (*Symphalangus syndactylus*) and Agile Gibbons (*Hylobates agilis*). In Gursky-Doyen, S., Supriatna, J. (eds.): *Indonesian Primates.* Springer, pp.97-119

Yeager, C.P. 1989. Feeding Ecology of the Proboscis Monkey (*Nasalis larvatus*). *International Journal of Primatology*, 10(6), pp.497-530

Yeager, C.P., Silver, S.C., Dierenfeld, D.S. 1997. Mineral and Phytochemical Influences on Foliage Selection by the Proboscis Monkey (*Nasalis larvatus*). *American Journal of Primatology*, 41, pp.117-128

Yeager, C.P., Kool, K. 2000. Behavioral ecology of Asian colobines. In Whitehead, P.F., Jolly, C.J. (eds.): *Old World Monkeys.* Cambridge: Cambridge University Press, pp.496-521

Yin, L.J., Liu, W., Zhao, Q., Qin, D.G., Li, X.D., Wang, D.Z., Jin, T., Chen, M., Pan, W.S. 2011. A Video-Aided Study of the Diet of Wild White-Headed Langurs (*Trachypithecus leucocephalus*). *Folia Primatologica,* 82(1), pp. 33-44

Yin, L.J., Jin, T., Watanabe, K., Qin, D.G., Wang, D.Z., Pan, W.S. 2013. Male attacks on infants and infant death during male takeovers in wild white-headed langurs (*Trachypithecus leucocephalus*). *Integrative Zoology,* 8, pp. 365-377

Zhao, D.P., Wang, X.W., Watanabe, K., Li, B.G. 2008. Eurasian blackbird predated by wild *Rhinopithecus bieti* in the Qinling Mountains, China. *Integrative Zoology*, 3 (3), pp.176-179

Zhao, D.P., Ji, W.H., Li, B.G., Watanabe, K. 2008. Mate competition and reproductive correlates of female dispersal in a polygynous primate species (*Rhinopithecus roxellana*). *Behavioural Processes,* 79(3), pp.165-170

Zhao, Q., Borries, C., Pan, W.S. 2011. Male takeover, infanticide, and female countertactics in white-headed leaf monkeys (*Trachypithecus leucocephalus*). *Behavioral Ecology and Sociobiology,* 65(8), pp.1535-1547

Zhang, D., Fei, H.L., Yuan, S.D., Sun, W.M., Ni, Q.Y., Cui, L.W., Fan, P.F. 2014. Ranging behavior of eastern hoolock gibbon (*Hoolock leuconedys*) in a northern montane forest in Gaoligongshan, Yunnan, China. *Primates,* 55, pp.239-247

Zhang, P., Li, B.G., Watanabe, K. 2006. Use of forest strata by Sichuan snub-nosed monkeys *Rhinopithecus roxellana* in spring and winter in Qinling Mountains, China. *Acta Zoologica Sinica,* 52(3), pp.429-436

Zhang, P., Li, B.G., Watanabe, K., Qi, X.G. 2011. Sleeping cluster patterns and retiring behaviors during winter in a free-ranging band of the Sichuan snub-nosed monkey. *Primates,* 52(3), pp.221-228

Zhang, S.Y. 1995. Sleeping Habits of Brown Capuchin Monkeys (*Cebus apella*) in French Guiana. *American Journal of Primatology,* 36(4), pp.327-335

Zhang, Y.P., Ryder, O.A. 1998. Mitochondrial Cytochrome b Gene Sequences of Old World Monkeys: With Special Reference on Evolution of Asian Colobines. *Primates,* 39(1), pp.39-49

Zhou, Q.H., Huang, C.M., Li, Y.B., Cai, X.W. 2007. Ranging behavior of the François langur (*Trachypithecus francoisi*) in the Fusui Nature Reserve, China. *Primates,* 48, pp.320-323

Zhou, Q.H., Huang, Z.H, Wei, X.S., Wei, F.W., Huang, C.M. 2009a. Factors Influencing Interannual and Intersite Variability in the Diet of *Trachypithecus francoisi*. *International Journal of Primatology,* 30(4), pp.583-599

Zhou, Q.H., Huang, C.M, Li, M., Wei, F.W. 2009b. Sleeping Site Use by *Trachypithecus francoisi* at Nonggang Nature Reserve, China. *International Journal of Primatology,* 30(2), pp.353-365

Zhou, Q.H., Tang, X.P., Huang, H.L., Huang, C.M. 2011a. Factors Affecting the Ranging Behavior of White-headed Langurs (*Trachypithecus leucocephalus*). *International Journal of Primatology,* 32, pp.511-523

Zhou, Q.H., Huang, C.M, Li, M., Wei, F.W. 2011b. Ranging behavior of the François langur (*Trachypithecus francoisi*) in limestone habitats in Nonggang, China. *Integrative Zoology,* 6, pp.157-164

Zhou, Q.H., Huang, C.M., Tang, Z., Li, Y.B., 2013. Food diversity and choice of white-headed langur in fragmented limestone hill habitat in Guangxi, China. *Acta Ecologica Sinica,* 33(2), pp.109-113

Zhu, W.W., Garber, P.A., Bezanson, M., Qi, X.G., Li, B.G. 2015. Age- and Sex- Based Patterns of Positional Behavior and Substrate Utilization in the Golden Snub-Nosed Monkey (*Rhinopithecus roxellana*). *American Journal of Primatology,* 77, pp.98-108

Zinner, D., Fickenscher, G.H., Roos, C., Groves, C.P., Richardson, M.C. 2013. Silvered Langur group. In Mittermeier, R.A., Rylands, A.B., Wilson, D.E. (eds.): *Handbook of the Mammals of the World.* Volume 3: Primates. Barcelona: Lynx Edicions, pp.305-329

ANNEXES

Annex 1. List of plant families identified in the botanical transects, with their respective number of species and their Importance Value Index (IVI)

Family	N of species	IVI
Lythraceae	2	44.61
Dipterocarpaceae	2	40.44
Ebenaceae	2	24.7
Irvingiaceae	1	15.64
Fabaceae	6	14.11
Malvaceae	2	13.16
Combretaceae	2	9.94
Sterculiaceae	2	9.53
Lauraceae	1	9.5
Myrtaceae	3	8.73
Annonaceae	2	8.25
Sapindaceae	3	7.25
Euphorbiaceae	1	6.83
Clusiaceae	1	6.66
Phyllanthaceae	2	6.31
Fagaceae	1	6.15
Anacardiaceae	2	5.34
Ochnaceae	2	4.39
Meliaceae	1	3.59
Theaceae	1	2.2
Rubiaceae	1	1.88
Lecythidaceae	1	1.84
Gentianaceae	1	1.72
Bignoniaceae	1	1.66
Hypericaceae	1	1.66
Apocynaceae	1	1.65
Ancistrocladaceae	1	1.63
Solanaceae	1	1.5
Moraceae	1	1.46

Annex 2. List of plant species identified in the botanical transects, with their respective number of individuals and their Importance Value Index (IVI)

Species	Total individuals	IVI
Lagerstroemia calyculata	25	46.28
Dipterocarpus alatus	13	26.84
Diospyros pilosanthera	30	22.56
Irvingia malayana	10	16.09
Anisoptera costata	6	13.51
Cinnamomum cambodianum	13	10.68
Schoutenia ovata	11	10.68
Sterculia lychnophora	13	9.28
Terminalia triptera	8	7.96
Nephelium melliferum	7	7.27
Polyalthia sp.	5	6.48
Croton tiglium	6	6.13
Antidesma cochinchinense	5	5.89
Garcinia schomburgkiana	4	5.72
Syzygium sp.	6	5.57
Lithocarpus elegans	5	5.45
Heritiera javanica	4	5.32
Sphaerocoryne affinis	5	5.19
Sandoricum koetjape	4	4.9
Pterospermum semisagittatum	5	4.74
Tristaniopsis burmanica	1	4.4
Dialium cochinchinense	3	4.18
Sindora cochinchinensis	2	4.11
Mangifera duperreana	2	3.98
Schima wallichii	3	3.36
Haldina cordifolia	2	2.83
Euphoria cambodiana	2	2.8
Ochna harmandii	2	2.77
Terminalia bellirica	2	2.17
Uvaria cordata	2	2.12
Barringtonia macrostachya	2	1.93
Bouea oppositifolia	1	1.79
Xylia xyliocarpa	1	1.69
Cratoxylon formosum	1	1.58
Fagraea fragrans	1	1.48
Melaleuca leucadendra	1	1.43

Oroxylum indicum	1	1.43
Solanum sp.	1	1.43
Willughbeia sp.	1	1.41
Euthemis leucocarpa	1	1.4
Pterocarpus macrocarpus	1	1.4
Ancistrocladus harmandii	1	1.39
Aporosa octandra	1	1.39
Diospyros decandra	1	1.39
Ficus sp.	1	1.39
Lagerstroemia floribunda	1	1.39
Nephelium hypoleucum	1	1.39
Dalbergia cochinchinensis	1	1.34

Annex 3. List of terrestrial vertebrates found in the silvered langur home range

CLASS MAMMALIA	Latin name	English Common Name	Direct observation	Call	Activity Signs	Mixed Evergreen forest	Mixed Deciduous Forest	Veal/Veal border	Riverine	Conservation Interest
Order Chiroptera										
fam. Rhinolophidae										
	Rhinolophus acuminatus	Acuminate Horseshoe Bat	X				X	X	X	
fam. Megadermatidae										
	Megaderma spasma	Lesser False Vampire	X			X				
Order Primates										
fam. Lorisidae										
	Nycticebus pygmaeus	Pygmy Slow Loris	X			X				VU
fam. Cercopithecidae										
	Trachypithecus margarita	Annamese Silvered Leaf Monkey	X	X	X	X	X		X	EN
	Pygathrix nemaeus	Red-shanked Douc	X			X				EN
	Macaca fascicularis	Long-tailed Macaque	X			X	X	X		

	Macaca leonina	Northern Pig-tailed Macaque	X			X				VU
fam. Hylobatidae										
	Nomascus annamensis	Northern Buffed-cheeked Gibbon	X	X		X	X			
Order Carnivora										
fam. Felidae										
	Prionailurus bengalensis	Leopard Cat			X			X	X	
	Prionailurus viverrinus	Fishing Cat			X	X	X		X	EN
fam. Viverridae										
	Viverricula indica	Small Indian Civet	X		X	X	X	X		
	Paradoxurus hermaphroditus	Asian Palm Civet	X			X				
fam. Herpestidae										
	Herpestes javanicus	Small Asian Mongoose	X			X				
	Herpestes urva	Crab-eating Mongoose	X					X		
fam. Canidae										
	Cuon alpinus	Dhole	X		X	X		X		EN
fam. Ursidae										
	Helarctos malayanus	Malayan Sun-bear			X	X	X			VU
fam. Mustelidae										
	Martes flavigula	Yellow-throated Marten	X			X				
	Arctonyx collaris	Hog Badger		X	X	X				NT

Aonyx cinerea	Oriental Small-clawed Otter			X				X	VU
Order Artiodactyla									
fam. Suidae									
Sus scrofa	Wild Boar	X		X	X	X	X		
fam. Tragulidae									
Tragulus kanchil	Lesser Mouse-deer	X		X	X				
fam. Cervidae									
Muntjacus vaginalis	Indian Muntjak	X	X	X	X	X			
Cervus unicolor	Sambar			X	X	X	X		VU
fam. Bovidae									
Bos gaurus	Gaur			X	X				VU
Order Rodentia									
fam. Sciuridae									
Ratufa bicolor	Black Giant Squirrel	X	X		X	X	X		
Callosciurus finlaysonii	Variable Squirrel	X	X		X	X	X		
Menetes berdmorei	Indochinese Ground Squirrel		X				X		
Tamiops rodolphii	Cambodian Striped Squirrel	X		X	X				
Petaurista philippensis	Indian Giant Flying Squirrel	X	X		X	X	X		
fam. Muridae									
Berylmys berdmorei	Small White-toothed Rat	X			X				

Maxomys surifer	Red Spiny Rat	X				X		
Mus caroli	Ryukyu Mouse	X					X	

Total Mammal Species: 32

CLASS AVES

Order Anseriformes

fam. Anatidae

Asacornis scutulata	White-winged Duck	X						EN

Order Galliformes

fam. Phasianidae

Gallus gallus	Red Junglefowl	X	X	X	X	X	X	
Lophura diardi	Siamese Fireback	X	X	X	X			
Francolinus pintadeanus	Chinese Francolin		X				X	
Arborophila chloropus	Scaly-breasted Partridge	X	X		X			
Pavo muticus	Green Peafowl		X		X			

Order Columbiformes

fam. Columbidae

Streptopelia tranquebarica	Red-collared Dove	X			X		X	
Spilopelia chinensis	Spotted Dove	X			X			

Chalcophaps indica	Common Emerald Dove	X		X			
Treron curvirostra	Thick-billed Green Pigeon	X			X		
Order Caprimulgiformes							
fam. Podargidae							
Batrachostomus affinis	Blythe's Frogmouth		X	X			
fam. Eurostopodidae							
Lyncornis macrotis	Great Eared Nightjar	X				X	
Order Apodiformes							
fam. Apodidae							
Hirundapus giganteus	Brown-backed Needletail	X					
Cypsiurus balasiensis	Asian Palm Swift	X					
Apus pacificus	Fork-tailed Swift	X					
Order Cuculiformes							
fam. Cuculidae							
Surniculus lugubris	Drongo Cuckoo		X	X			
Phaenicophaeus tristis	Green-billed Malkoha	X	X	X	X	X	X
Centropus bengalensis	Greater Coucal	X	X	X	X	X	X

Centropus sinensis	Lesser Coucal	X	X	X	X	X	X	
Order Ciconiiformes								
fam. Ciconiidae								
Ciconia episcopus	Woolly-necked Stork	X			X	X	X	
Order Charadriiformes								
fam. Charadriidae								
Vanellus indicus	Red-wattled Lapwing	X				X		
Order Pelecaniformes								
fam. Ardeidae								
Bubulcus ibis	Cattle Egret	X				X		
Mesophoyx intermedia	Intermediate Egret	X			X			
fam. Threskiornithidae								
Thaumatibis gigantea	Giant Ibis	X	X		X	X	X	CR
Order Accipitriformes								
fam. Accipitridae								
Elanius caeruleus	Black-winged Kite	X				X		
Aviceda leuphotes	Black Baza	X	X	X	X			
Accipiter trivirgatus	Crested Goshawk	X			X			

Accipiter virgatus	Besra	X		X		
Spilornis cheela	Crested Serpent Eagle	X		X	X	
Order Strigiformes						
fam. Strigidae						
Bubo ketupu	Buffy Fish Owl	X		X		
Glaucidium cuculoides	Asian Barred Owlet	X		X	X	
Order Trogoniformes						
fam. Trogonidae						
Harpactes oreskios	Orange-breasted Trogon	X	X	X		
Order Coraciiformes						
fam. Meropidae						
Merops leschenaulti	Chestnut-headed Bee-eater	X			X	X
fam. Coraciidae						
Coracias benghalensis	Indian Roller	X			X	
Eurystomus orientalis	Dollarbird	X			X	
fam. Alcedinidae						
Alcedo meninting	Blue-eared Kingfisher	X				X
fam. Halcyonidae						
Pelargopsis capensis	Stork-billed Kingfisher	X		X		X

Order Bucerotiformes								
fam. Bucerotidae								
Anthracoceros albirostris	Oriental Pied Hornbill	X	X	X	X	X	X	
Buceros bicornis	Great Hornbill	X	X	X	X	X		NT
fam. Upupidae								
Upupa epops	Hoopoe	X				X		
Order Piciformes								
fam. Megalaimadae								
Megalaima faiostricta	Green-eared Barbet	X						
Megalaima haemacephala	Coppersmith Barbet	X						
fam. Picidae								
Meiglyptes jugularis	Black-and-Buff Woodpecker	X		X				
Picus chlorolophus	Lesser Yellownape	X		X				
Picus vittatus	Laced Woodpecker	X		X	X			
Picus erythropygius	Black-headed Woodpecker	X			X	X		
Mulleripicus pulverulentus	Great Slaty Woodpecker	X		X	X	X		VU
Chrysocolaptes guttacristatus	Greater Flameback	X	X	X	X	X		

Order Psittaciformes								
fam. Psittaculidae								
Loriculus vernalis	Vernal Hanging Parrot	X		X				
Psittacula alexandri	Red-breasted Parakeet	X	X	X	X	X	X	NT
Order Passeriformes								
fam. Eurylaimidae								
Corydon sumatranus	Dusky Broadbill	X		X	X			
Eurylaimus javanicus	Banded Broadbill	X		X				
fam. Alaudidae								
Mirafra erythrocephala	Indochinese Bush Lark	X				X		
fam. Phylloscopidae								
Phylloscopus fuscatus	Dusky Warbler	X			X			
fam. Pnoepygidae								
Pnoepyga pusilla	Pygmy Wren-babbler	X		X				
fam. Campephagidae								
Coracina macei	Large Cuckooshrike	X						
Hemipus picatus	Bar-winged Flycatcher-shrike	X						
Pericrocotus speciosus	Scarlet Minivet	X						

fam. Pycnonotidae							
Pycnonotus flaviventris	Black-crested Bulbul	X	X		X	X	
Pycnonotus finlaysoni	Stripe-throated Bulbul	X				X	X
Alophoixus pallidus	Puff-throated Bulbul	X	X	X	X		
fam. Chloropseidae							
Chloropsis cochinchinensis	Blue-winged Leafbird	X			X		
Chloropsis aurifrons	Golden-fronted Leafbird	X			X		
fam. Cisticolidae							
Orthotomus sutorius	Common Tailorbird	X		X			
Prinia rufescens	Rufescent prinia	X		X			
fam. Stenostiridae							
Culicicapa ceylonensis	Grey-headed Canary Flycatcher	X			X		
fam. Muscicapidae							
Eumyias thalassinus	Verditer Flycatcher	X			X		
Muscicapa latirostris	Asian Brown Flycatcher	X		X		X	X
Copsychus malabaricus	White-rumped Shama	X		X	X	X	
Saxicola caprata	Pied Bushchat	X		X			
fam. Pellorneidae				X			
Alcippe poioicephala	Brown-cheeked Fulvetta	X					

Malacopteron cinereum	Scaly-crowned Babbler	X		X			
Pellorneum ruficeps	Puff-throated Babbler	X		X			
fam. Leiotrichidae							
Garrulax leucolophus	White-crested Laughingthrush	X	X	X	X	X	
fam. Sittidae							
Sitta frontalis	Velvet-fronted Nuthach	X		X			
fam. Nectariniidae							
Chalcoparia singalensis	Ruby-cheeked Sunbird	X					X
Cinnyris asiaticus	Purple Sunbird	X			X	X	
Cinnyris jugularis	Olive-backed Sunbird	X				X	
fam. Oriolidae							
Oriolus chinensis	Black-naped Oriole	X				X	X
Oriolus xanthornus	Black-hooded Oriole	X			X	X	
fam. Irenidae							
Irena puella	Asian Fairy Bluebird	X			X		
fam. Dicruridae							
Dicrurus aeneus	Bronzed Drongo	X		X	X	X	
Dicrurus macrocercus	Black Drongo	X		X		X	
Dicrurus hottentottus	Hair-crested Drongo	X		X			

Dicrurus paradiseus	Greater Racket-tailed Drongo	X	X	X	X	X
fam. Monarchidae						
Hypothymis azurea	Black-naped Monarch	X	X			
fam. Artamidae						
Artamus fuscus	Ashy Woodswallow	X		X		
fam. Corvidae						
Corvus machrorhynchos	Jungle Crow	X				X
fam. Sturnidae						
Gracula religiosa	Common Hill Myna	X	X	X	X	
Sturnus burmannicus	Vinous-breasted Starling	X			X	
fam. Vangidae						
Tephrodornis pondicerianus	Common Woodshrike	X			X	
fam. Vireonidae						
Erpornis zantholeuca	White-bellied Erpornis	X	X			

Total Bird Species: 102

CLASS REPTILIA

Order Squamata

fam. Agamidae								
Calotes bachae	Neon Blue Dragon	X				X	X	
Calotes emma	Forest Crested Lizard	X			X			
Draco maculatus	Spotted Flying Dragon	X			X	X		
Physignathus cocincinus	Chinese Water Dragon	X		X				X
fam. Gekkonidae								
Gekko gecko	Tokay	X	X			X	X	
Hemidactylus frenatus	Asian House Gecko	X					X	
Hemidactylus garnottii	Indo-pacific Gecko	X					X	
Hemidactylus platyurus	Flat-tailed House Gecko	X					X	
fam. Scincidae								
Eutropis longicaudata	Giant Copper Skink	X			X	X	X	
Eutropis macularia	Bronze Grass Skink	X			X			
Eutropis multifasciata	Common Sun Skink	X			X			
Lipinia vittigera	Common Striped Skink	X				X	X	

Lygosoma quadrupes	Short-limbed Supple Skink	X				X		
fam. Varanidae								
Varanus nebulosus	Clouded Monitor	X	X	X	X			
Varanus salvator	Water Monitor		X			X		
fam. Colubridae								
Boiga siamensis	Gray Cat Snake	X				X		
Chrysopelea ornata	Golden Flying Snake	X				X		
Lycodon laoensis	Laotian Wolf Snake	X				X		
Oligodon fasciolatus	Small-banded Kukri Snake	X			X	X		
Psammodynastes pulverulentus	Mock Viper	X		X				
Rhabdophis subminiatus	Red-necked Keelback	X		X		X	X	
fam. Elapidae								
Ophiophagus hannah	King Cobra		X		X			VU
fam. Typhlopidae								
Ramphotyphlops brahminus	Brahminy Blind Snake	X				X		
fam. Viperidae								
Calloselasma rhodostoma	Malayan Pit Viper	X		X	X			
Cryptelytrops macrops	Large-eyed Pit Viper	X			X			

Total Reptile Species: 25

CLASS AMPHIBIA

Order Anura						
fam. Bufonidae						
Duttaphrynus melanostictus	Black-spectacled Toad	X			X	
fam. Microhylidae						
Kalophrynus interlineatus	Spotted Narrow-mouthed Frog	X	X	X		
Microhyla berdmorei	Large Pygmy Frog	X				X
Microhyla butleri	Painted Chorus Frog	X		X		
Microhyla heymonsi	Dark-sided Pygmy Frog	X		X		
fam. Dicroglossidae						
Fejervarya limnocharis	Asian Grass Frog	X	X			
Hoplobatrachus rugulosus	East Asian Bullfrog	X				X
fam. Rhacophoridae						
Polypedates leucomystax	Golden Tree Frog	X	X	X	X	X
fam. Ranidae						
Hylarana nigrovittata	Black-striped Frog	X		X		

	Occidozyga martensii	Round-tongued Floating Frog	X		X
Order Apoda					
fam. Ichtyophiidae					
	Ichtyophis sp.	Yellow-banded Caecilian	X		X

Total amphibian species: 11

Total vertebrate species: 170