ACTIVITY PATTERNS AND FOOD HABITS OF THE PHAYRE'S LEAF MONKEY (*Trachypithecus phayrei*) IN FREE-RANGING AND CAPTIVE CONDITIONS IN SEPAHIJALA WILDLIFE SANCTUARY, TRIPURA

DISSERTATION SUBMITTED TO
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By

Pragya Aishwarya Lama

UNDER THE SUPERVISION OF

Shri P.C. Tyagi

&

CO-SUPERVISION OF

Dr. K. Sankar and Dr. Parag Nigam

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that the thesis titled **"Activity patterns and food habits of the Phayre's leaf monkey (*Trachypithecus phayrei*) in free-ranging and captive conditions in Sepahijala Wildlife Sanctuary, Tripura"** submitted for the award of the Masters Degree in Wildlife Science from Saurashtra University, Rajkot, India is an original and independent piece of research work carried out by Ms. Pragya Aishwarya Lama, student of Wildlife Institute of India, Dehradun. These investigations were carried out under our supervision from December 2014 to June 2015. We certify that no part of this thesis has been submitted for any degree to any other university and it fulfils all the requirements laid down by Saurashtra University.

Shri P. C. Tyagi (Supervisor)

Department of Landscape Level Planning and Management

Dr. K. Sankar (Co-Supervisor)

Scientist –G

Department of Habitat Ecology

Capt. Dr. Parag Nigam (Co-Supervisor)

Scientist – D

Department of Wildlife Health Management

Dated: June 17th, 2015

Place: Dehradun

पत्रपेटी सं0 18, चन्द्रबनी, देहरादून – 248001, उत्तराखण्ड, भारत
Post Box No. 18, Chandrabani, Dehradun – 248001, Uttarakhand, INDIA
ई.पी.ए.बी.एक्स : +91-135-2640111 से 2640115 फैक्स : 0135-2640117
EPABX : +91-135-2640111 to 2640115; Fax : 0135-2640117;
ई–मेल / E-mail: wii@wii.gov.in, वेब / website: www.wii.gov.in

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EXECUTIVE SUMMARY

Maintenance of *ex-situ* populations of species threatened with extinction is a potential tool for ensuring recovery. Ex-situ conservation efforts though ongoing in India have been minimally documented. The present study aimed to fill gaps in information on the activity patterns and food habits of the endangered Phayre's leaf monkey (*Trachypithecus phayrei*), a specialist feeder primarily a foliovore. This aspect was studied both in free-ranging and captive conditions.

The study site posed a unique feature wherein the captive study species was located only in one zoo all over India which also happened to be within its geographical area. Thus, the Sepahijala Zoological Park (SZP) situated within the Sepahijala Wildlife Sanctuary (SWLS), Tripura was chosen as a study site.

It was hypothesized that the activity patterns obtained from both the settings would be similar and that the nutrient composition of the food items consumed in wild and offered in captivity would not be much different from each other.

A reconnaissance survey was carried out in which the available population, troop size and composition of Phayre's leaf monkey was assessed in both, the SWLS and SZP. A 15-minute 'scan sampling' was conducted from dawn to dusk for studying the activity patterns of the troop selected for observation in the wild (after habituation) and in captivity. The activity data was analysed keeping in mind different age and sex categories within the wild and captive troops and across the two different settings. Chi square test was used to test for significant differences in activity patterns within and across the captive and wild troop.

The food habits (plants, plant parts and frequency eaten) of the Phayre's leaf monkey were studied on the basis of scans obtained as well as casual observations of the other free-ranging counterparts. Eaten food plants were identified and nutrient analysis was done for positive and negative nutrients after collecting and drying the samples from the field. Subsequently, it was processed at the laboratory in Wildlife Institute of India, Dehradun. The nutrients analysed were compared using the independent samples t-test.

The subsequent results generated, indicate that there was significant difference in the activity budgets ($\chi^2 = 23.80$, $p = <0.05$) and activity patterns for major activities like feeding ($\chi^2 = 987.12$, $p = <0.05$), sleeping ($\chi^2 = 612.56$, $p = <0.05$), moving ($\chi^2 = 116.73$, $p = <0.05$) and resting ($\chi^2 = 286.09$, $p = <0.05$) between the individuals in the wild and in captivity.

On comparing the nutrient composition of six parameters such as Crude protein (CP), Calcium (Ca), Iron (Fe), Phosphorous (P), Zinc (Zn) and Neutral Detergent Fibre (NDF) across the food items offered in captivity and those consumed in the wild, significant differences were observed in four parameters. The t-test gave significantly different results for Calcium (t= -3.219, sig. two tailed=0.002), Iron (t= -5.458, sig. two tailed=0.000), Zinc (t= -4.942, sig. two tailed=0.000) and NDF (t= -8.237, sig. two tailed=0.000). Crude protein (t= -0.731, sig. two tailed=0.480) and Phosphorous (t= -2.316, sig. two tailed=0.030) did not seem to be significantly different between both the settings.

Therefore the study rejects the hypotheses proposed and states that the activity patterns and food habits of the Phayre's leaf monkey in wild and in captivity are significantly different. This implies that efforts need to be made to maintain a healthy population in captivity as it is well studied that both, activity patterns and food habits can affect reintroduction, reproduction among other physiological processes which is important for both in-situ and ex-situ conservation efforts.

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"One man may hit the mark, another blunder; but heed not these distinctions.

Only from the alliance of the one, working with and through the other,

are great things born."

– Antoine de *Saint-Exupéry*

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Pragya Aishwarya Lama

(Totola)

1. INTRODUCTION

The global Living Planet Index (LPI) which measures the trends of thousands of vertebrate species populations shows a decline of 52% in 40 years (1970-2010). Habitat loss and degradation, and exploitation through hunting and fishing are the primary causes for decline in vertebrate populations followed by climate change, invasive species, pollution and diseases (LPR, 2014).

In order to control the rapid loss of biodiversity, many initiatives have been taken to strengthen conservation efforts in the field itself across the globe. These may include amendments in governance laws and formulating policies, carving out Protected Areas (PAs), carrying out field research which cover aspects such as ecology of the species and interaction with the surroundings, threats and brainstorming mitigation measures.

One such measure is the Species Survival Plan of the Association of Zoos and Aquariums (AZA) (Conway, 2011) also known as Breeding and Conservation Programme. It is designed to maintain a healthy, self-sustaining, genetically diverse and viable, as well as demographically stable population of a species in human care. They also aim to organise zoo and aquarium-based efforts to preserve the species *in situ*. Zoos have the potential to play an active role in conservation in terms of education and campaigning about conservation issues, research that would benefit the science and practice of conservation, maintenance of captive stocks of endangered species as a part of species survival plans (with reintroductions as their ultimate goals), and support for and practical involvement with *in situ* conservation projects (Hosey et al. 2009).

There are 195 Zoos in India (CZA, 2013) with many of them involved in ex-situ conservation breeding programmes. The CZA has recognised more than 60 species for conservation breeding in India (CZA 2013), among which 26 endangered species have been prioritized based on scientific criteria for the conservation breeding program.

Boorer (1972) mentions that of all the taxa usually kept in captivity, the behaviour repertoires of carnivores and primates have been most affected. Lack of environmental, psychological or physiological requirements (Millam et al. 1988; Merola 1994), inadequate diet (Balistreri et al. 1987) are only some of the causes for breeding to be a failure in captivity. Significant

behavioural deficiencies in captive animals with respect to foraging, predator avoidance and social behaviour have been some of the major factors for causing failures in reintroductions of captive-bred animals (Snyder et al. 1996).

At present, the International Union for Conservation of Nature (IUCN) recognises 415 primate species of which 37 are critically endangered, 86 are endangered and 78 are vulnerable to decline (IUCN 2012). This representation shows that the future of nearly half of the primate species' populations is in doubt. India is home to 15 of these species both in wilderness and captivity (Gupta 2001).

The Phayre's leaf monkey (*Trachypithecus phayrei*) is a unique species in a way that it falls under the priority list formulated by the CZA and is also the only primate in captivity in a single zoo all across India found within its geographical range i.e. Sepahijala Wildlife Sanctuary (SWLS), Tripura.

1.1 LITERATURE REVIEW

Taxonomical classification of the study species, Phayre's leaf monkey:

Phylum: Chordata
Sub-phylum: Vertebrata
Class: Mammalia
Order: Primates
Family: Cercopithecidae
Sub-family: Colobinae
Genus: *Trachypithecus*
Species: *phayrei*

Commonly also called the spectacled langur, it is an old world monkey found in the tropical forests of Southeast Asia. This species has three sub-species occupying different ranges viz. *Trachypithecus phayrei phayrei,* which is found in Bangladesh, north-eastern India (Assam, Mizoram, and Tripura), and western Myanmar (Groves 2001); *Trachypithecus phayrei crepuscula* is found in Bangladesh, southern China, south-western Laos, central and north-western Thailand, and northern Vietnam (Groves 2001). In Bangladesh this sub-species occurs to the south of the range of the sub-species *Trachypithecus phayrei phayrei* (Groves, 2001); and

Trachypithecus phayrei shanicus is found in south-western China in the Yingjiang-Namting river and Tunchong-Homushu Pass districts and northern and eastern Myanmar (Groves 2001).

The sub-species studied here is the *Trachypithecus phayrei phayrei*, which is one of the rarest Colobids found in India. It is endangered (Bleisch et al. 2008) and listed under schedule I of Indian Wildlife Protection Act, (The Wildlife (Protection) Amendment Act, 2002) and appendix II on Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES 2014).

The study species is a specialised feeder depending on largely a leaf diet most part of the year (Suarez, 2013). It inhabits a wide range of habitats like evergreen forests, semi-evergreen, and deciduous secondary forest of biotic origin (shifting cultivation, logging, clear felling and fire). It is also found in mixed forestry plantations (Gupta, 2013).

Time and again it has been reiterated that in order to maintain sustainable populations in captivity, serious considerations should be given in all captive breeding programs with respect to effects of captive conditions and reintroductions (Kleiman 1980; Van Hooff, 1986; Redshaw and Mallinson, 1991a,b; Carlstead and Shepherdson 1994). Not only in terms of conservation value, is maintaining natural behaviour in captivity important but also it is an ethical obligation from the perspective of animal welfare (McPhee and Carlstead, 2010). Since the ultimate goal of these programmes is restoration of the species to the wild, it is essential to preserve wild-like behaviours in captivity to avoid behavioural adaptation to captive environments and loss of behaviours which may be necessary for survival in the wild (Frankham et al 1986).

Since the activity budgets obtained from the wild are a good source of valuable information, they could be incorporated into the management of captive animals (Bercovitch and Ziegler 1989; Maple and Finlay 1989; Lees 1993). This in turn can be used to detect divergence if any, in the frequency of behaviours observed in captivity (Melfi and Feistner 2002). Considering that behaviour of a species may be affected by its geographical range (Chamove 1988; Boinski and Mitchell 1992), the present study subsumes the Phayre's leaf monkey (*Trachypithecus phayrei*

phayrei) as a case study since the only conservation breeding centre for this species which is located within the geographical range of its wild counterparts.

Knowing that there is a tendency to match the nutrition of wild species to related domestic species which have known requirements and nutritional values for feeds, this may not be a safe extrapolation. Since the nutrient content of the food that comprises the diet of wild species in their native habitats is understudied, the diet given in captive settings may significantly deviate in nutrient contents obtained from the wild (Van Soest 1996). Also, studying the nutritional needs of primates greatly contributes to understanding primate ecology as adequate nutrition is a prerequisite for successful reproduction (Cameron 1996; Rothman et al 2011). This knowledge is beneficial in construction of informed conservation or restoration plans for endangered species (Chapman et al. 2004; Felton et al. 2010).

As a measure to assess how this species behaves in free ranging and captivity conditions, this study aimed to compare the activity budget data from the captive monkeys with those recorded from the wild, and also analysed the nutrient contents of the food materials consumed in the wild and captivity by the study species.

1.2 OBJECTIVES

The study was designed with the following objectives:

1. To study the activity patterns of the endangered Phayre's leaf monkey in the wild and in captivity.
2. To study food habits of the Phayre's leaf monkey in the wild and captivity.
3. To provide management recommendations for effective conservation of this species in both captive and wild conditions.

2. STUDY AREA

Tripura is one of the seven states which fall under the north eastern part of India with a geographical area of 10,491km^2. It is located in the south-west extreme corner of the north-eastern region, between latitudes 22°57' and 24°33' N and longitudes 91°10' and 92°20' E. The state is situated between the river valley of Myanmar and Bangladesh, and is bound by

Bangladesh on the north, west, south and southeast. In the east it has a common boundary with Assam and Mizoram.

In terms of Protected Areas, Tripura consists of four Wildlife Sanctuaries and two National Parks. The largest of them all is the Gumti Wildlife Sanctuary with an area of 389.54km^2, followed by Trishna Wildlife Sanctuary (194.71km^2), Sepahijala Wildlife Sanctuary (SWLS) (18.53km^2) and Roa is Wildlife Sanctuary (0.86km^2).

2.1 Sepahijala Wildlife Sanctuary

For this study, the Sepahijala Wildlife Sanctuary was chosen as the study site. It is located approximately 20km from the state capital, Agartala (Figure 1). The Sanctuary with an area of 18.53km^2 (N- 23°39.943′ and E- 91°19.332′) was established in 1987. The Clouded leopard National Park with an area of 5.08km^2 forms the core zone and an area of 0.68km^2 forms the buffer zone of the Sepahaijala Zoological Park.

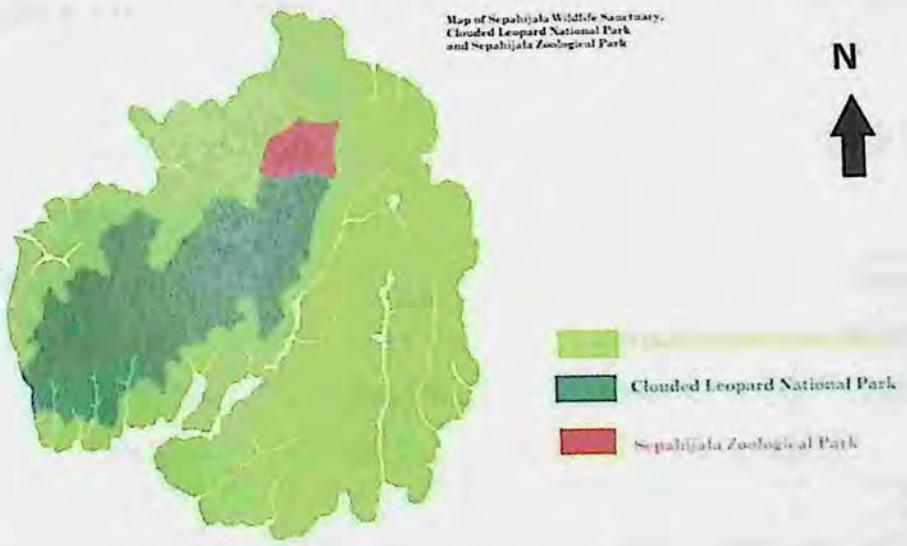


Figure 1. The study area, Sepahijala Wildlife Sanctuary, Tripura.

According to the Sepahijala Wildlife Sanctuary (SWLS) Management Plan (2013), the forest types consist of:

i. Moist mixed deciduous forest
ii. Secondary moist bamboo brakes, and

iii. Moist-mixed deciduous forest-dry bamboo brakes

Due to the presence of such vegetation, the SWLS is home to a diverse group of primates along with many other mammals like the barking deer (*Muntiacus muntjak*), wild pig (*Sus scrofa*), and Indian porcupine (*Hystrix indica*). It is particularly recognized for housing five of the six primate species found in Tripura namely, the endangered Phayre's leaf monkey (*Trachypithecus phayrei phayrei)* (Bleisch et al. 2008) and endangered Capped langur (*Trachypithecus pileatus*) (Das et al. 2008), the vulnerable northern pig-tailed macaque (*Macaca leonina*) (Boonaratana et al. 2008), the most common, also listed as of least concern, the Rhesus macaque (*Macaca mulatta*) and the vulnerable, Bengal slow loris (*Nycticebus bengalensis* (Streicher et al. 2008).

2.2 Climate

During the study period, the study site recorded an average of 10.84°C and 32.08°C as minimum and maximum temperature, respectively. The average relative humidity was calculated to be 62.15% whereas the area received a total rainfall of 46.3 mm in the course of four months (Table 1).

Table 1: Recorded temperature, rainfall and relative humidity in Sepahijala Wildlife Sanctuary from January 2015 to March 2015

	Average minimum temperature (°C)	**Average maximum temperature (°C)**	**Average relative humidity (%)**	**Average Rainfall (mm)**
Week 1	15.16	30	58	0
Week 2	11.84	30.02	76.6	0
Week 3	10.4	30.54	75.2	1.2
Week 4	10.4	30.9	69.5	0
Week 5	10.4	30.9	61.14	0
Week 6	10.4	30.9	62	0
Week 7	10.4	30.9	58.8	1.8
Week 8	10.4	30.9	69.5	5.6

Week 9	10.4	32.11	67.66	0
Week 10	10.4	32.85	56.66	6.1
Week 11	10.4	34.4	47.85	0
Week 12	10.4	34.4	46.5	0
Week 13	10.4	35.2	58.8	3.8
Week 14	10.4	35.2	62	27.8
Overall Average	10.84	32.08	62.15	46.3
Standard deviation	1.30	1.94	8.93	7.38

In India, the SWLS is best known for the sightings of the Phayre's leaf monkey. On the basis of a primate survey carried out in the month of December 2014, the density of the Phayre's leaf monkey was estimated to be 34.31 per km^2 (Primate Survey Report, 2014).

2.3 Sepahijala Zoological Park

The Sepahijala Zoological Park (SZP) spans over an area of 68 hectares (23° 40'22.39" N and 91° 19'13.20"E). It is a medium Zoo housing many indigenous mammals, birds and reptiles in captivity. It is the coordinating and the only Zoo for the Conservation Breeding Programme (CBP) of the Phayre's leaf monkey in the world. At present (April 2015), the living population of Phayre's leaf monkey in captivity is 27 individuals with eight individuals at the conservation breeding centre (2 adult males, 4 adults females and 2 juveniles) and the remaining displayed in two exhibits (3 males, 5 females and 3 juveniles and 1 male, 4 females and 3 juveniles). The exhibit housing 11 individuals with an open dry moat was selected as the study troop in a captive setting.

Owing to the presence of the Phayre's leaf monkey in captivity within its geographical range (Bleisch et al. 2008), a unique feature seldom found, it was proposed to conduct a study to observe and compare the activity patterns and food habits of the endangered Phayre's leaf monkey in the wild and in captivity in Sepahijala Wildlife Sanctuary, Tripura. The Sanctuary premises and the Zoological Park having natural forest growth and free-ranging wild animals

(inside the Zoological Park as well) made this area an ideal site for study. This study in turn will help in understanding the importance of certain behavioural activities and nutrients in the diet for the conservation of the Phayre's leaf monkey.

3. STUDY PERIOD

This study was conducted between December 2014 and March 2015.

4. METHODOLOGY

4.1 Activity patterns

During December 2014, a reconnaissance survey was conducted during which the available population, troop size and composition of Phayre's leaf monkey was assessed in both, the SWLS and the forests of the SZP (Primate Survey Report, 2014). Of the four wild troops present in the study area, one troop of the Phayre's leaf monkey comprising different age and sex class individuals was selected and monitored intensively during the entire study period. The habituation of selected troop did not take much time as it was ranging within the Zoo premises and partially habituated to humans. Considering the short study period, no attempt was made to collect data on other wild troops in the study area.

The study species was classified into different age and sex classes as described by Prater (1971) on the basis of apparent physical characteristics which are as follows:

1. Adult
2. Sub-adult
3. Juvenile

The free-ranging study troop composed of a single adult male, three adult females (two of them suspected to be carrying mothers), one sub-adult female and two juveniles (Table 2). The observations were made on foot. One day prior to the commencement of data collection, the roosting tree of the study troop (free-ranging) was located in order to sight the troop early next morning for observations.

Table 2: Wild troop composition of Phayre's leaf monkey in Sepahijala Wildlife Sanctuary

AGE CLASS	TOTAL NUMBER (SEX CLASS)
Adult	4 (3 Females and 1 Male)
Sub-Adult	1 (Female)
Juvenile	2 (Sex not known)
Infant	2 (Sex not known)
Troop size	9

Of the three troops kept in captivity, one troop of the Phayre's leaf monkey comprising different age and sex classes was selected for the present study. This troop was kept in a moated enclosure meant for exhibit in the primate section and was identified as the study troop. It was composed of eleven individuals, a single adult male, three adult females, two sub-adult females, two sub-adult males and three juveniles (Table 3).

Table 3: Captive troop composition of Phayre's leaf monkey in Sepahijala Zoological Park

AGE CLASS	TOTAL NUMBER (SEX CLASS)
Adult	4 (3 Females and 1 Male)
Sub-Adult	4 (2 Females and 2 Males)
Juvenile	3 (Sex not known)
Infant	0
Troop size	11

In a month, the activity data on the Phayre's leaf monkey was collected from dawn to dusk for both the wild and captive troops. For the collection of data on activity patterns, 'Scan Sampling' technique was adopted (Altman 1974), both for wild and the ones in captivity. Scan sampling was done every 15 minutes beginning from the individual on the extreme left to extreme right. Whenever it was not possible to collect the entire day's data in a single day, the remaining day's data was collected in the consecutive day. In each scan, age and sex class of the animal, activity, and plant species and plant part eaten if they were feeding, was recorded. The scan sampling techniques are also termed as "time sampling" (Hutt and Hutt 1974), "point sampling" (Dunbar 1976) and "on the dot sampling" (Slater 1978). If the scan was completed with time to spare, focal sampling was carried out in which a particular individual was observed continuously till it went out of sight or until the next scan began.

In order to collect the behavioural data, the behavioural states were identified based on ad-libitum sampling before actual data collection as follows:

1. Feeding (FE) – manipulation of food and potential food items, ingestion and chewing
2. Moving (MO) – the animals move from one place to another hanging and clinging on branches
3. Resting (RE) – lying down with eyes open, sitting inactive or simply watching
4. Sleeping (SL)- animal is stationary with eyes closed
5. Playing (PL) – animal is engaging in playful activity
6. Auto-grooming (AUG) – the animals groom themselves
7. Allo-grooming (ALG) – the animals groom other individuals which are near to them.
8. Drinking (DR) – the animals drink water.
9. Aggressive behaviour (AB) – the animal engages in a fight with another individual or chases another individual.
10. Sexual behaviour (SB) - the animal engages in sexual acts (mounting or being mounted on)
11. Defecating/Urinating (UR.DE) – the animal defecate/urinates.
12. Vocalization (VO) – the animals vocalize (including alarm calls).
13. Alert behaviour (ALB) – the animals raise their head up and look in a particular direction.
14. Out of Sight (OS) – The animal is not visible

4.2 Food habits

The data on the food plants and parts eaten by the Phayre's leaf monkeys was collected during scan sampling. Inspection of the sites where the animals were seen feeding was also done in order to identify the food plants. Samples of the eaten food plants (in the wild and captivity) were collected which were then dried and subjected to laboratory analysis at the Wildlife Institute of India, Dehradun for the following positive and negative nutrients: Positive nutrients - crude protein and minerals (Ca, Na, Mg, K, Fe, Zn); Negative nutrients – tannins, alkaloids and fiber in terms of neutral detergent fiber (NDF), acid detergent fiber (ADF) and crude lignin.

4.2.1. Crude Protein (CP)

The crude protein was estimated using Kjeldahl method (Maynard and Loosli 1969). This parameter was analysed using the Auto Kjeldhal Nitrogen Analyzer (FOSS Analytical 2003). It consists of two separate units, the block digester and the distillation, titration assembly. Firstly, 0.5 gm of oven dried sample was taken and mixed with a catalyst ($CuSO_4 + K_2SO_4$) and 10 ml. of concentrated sulphuric acid and then digested at 420°C for five to six hours in the block digester. The digested samples were transferred into the distillation titration assembly where the ammonia generated during distillation was absorbed in 2% Boric acid, which was then titrated against 0.01N sulphuric acid. A blank (without sample) was run for each set of samples. The percent crude protein was estimated as follows:

n (%) = (S – B) x N x 1.407/ Sample weight (g)

Where, n (%) is Percent nitrogen, S is volume of acid used against sample, B is volume of acid used against blank and N is Normality of acid. Therefore,

Crude protein (CP) % = n x 6.25

4.2.2. Mineral analysis

The analysis of minerals (Ca, Mg, Na, K, Fe and Zn) was performed with the help of an atomic absorption spectrophotometer (AAS) and flame photometer (Buurman *et al.* 1996, Singh *et al.* 1999 and Chaturvedi and Sankar 2006). The dried and ground sample was weighed for 0.5 gm and mixed with nitric acid and perchloric acid (9 ml: 4 ml). The mixture was then digested at 180°C for about 5 – 6 hrs. After digestion the sample was filtered through Whatman #42 filter

paper. Only Sodium (Na) and Potassium (K) was estimated using flame photometer whereas Calcium (Ca), Magnesium (Mg), Zinc (Zn) and Iron (Fe) were estimated using atomic absorption spectrophotometer. The flame photometer and atomic absorption spectrophotometer were calibrated with standard solutions of the elements to be analysed and the minerals in the samples were estimated as parts per million (ppm) and converted to percentage.

4.2.3. Fibre analysis

The fibre content in terms of neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin (acid detergent lignin) was estimated according to the Van Soest (1963 and 1967) method. The instrument, Fibre Analyzer (FOSS Analytical 2003) was used for fibre analysis. For the estimation of NDF and ADF, 0.5 gm of oven dried sample was boiled and refluxed with 100 ml. of neutral detergent solution (NDS) or acid detergent solution (ADS). It was filtered through a pre weighed crucible and washed with hot water and then with acetone. All the above processes were carried out in the fibre analyzer. The crucibles were kept overnight in an oven at 80°C and then cooled in a desiccator and weighed. The residue which remained insoluble in the hot NDS/ADS was the amount of NDF/ADF, percentage of which was calculated as follows:

$$\text{NDF or ADF (\%)} = (W_3 - W_1)/W_2 \times 100$$

Where, W_1 is the empty crucible weight, W_2 is the sample weight and W_3 is the weight of the crucible after extraction process.

4.2.4. Lignin

After the estimation of ADF the crucibles were filled with 72% sulphuric acid (20 ml.) and after three hours the acid was filtered off and the contents were washed with boiling water. The crucibles were kept in an oven overnight at 80°C and weighed. The crucibles were then burned in a muffle furnace at 550°C for three hours so as to ash the entire sample. The crucibles were then cooled in a desiccator and weighed again. The percent lignin (acid detergent lignin) was estimated as follows:

$$\text{Lignin (\%)} = (W_5 - W_6)/W_2 \times 100$$

Where, W_5 is the weight after lignin extraction (crucible + lignin), W_2 is the sample weight at ADF initiation and W_6 is the weight after ash (crucible + ash).

4.2.5. Tannin

The vanillin assay technique using catechine as a standard was followed to analyse the condensed tannins present in the food plants (Hagerman 2002). A standard solution of catechine was prepared by dissolving 100 mg catechin in 100 ml methanol. Various dilutions of the standard catechine solution were prepared using methanol and the acid vanillin reagent was added to these dilutions. After the formation of the red coloured complex the absorbance of these dilutions was read in a spectrophotometer (model: Varian Cary 100 Bio) at 525nm. The absorbance was plotted against catechine concentration to obtain the calibration curve. For the analysis of tannins in the plant samples collected, 0.5 gm of plant sample was mixed with 25 ml methanol in a stoppard measuring cylinder. The solution was shaken periodically and was then allowed to settle. The clear supernatant obtained after 24 hours was drawn into separate test tubes and the acid-vanillin reagent was added to it. After 20 minutes the absorbance of the different samples was read in the spectrophotometer at 525nm and the tannin content in the plant samples was estimated based on the calibration curve obtained from the standard catechine solution.

4.3 Phenology

Ten species of plants were selected for phonological observations which were observed to be fed on by the study species based on the reconnaissance survey and published literature (Aziz and Feeroz 2009; Suarez 2013) (Table 4). Six individuals of each of the selected species were permanently tagged in the study site and observed for the entire duration of the study period (December 2014-March 2015). The trees were tagged with a metal plate bearing painted codes for the respective individuals.

The plant phenophases were categorized into vegetative and reproductive phase. The vegetative phase consisted of – young leaf (YL), mature leaf (ML) and no leaf (NL) whereas the reproductive phase consisted of flower (FL), young fruit (YF) and mature fruit (MF). All these parameters were recorded once a week based on approximate ocular estimation. Flowering was recorded as percentage of flower visible on the canopy, while foliation meant the flower formation, where 100 % foliage meant all the leaves on the tree are young. Fruiting was recorded in terms of percentage of fruit formation.

An average for the six individuals for each plant species was taken for analysis. The phenophase was assumed as initiated if a change in the phenology was observed in even one individual. Flowering, foliation and fruiting for each species were compared with rainfall, temperature and humidity. Phonological patterns were analysed on a temporal scale.

Table 4: List of selected plant species for phonological study

S.No.	Tree species
1	*Acacia auriculiformis*
2	*Aquilaria malaccensis*
3	*Artocarpus chaplasha*
4	*Bombax ceiba*
5	*Delonix regia*
6	*Dillenia pentagyna*
7	*Engelhardtia spicata*
8	*Syzygium cumini*
9	*Terminalia bellirica*
10	*Gynocardia odorata*

5. DATA ANALYSIS

5.1 Activity patterns

Excel spreadsheet was used for data entry and summarization. The percentage time spent on each activity was calculated as follows (Kumar 1987):

$$P_i = (n_i / N) \times 100$$

Where, P_i = % time spent on activity 'i'

n_i = number of records of activity 'i'

N = number of total activity records

The percentage time spent on each activity was calculated for all the five different age and sex classes of the Phayre's leaf monkey both, in the free-ranging and captive conditions for the study

period. The data for all the age and sex classes was pooled together to calculate the percent time spent in different activities by the study species in general. The activity budgets and activity patterns were calculated for all the age and sex classes of the Phayre's leaf monkey and in general. For the analysis of activity pattern the entire day (0600-1700 hrs) was divided in eleven time frames of one hour each *viz.* 0600-0700, 0700-0800, 0800-0900, 0900-1000, 1000-1100, 1100-1200, 1200-1300, 1300-1400, 1400-1500, 1500-1600 and 1600-1700 hrs.

Percent time spent on activities like feeding, moving, resting and alert behaviour by each age and sex class of the Phayre's leaf monkey was tested for significant difference. Also the time spent in these activities was tested for significant difference across the different age and sex classes of the leaf monkey. Percentage frequency occurrence and event rates were calculated for the social interactions and other behaviours like drinking and vocalisations. Since the distribution of all the age and sex classes of the leaf monkeys in the population was unequal and also all the age and sex classes had differential detectability, event rates (number of records for the particular behaviour/scan records for that particular age and sex class) gave a better idea of the frequency of a behaviour for each age and sex class.

Pearson's chi-squared test was used to test for significant differences in activity pattern and activity budgets within the troops (captive and free-ranging). The package, VGAM (Vector Generalized Linear and Additive Models) was used in statistical software R 3.2.0 (Yee 2015).

5.2 Food habits

Excel spreadsheet was used for data entry and summarization. The percentage time spent feeding on a particular food item was estimated from the scan sampling data as follows (Kumar 1987):

$P_i = (n_i / N) \times 100$

Where,

P_i = % time spent on food item 'i'

n_i = number of records of feeding on item 'i'

N = total number of feeding records.

The percentage time spent feeding on different plant species and plant parts by the Phayre's leaf monkey was estimated for the study period.

It was hypothesized that nutritional composition of the food items offered in captivity and those consumed by the free-ranging troop would be similar. Hence the values of the positive nutrients (crude protein and minerals) and negative nutrients (NDF) were compared against each other (wild and captive diet) to test for significant difference. The statistical package SPSS was used for data analysis (Norusis 1993). The independent samples t-test was run with Levene's Test for Equality of Variances to check for homogeneity of variance.

6. RESULTS

6.1 In free-ranging

Table 5: Scan records obtained for different age and sex classes of Phayre's leaf monkey in the wild (December 2014-March 2015)

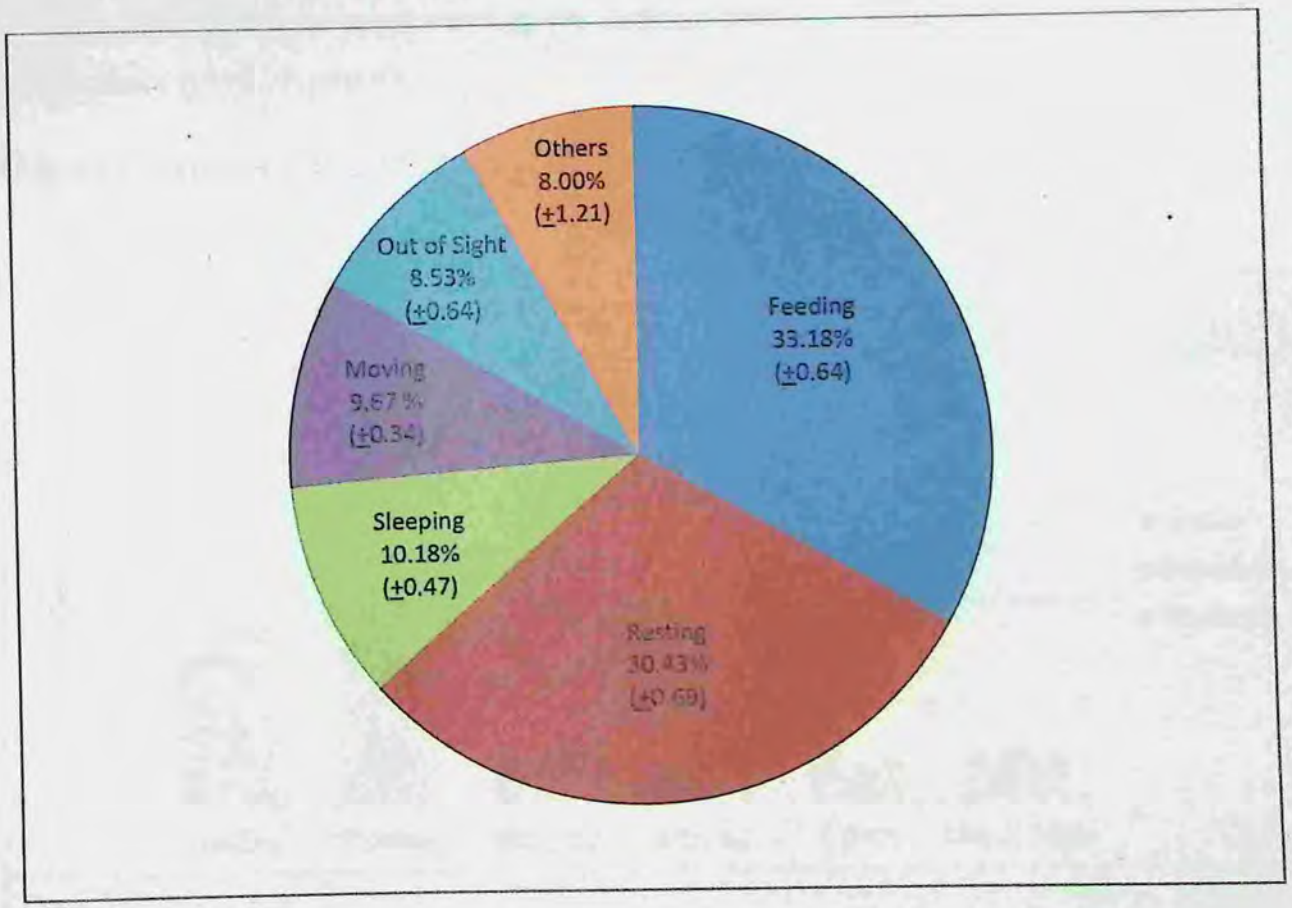
Age and sex classes	Total Scan Records
Adult female	4532
Sub-Adult female	1510
Adult male	1511
Juvenile	3020
Grand total	**10573**

The scan records were highest for adult female (n=4523) and were lowest for sub-adult female (n=1510) as the percentage of adult female in the wild troop was highest (42.86%). Due to the presence of only a single adult male and a single sub-adult female, the observations obtained were very low during the study period (Table 5). The total observation days were 35 with observation being carried out from dawn to dusk.

6.1.1 Activity Budgets

A total of 10,573 scan records were obtained for the free-ranging Phayre's leaf (taking all the age and sex classes together). The daily activity budget of the study species in Sepahijala Wildlife Sanctuary, Tripura is given in Figure 2. It was observed that feeding, resting, sleeping and moving constituted the major activities of the monkeys throughout the study period although they remained 8.04% of the time out of sight. The percentage time spent on feeding, resting, sleeping and moving was 33.18%, 30.43%, 10.18% and 9.67% respectively. About 8% time was spent on other activities like auto-grooming, social interactions, etc.

Figure 2: Activity budget of Phayre's leaf monkey in the wild (December 2014-March 2015).



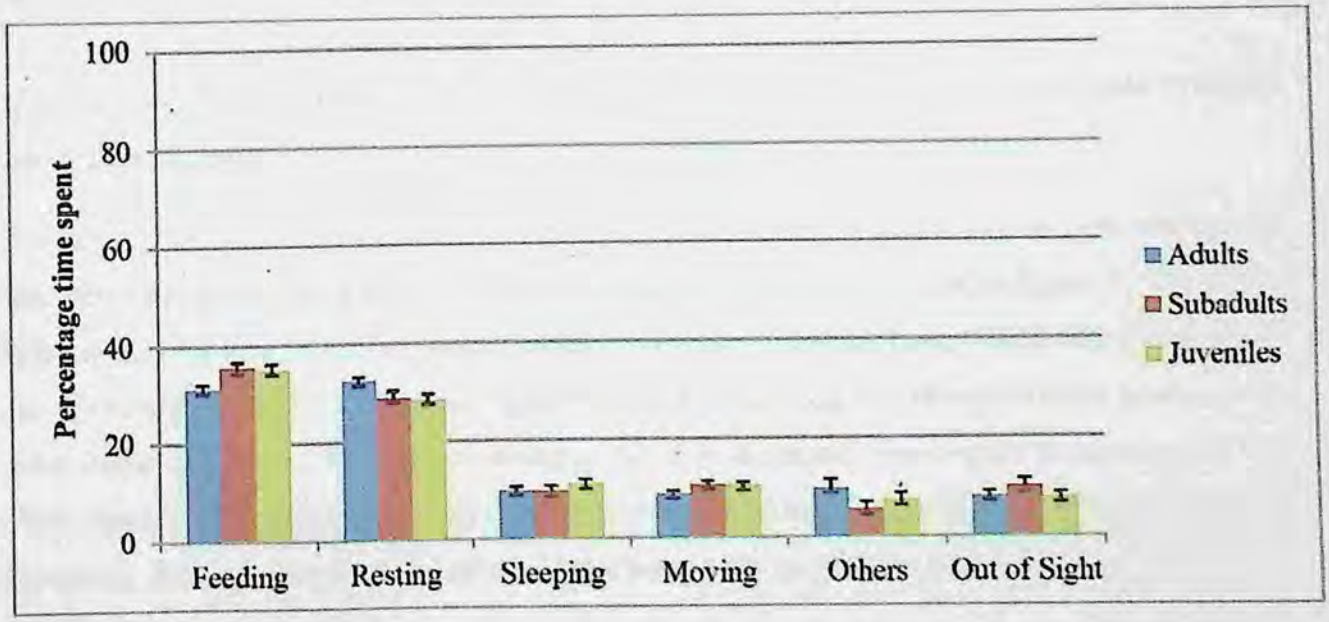
Number of scan records: n=10573

Activity budget of different age and sex classes of the Phayre's leaf monkey:

The activity budget of adults (figure 3) showed that the time spent in resting (31.14%) was highest followed by feeding (31.14%), sleeping (9.78%) and moving (8.83%). The sub-adults were observed to be spending 35.52% of their time feeding, 28.82% resting, 10.67% moving and 9.59% sleeping. The activity budget of the juveniles indicated that they spent their time doing similar activities like those of the sub-adults: feeding (35.10%), resting (28.40%), sleeping (10.99%), moving (10.43%) and other activities (7.26%). The activity budget of adults, sub-adults and juveniles for the study period is given in Figure 17.

Time spent feeding, resting, sleeping, moving and other activities except playing was found to be similar between the different age classes of the Phayre's leaf monkey. No significant difference was observed in the time spent carrying out different activities by different age classes of the study species (χ^2=2.22, p=0.97).

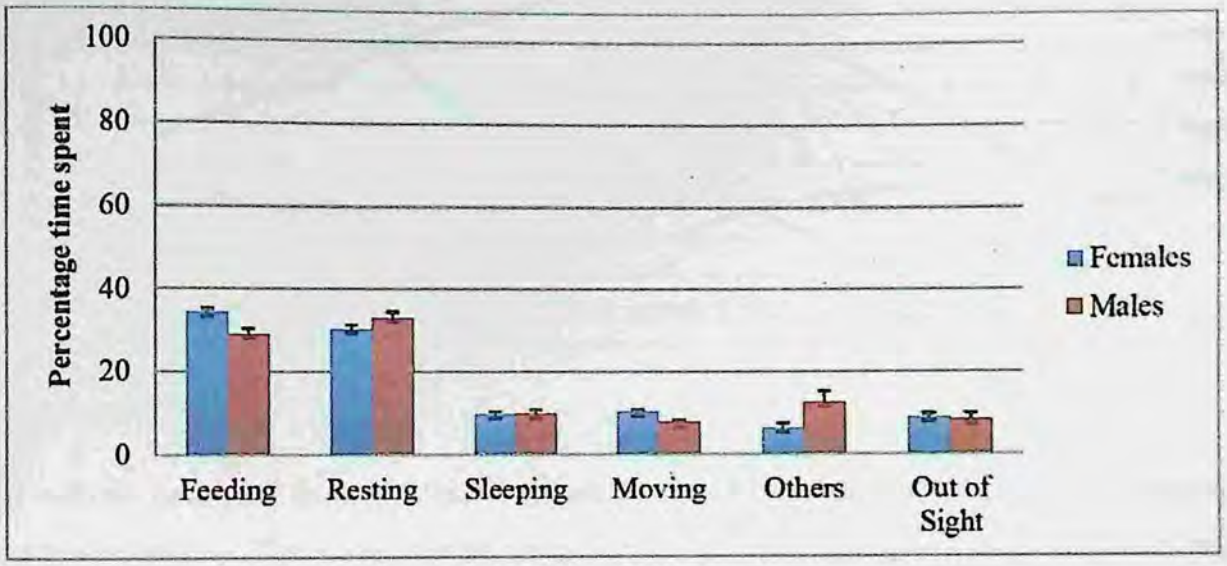
Figure 3: Age-wise activity budgets of Phayre's leaf monkey in the wild (December 2014-March 2015).



Number of scan records: n=10573

No significant difference was seen in the time spent in all the activities recorded across the sex classes (χ^2 =2.99, p=0.56) (Figure 4).

Figure 4: Sex-wise activity budgets of Phayre's leaf monkeys in the wild (December 2014-March 2015).

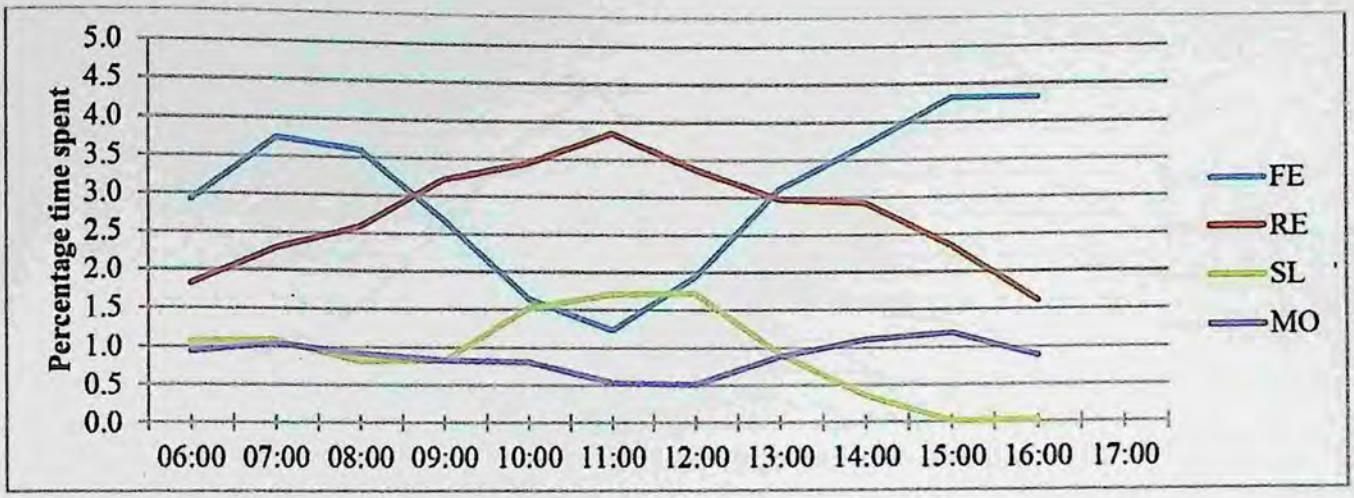


Number of scan records: n=7553

6.1.2 Activity Pattern of major activities of the Phayre's leaf monkey in Sepahijala Wildlife Sanctuary, Tripura

The activity pattern of the Phayre's leaf monkey (pooled data for all the age and sex classes) for the major activities like feeding, resting, sleeping and moving is given in figure 5. The major activity was feeding (33.22%) which peaked in the early morning hours (0630-0830 hrs) and in the afternoon (1330-1600 hrs). Time spent feeding by the troop was observed to be lowest in the time frame of 0930-1230 hrs after which it steadily increased. Time spent in moving did not show much variation across the day. The monkeys moved most in the afternoon hours (1230 hrs onwards). Resting activity showed one prominent peak in the late morning hours from 1000 to1200 hrs.

Figure 5: Activity pattern of major activities of the free-ranging Phayre's leaf monkey (December 2014-March 2015).



Adult female

The activity pattern of the adult female (figure 6) showed that feeding was the major activity throughout the day. Time spent feeding was highest in late afternoon hours (1430-1530 hrs). Time spent for resting peaked in the late morning (1000-1200 hrs) whereas moving was highest in the afternoon hours (1300-1600 hrs).

Figure 6: Major activity patterns of free-ranging adult female (December 2014-March 2015).

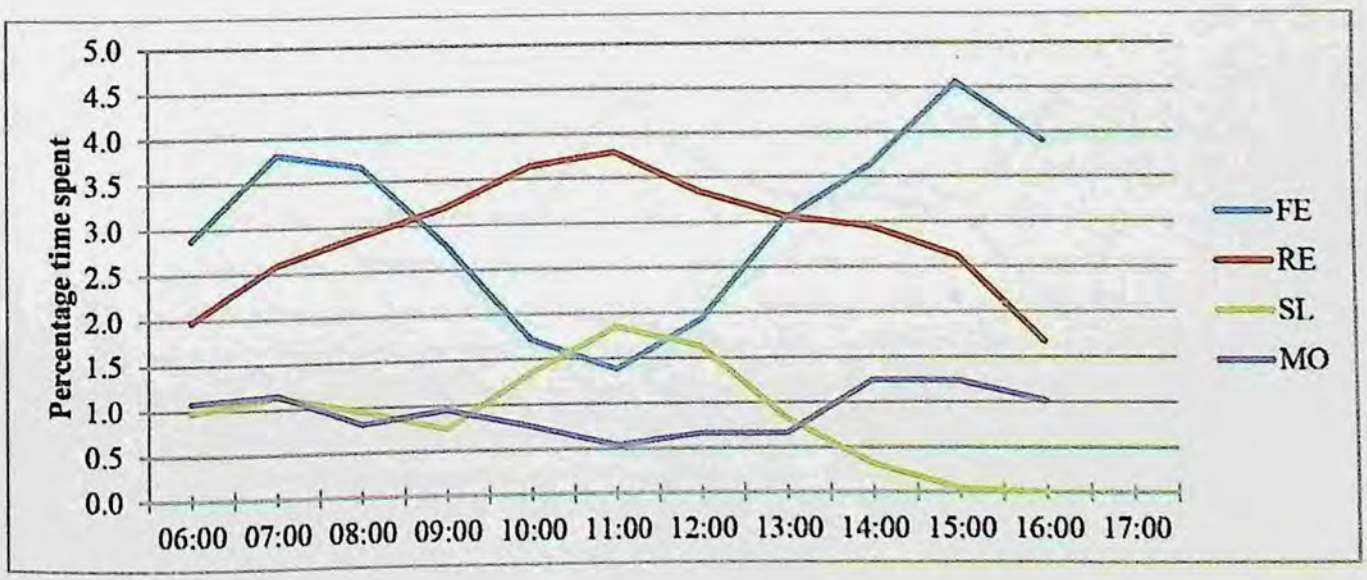
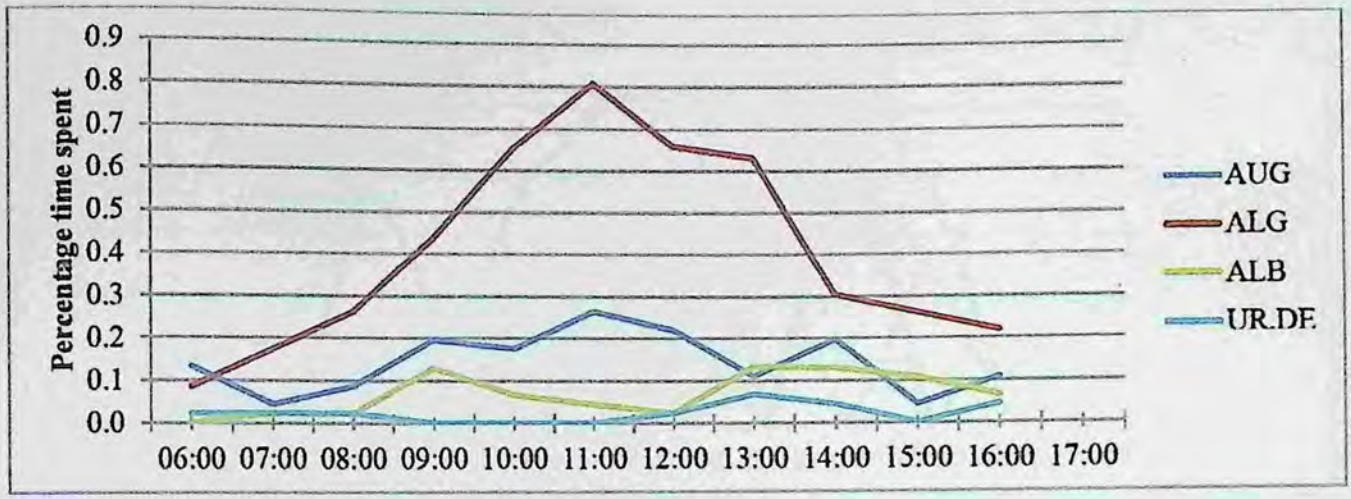


Figure 7: Activity patterns of other activities for free-ranging adult female (December 2014-March 2015).



Adult male

The activity pattern of the adult male (figure 8) showed that resting was the major activity throughout the day followed by feeding, sleeping, displaying alert behavior and moving. Time spent resting was highest in the late morning and afternoon hours (1100-1400 hrs). Time spent feeding was highest in the early morning hours (0600-0800 hrs) and evening hours (1400-1700 hrs) whereas sleeping peaked in the late morning (1000-1200 hrs).

Figure 8: Major activity patterns of free-ranging adult male (December 2014-March 2015).

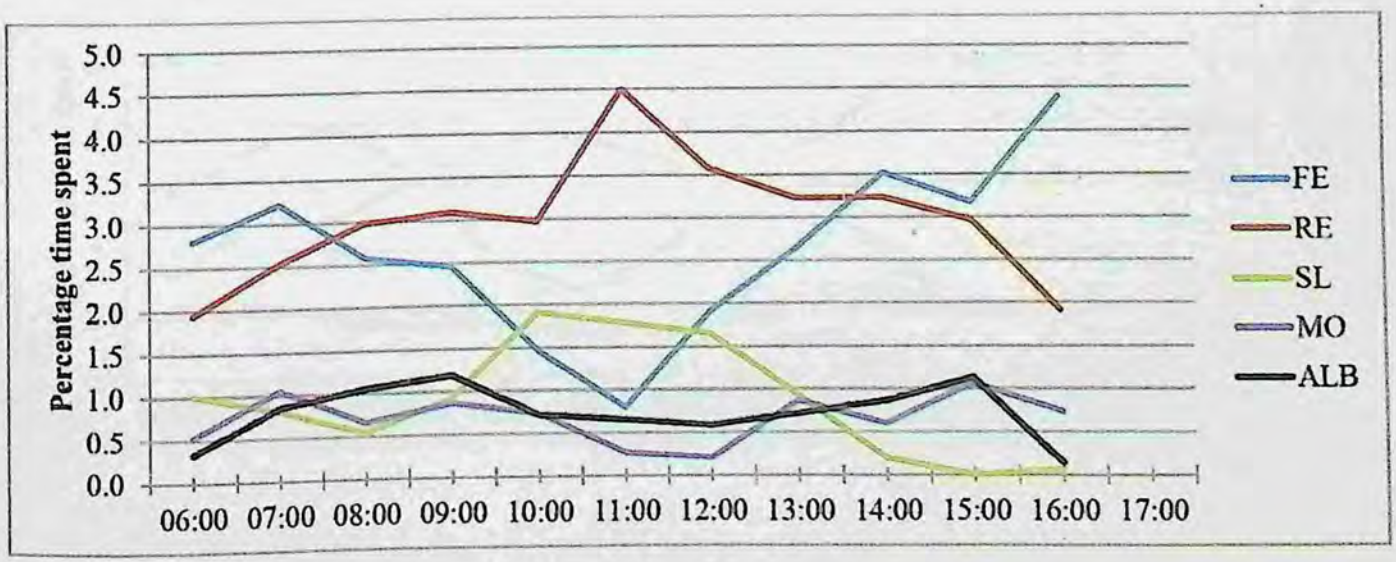
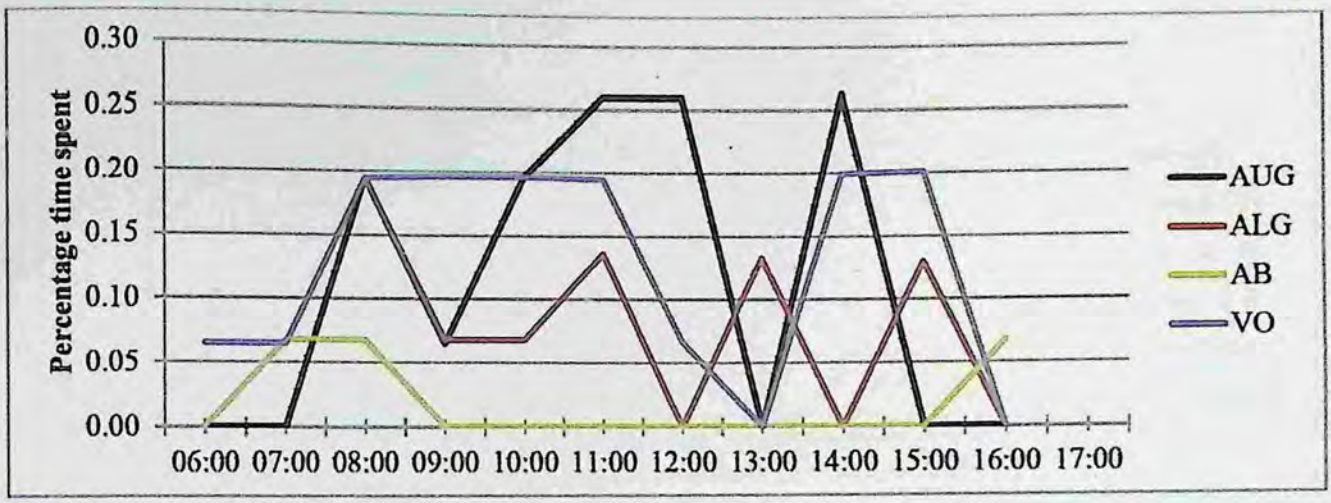


Figure 9: Activity patterns of other activities for free-ranging adult males (December 2014-March 2015).



Sub-adult female

The sub-adult female spent most of her time feeding followed by resting, moving and sleeping. The time spent feeding was found to be highest in the afternoon hours (1300-1600 hrs) (figure 10). Time spent resting showed a steadily declining pattern from 1000 to1700 hrs.

Figure 10: Major activity patterns of free-ranging sub-adult female (December 2014-March 2015).

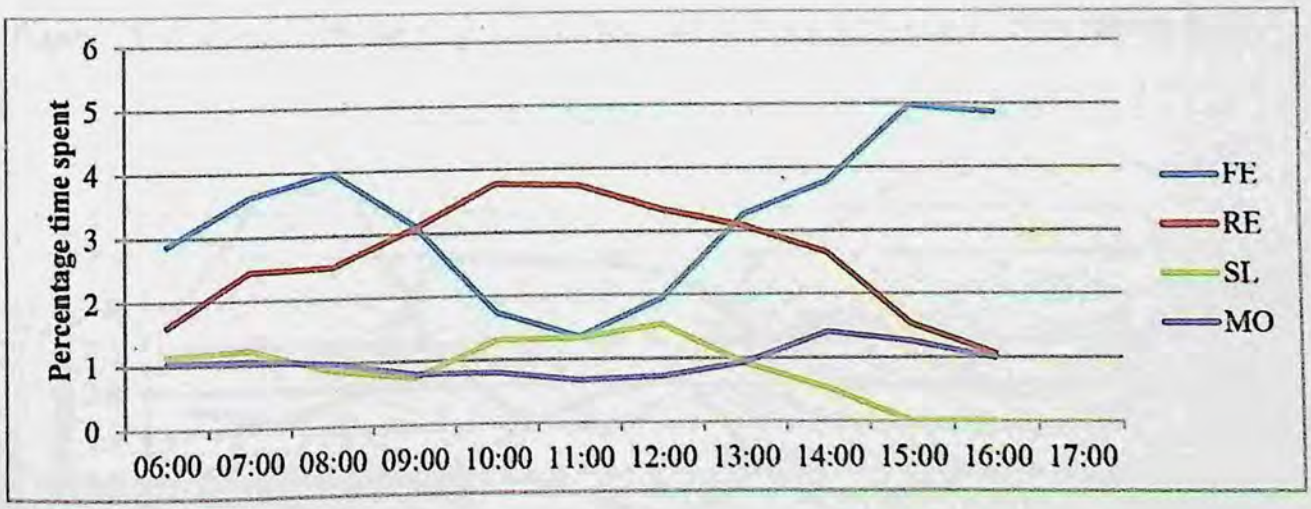
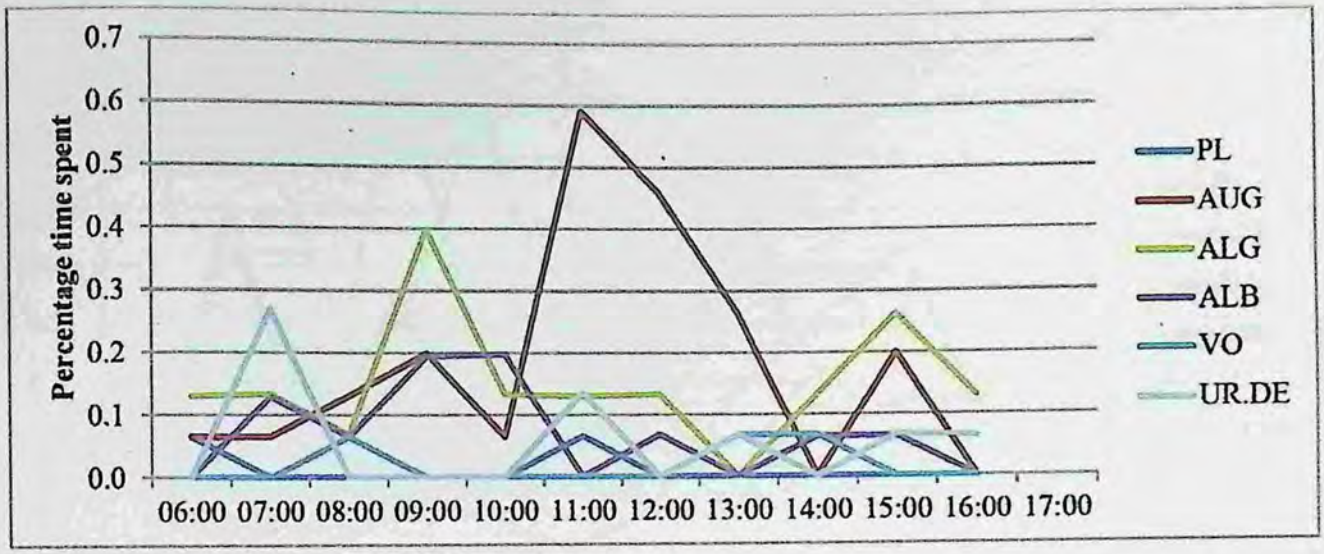


Figure 11: Activity patterns of other activities for free-ranging sub-adult females (December 2014-March 2015).



Juvenile

The activity pattern of the juveniles (figure 12) showed feeding, resting, sleeping and moving as the major activities. Time spent feeding showed a steadily increasing pattern from 1300 to1500 hrs.

Figure 12: Major activity patterns of free-ranging juveniles (December 2014-March 2015).

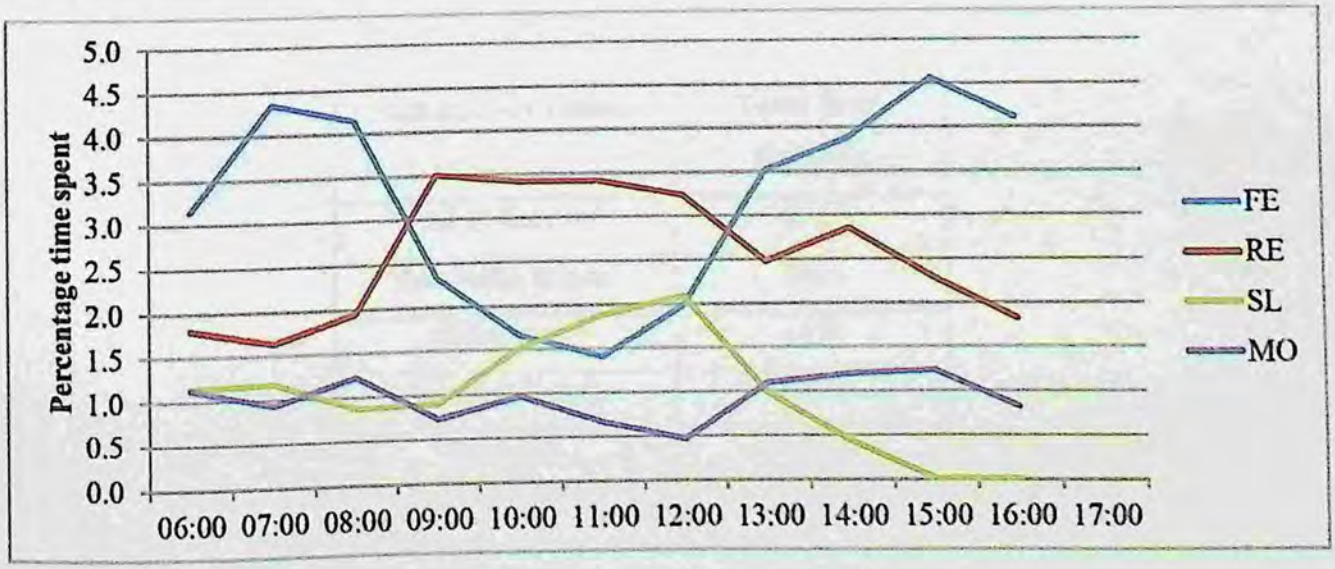
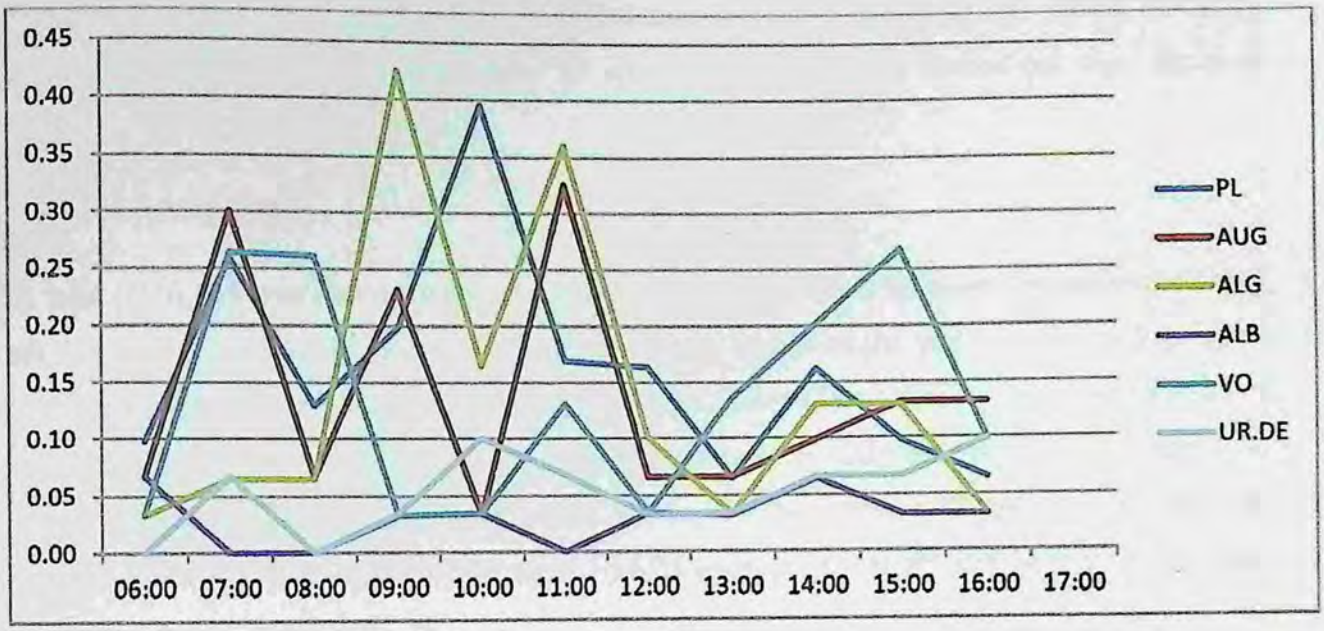


Figure 13: Activity patterns of other activities for free-ranging juveniles (December 2014-March 2015).



6.2 In captivity

The details of the scan records obtained for each age and sex class of the Phayre's leaf monkey are given in table 6:

Table 6: Scan records obtained for different age and sex classes of Phayre's leaf monkey in captivity (December 2014-March 2015)

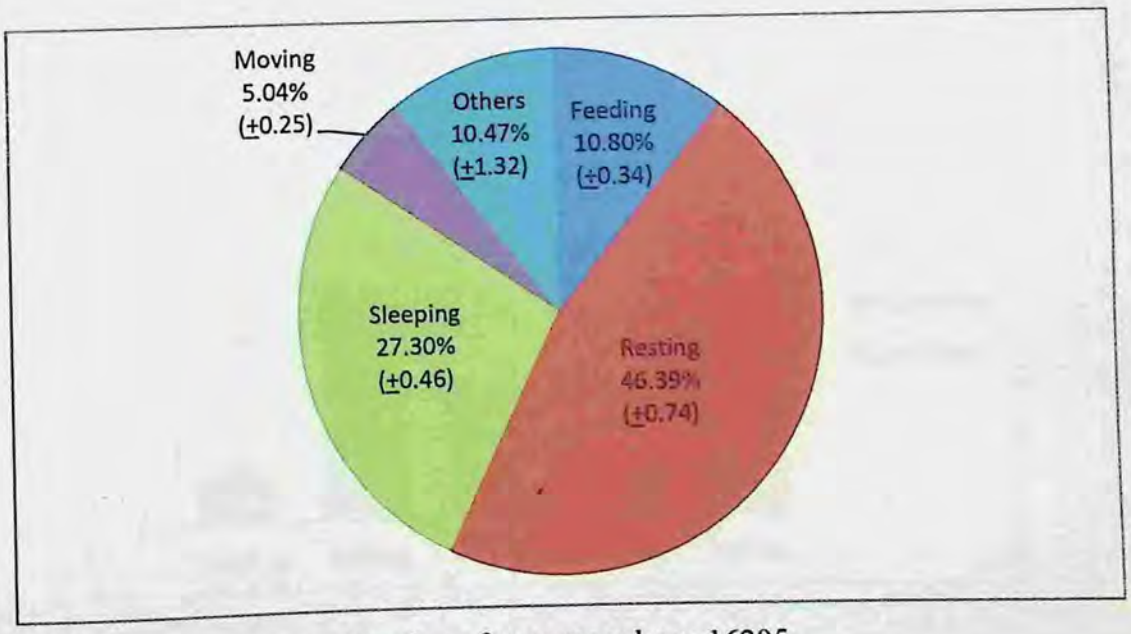
Age and sex classes	Total Scan Records
Adult female	4523
Sub-Adult female	3016
Adult male	1508
Sub-Adult male	2808
Juvenile	4350
Phayre's Leaf Monkey	**16205**

The scan records were highest for adult female (n=4523) and were lowest for adult male (n=1508) as the percentage of adult female in the captive troop was highest (27.27%). Due to the presence of only a single adult male, the observations obtained were very low during the study period. The total observation days were 35 with observation being carried out from dawn to dusk.

6.2.1 Activity Budgets

A total of 16,205 scan records were obtained for the Phayre's leaf monkeys in captivity (taking all the age and sex classes together). The daily activity budget of the study species in Sepahijala Zoological Park, Tripura is given in Figure 14. It was observed that feeding, sleeping and resting constituted the major activities of the monkeys throughout the study period. The percentage time spent on feeding, sleeping and resting was 10.8%, 27.3% and 46.39% respectively. Moving accounted for 5.04% of the time and about 10.47% time was spent on other activities like auto-grooming, social interactions, etc.

Figure 14: Activity budget of Phayre's leaf monkey in captivity (December 2014-March 2015).



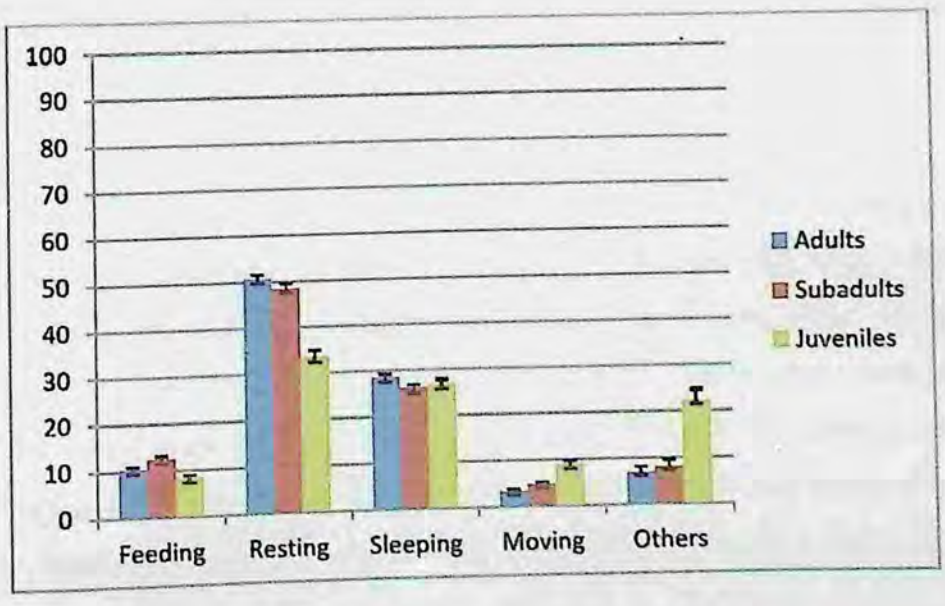
Number of scan records: n=16205

Activity budget of different age and sex classes of the Phayre's leaf monkey:

The activity budget of adults (figure 15) showed that the time spent in resting (50.71%) was highest followed by sleeping (28.59%), feeding (10.4%) and standing (10.3%). Similarly, the sub-adults were observed to be spending 48.56% of their time in resting, 26.20% in sleeping and 12.46% in feeding. The activity budget of the juveniles indicated that they spent 17.68% of their time in playing, resting (33.43%), sleeping (26.93%), moving (8.93%) and other activities (22.44%). The activity budgets for adults, sub-adults and juveniles for the study period are given in Figure 3.

Time spent feeding, resting, sleeping, moving and other activities except playing was found to be similar between the different age classes of the Phayre's leaf monkey (χ^2 =7.28, p=0.50). A significant difference was observed in the time spent playing by different age classes of the study species (χ^2 =34.76, p=<0.05) with juveniles spending 17.58%, the adults not showing the activity at all and the sub-adults spending 0.66% of their time playing .

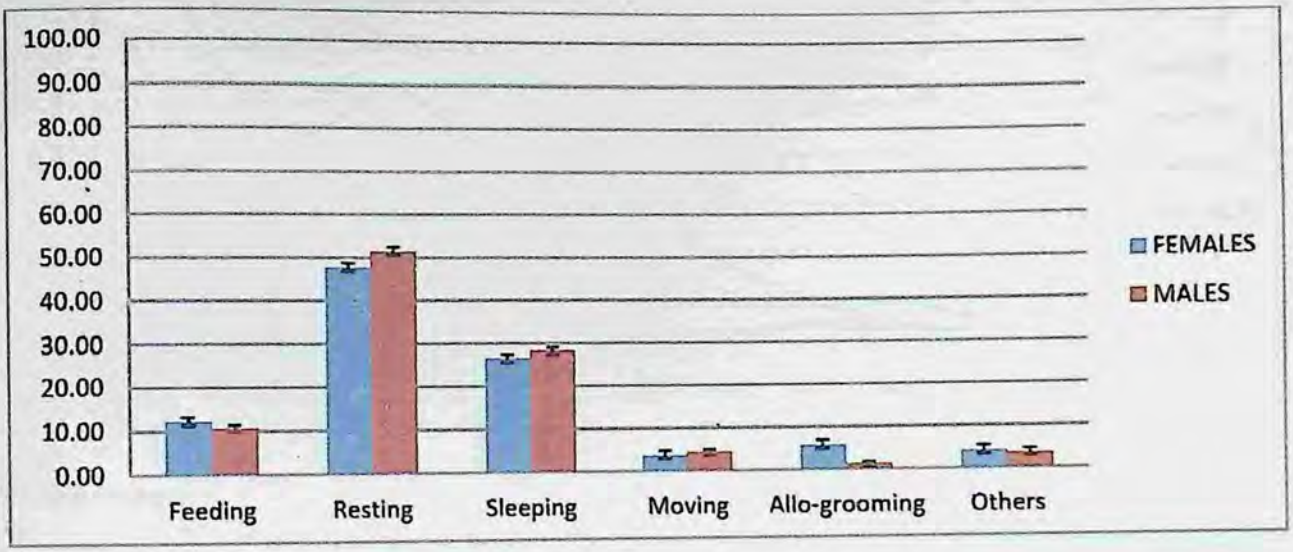
Figure 15: Age-wise activity budgets of Phayre's leaf monkey in captivity (December 2014-March 2015).



Number of scan records: n=16205

No significant difference was observed in the time spent in all the activities recorded across the sex classes (χ^2 =1.54, p=0.82) (Figure 16).

Figure 16: Sex-wise activity budgets of Phayre's leaf monkey in captivity (December 2014-March 2015).

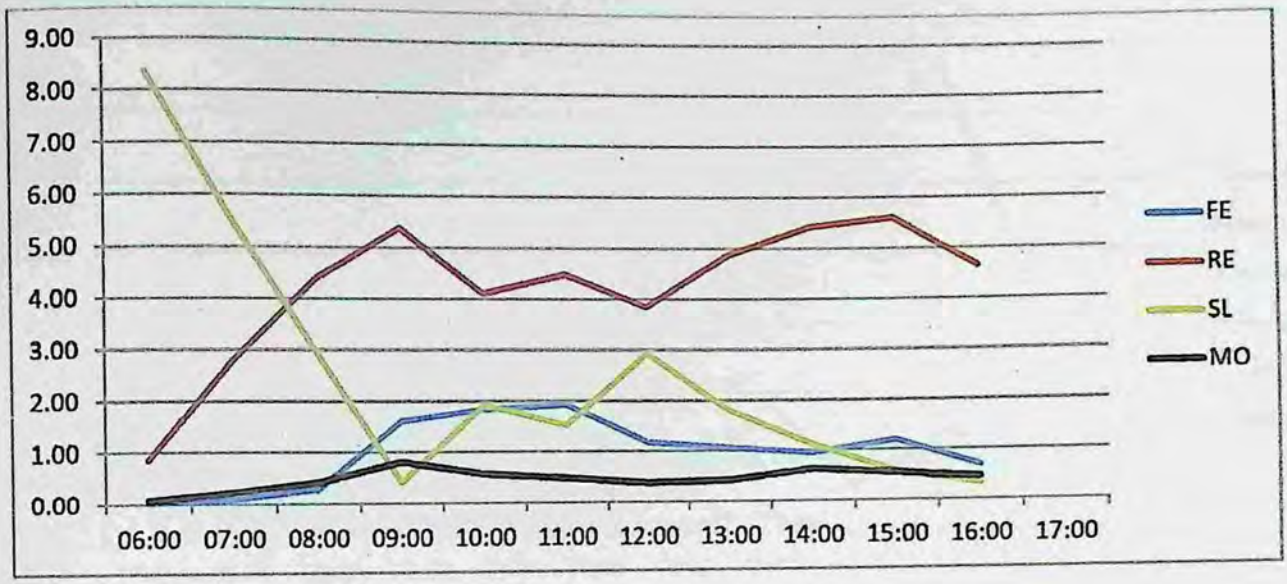


Number of scan records: n=11855

6.2.2 Activity Pattern of major activities of the Phayre's leaf monkey in Sepahijala Zoological Park, Tripura (December 2014-March 2015)

The activity pattern of the Phayre's leaf monkey (pooled data for all the age and sex classes) for the major activities like feeding, resting and sleeping is given in figure 17. The feeding activity peaked in the late morning hours (0900-1130 hrs) and in the late afternoon (1500-1530 hrs). Time spent feeding by the troop was observed to be lowest in the time frame of 0600-0800 hrs after which it steadily increased. Time spent in moving did not show much variation across the day. The monkeys moved most in the late morning hours (0900-0930 hrs) when food was offered by the animal keepers. Resting activity showed two prominent peaks in the mid-day hours from 0900-1500 hrs but it was minimal during the early morning and evening time frames.

Figure 17: Activity pattern of major activities of the Phayre's leaf monkey in captivity (December 2014-March 2015).



Adult female

The activity pattern of the adult female (figure 18) showed that resting was the major activity throughout the day. Time spent for resting was highest in late morning hours (0900-1600 hrs). Time spent for sleeping peaked in the early morning and afternoon hours (0600-1200 hrs) whereas feeding was highest in the late morning hours (0900-1200 hrs).

Figure 18: Major activity patterns of adult female in captivity (December 2014-March 2015).

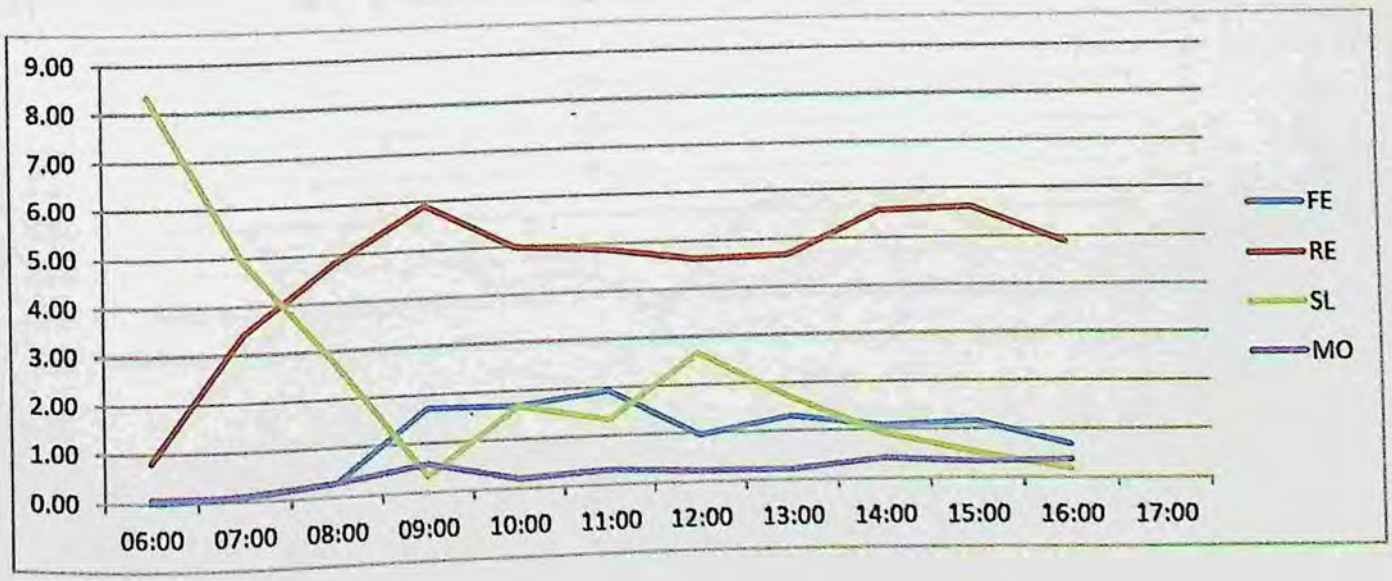
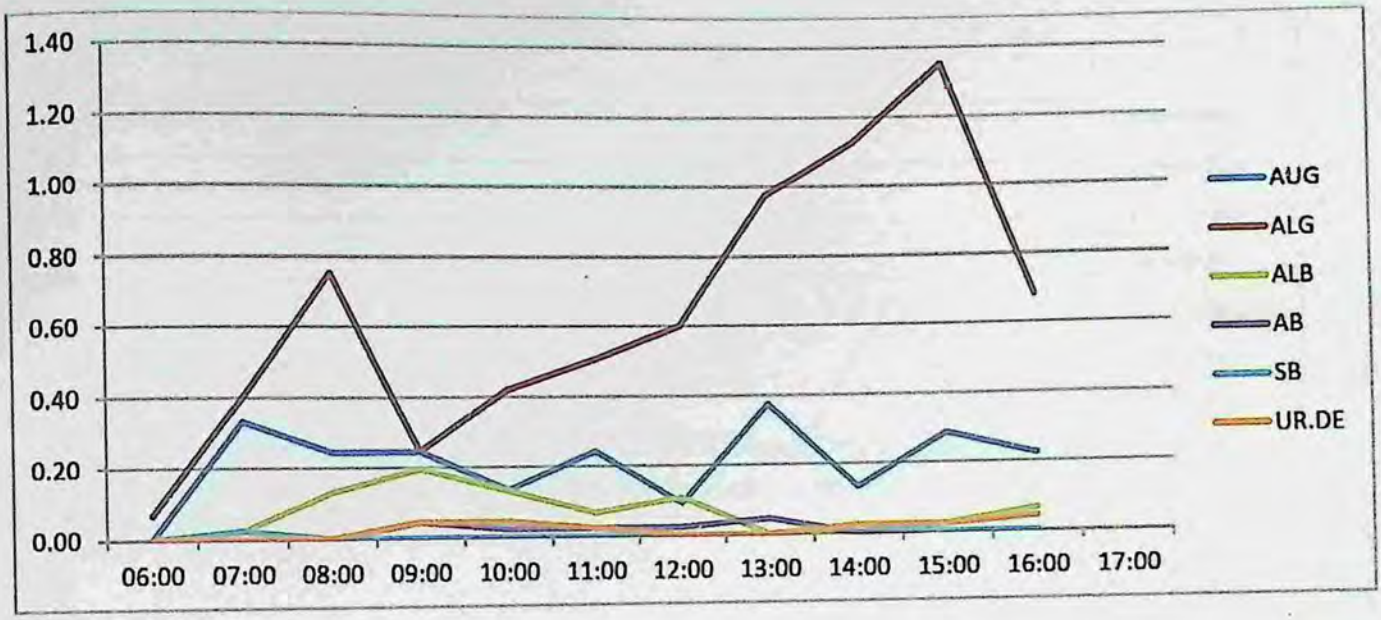


Figure 19: Activity patterns of other activities for adult female in captivity (December 2014-March 2015).



Adult male

The activity pattern of the adult male (figure 20) also showed that resting was the major activity throughout the day followed by sleeping and feeding. Time spent for resting was highest in the late morning and afternoon hours (0900-1500 hrs). Time spent for sleeping peaked in the early morning and afternoon hours (0600-1200 hrs) whereas feeding was highest in the late morning hours (0900-1200 hrs).

Figure 20: Major activity patterns of adult male in captivity (December 2014-March 2015).

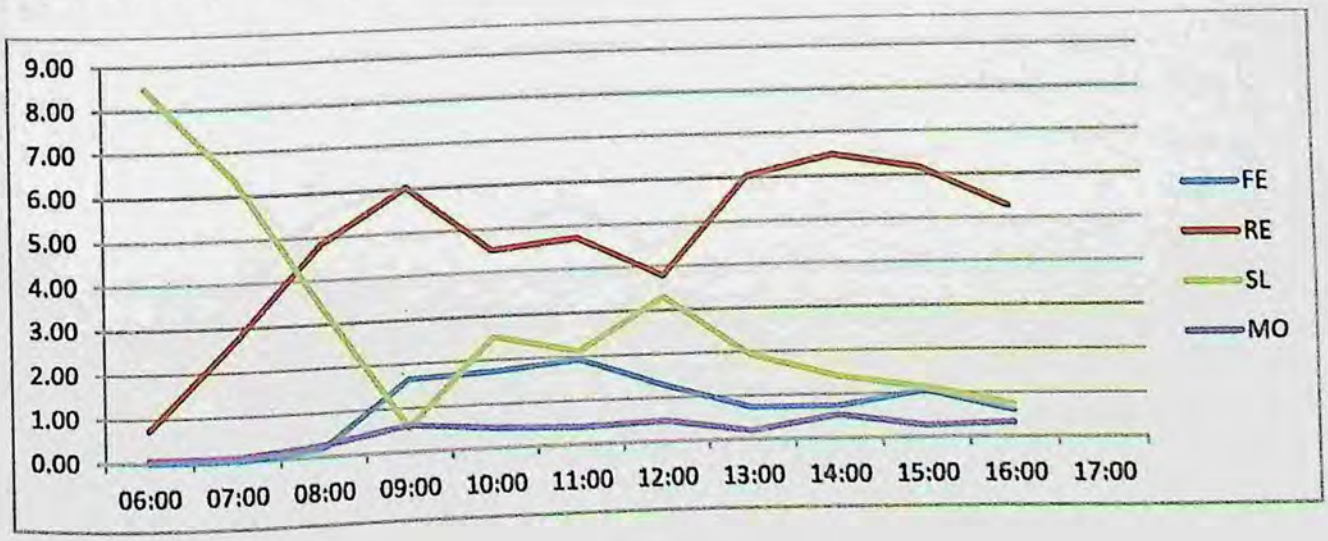
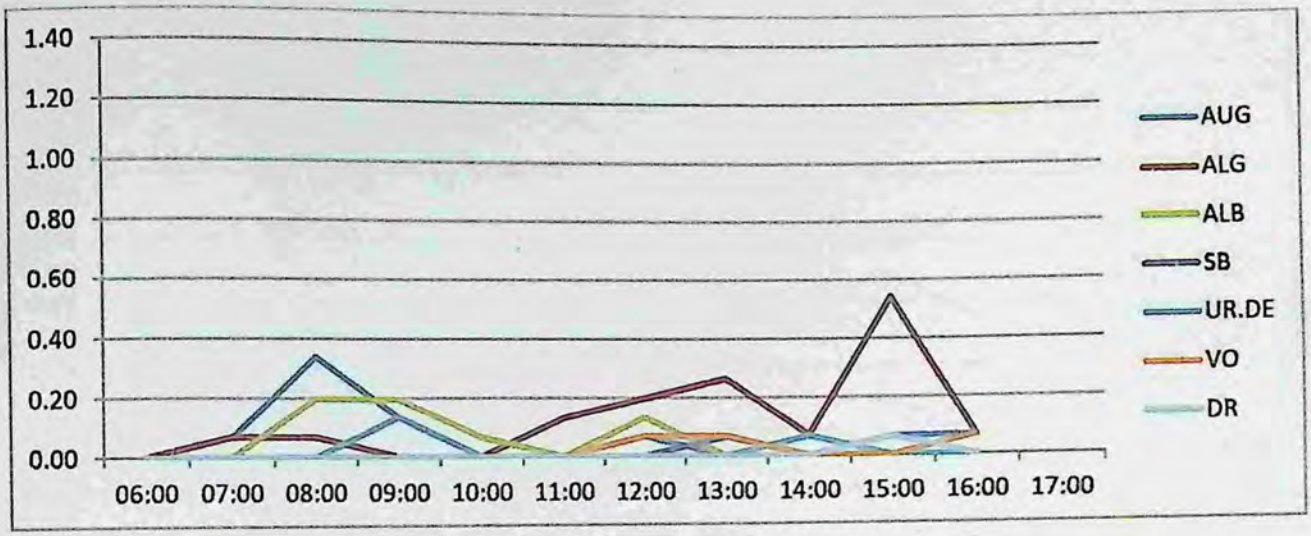


Figure 21: Activity patterns of other activities for adult male in captivity (December 2014-March 2015).



Sub-adult female

The time spent resting by sub-adult female was found to be highest in the afternoon hours (1400 hrs) (figure 22) Time spent moving showed a steadily declining pattern from 0900-1700 hrs. Resting occurred mainly during the mid-day hours.

Figure 22: Major activity patterns of sub-adult female in captivity (December 2014-March 2015).

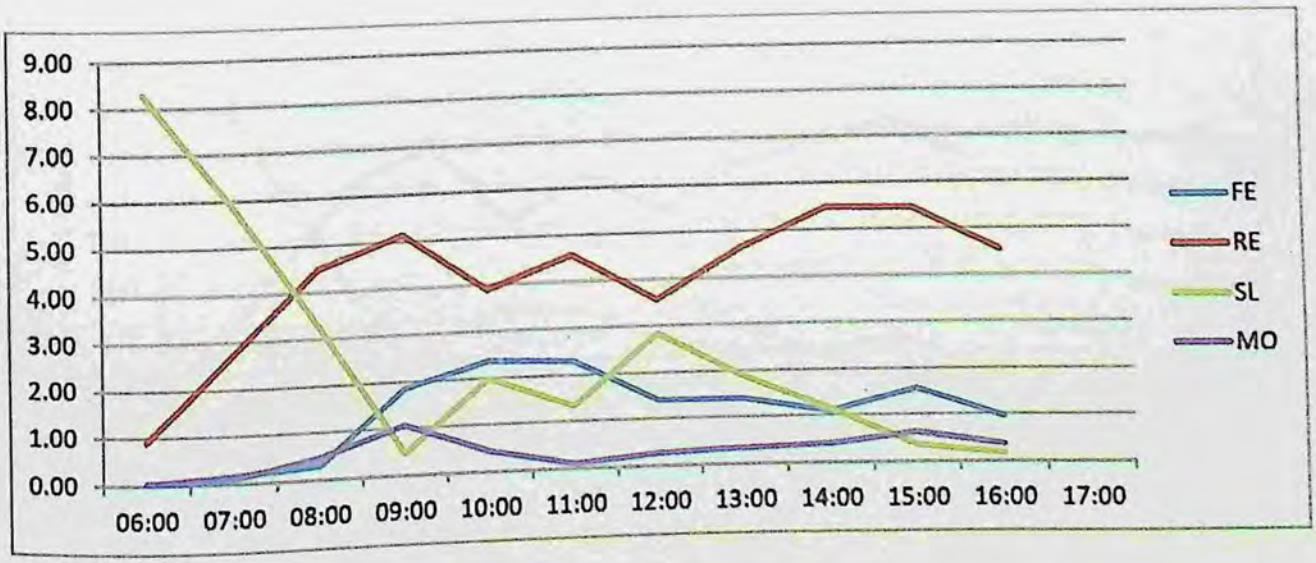
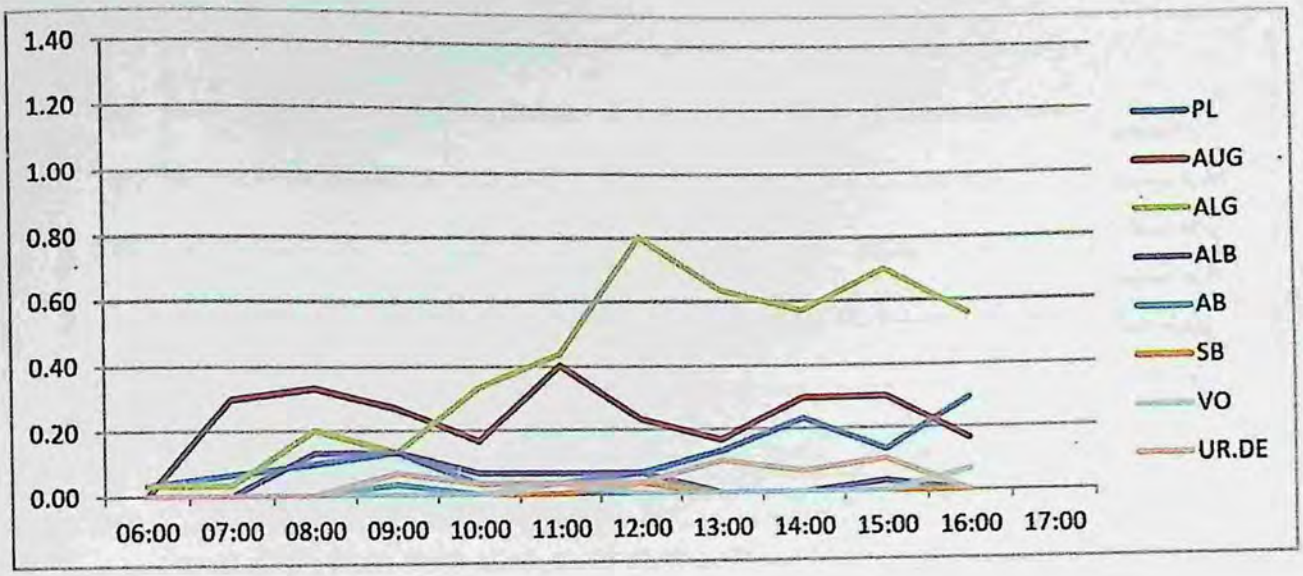


Figure 23: Activity patterns of other activities for sub-adult female in captivity (December 2014-March 2015).



Sub-adult male

The time spent resting by sub-adult male was found to be highest in the afternoon hours (1500 hrs) and the rest of the activities showed a similar pattern to those of adults and sub-adult female (figure 24). Time spent moving showed a steadily declining pattern from 0900-1700 hrs.

Figure 24: Major activity patterns of sub-adult male in captivity (December 2014-March 2015).

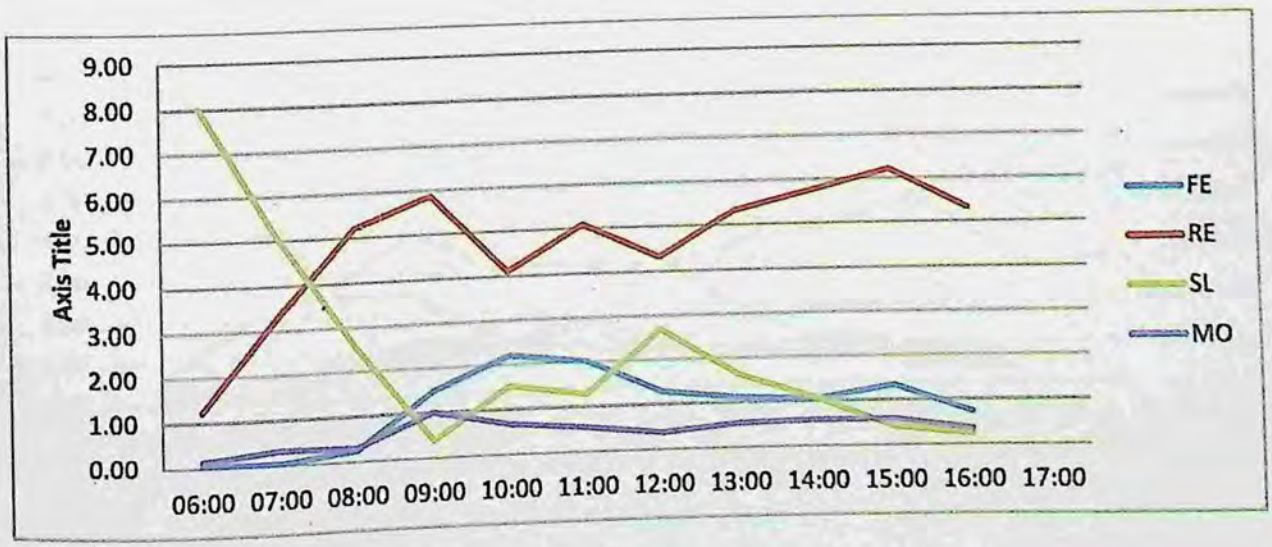
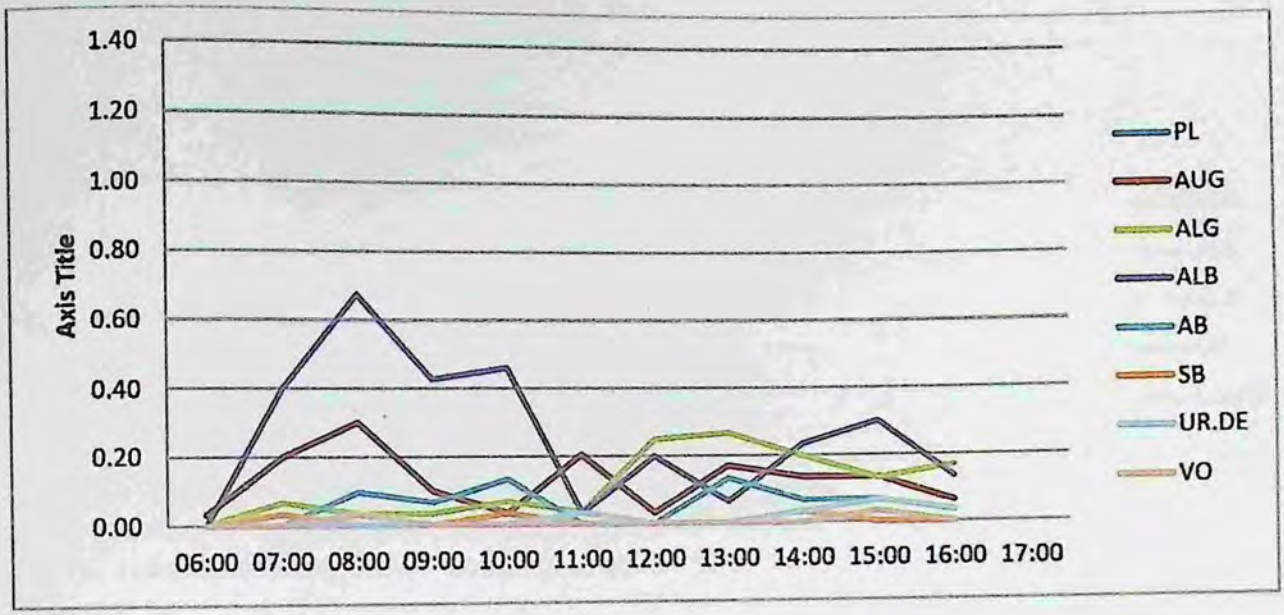


Figure 25: Activity patterns of other activities for sub-adult male in captivity (December 2014-March 2015).



Juvenile

The activity pattern of the juveniles (figure 26) showed resting, sleeping, playing and feeding as the major activities. The juveniles were seen actively playing from 0800-1000 hrs.

Figure 26: Major activity patterns of juveniles in captivity (December 2014-March 2015).

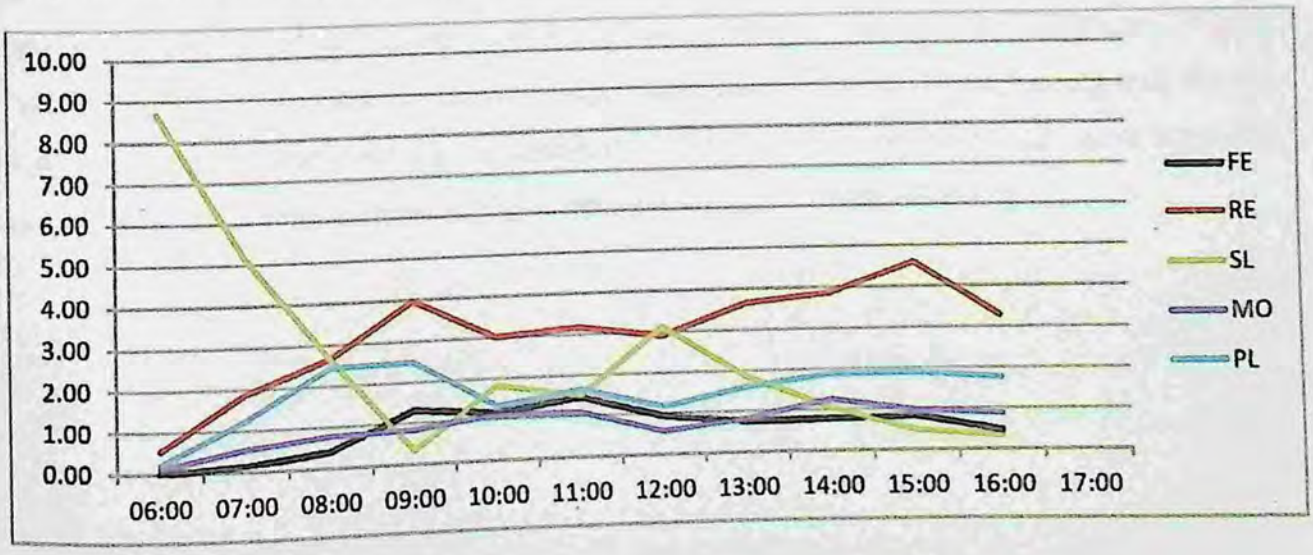
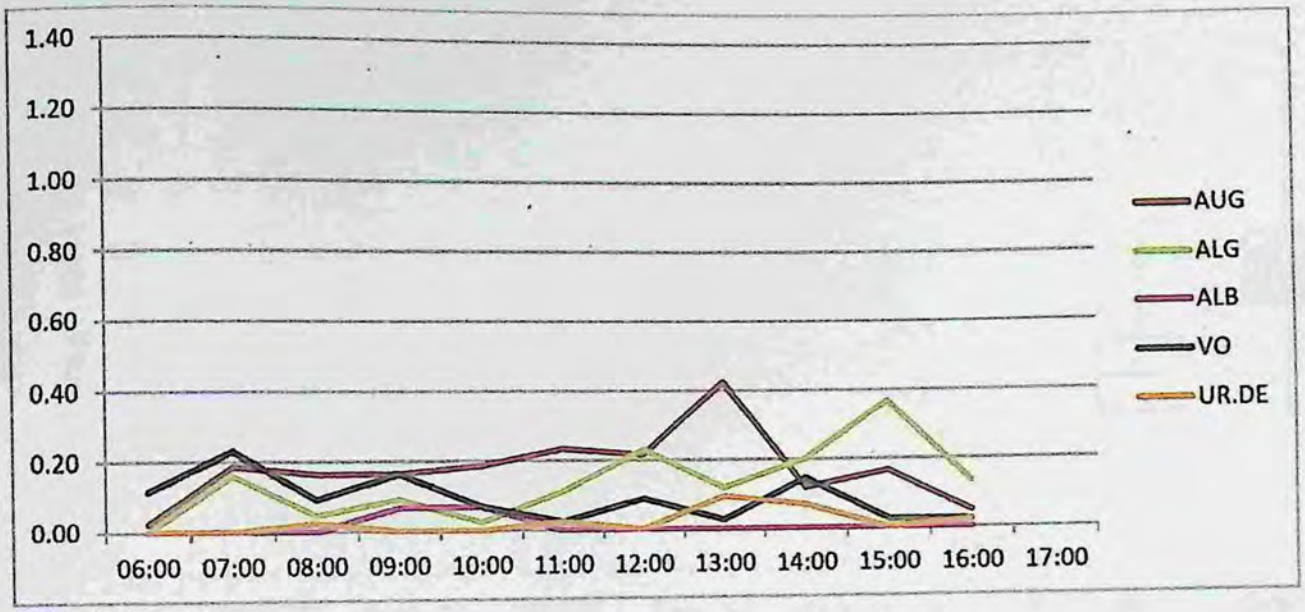


Figure 27: Activity patterns of other activities for juveniles in captivity (December 2014-March 2015).

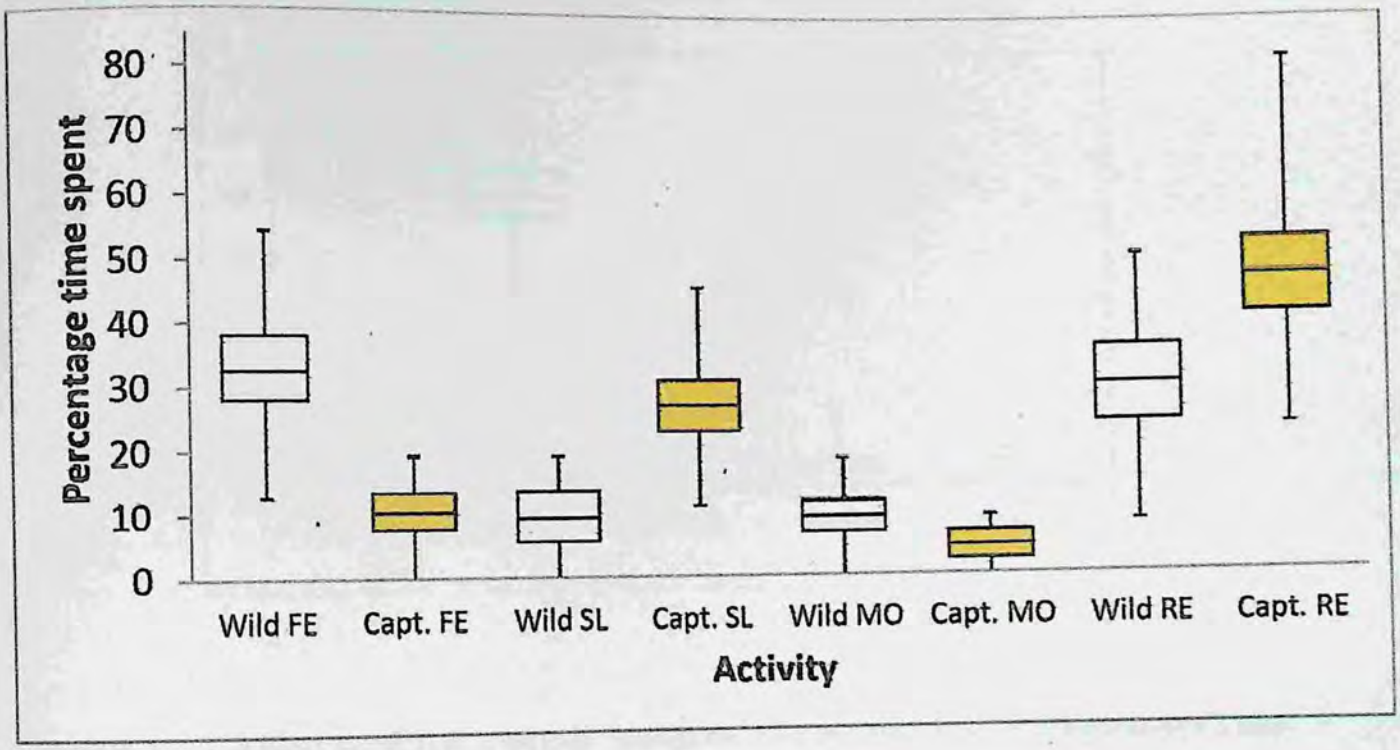


6.3. Comparison of activities between free-ranging and captive Phayre's leaf monkey

6.3.1 Activity Budget

With reference to the activity budgets obtained for the troops both, in captivity as well as free-ranging conditions (all age and sex classes pooled together), box plots were constructed (Figure 28). The box plots represent the activity budgets across thirty-five days which along with the chi square test implied that there was a significant difference observed among the major activities carried out between the captive and free-ranging troop ($\chi^2 = 23.80$, $p=<0.05$).

Figure 28: Box plots for major activities carried out by the Phayre's leaf monkey in wild and captivity (December 2014-March 2015).



AGE CLASSES

In terms of age classes across the two settings (captivity and free-ranging), there was a significant difference observed between the major activities among all three classes- adults (χ^2 =1648.9, p=< 0.05) (figure 29 and 30), sub-adults (χ^2=747.39, p= <0.05) (figure 32 and 33) and juveniles (χ^2=1328, p=<0.05) (figure 34 and 35).

Figure 29: Box plots for major activities carried out by the adult Phayre's leaf monkey in captivity (December 2014-March 2015).

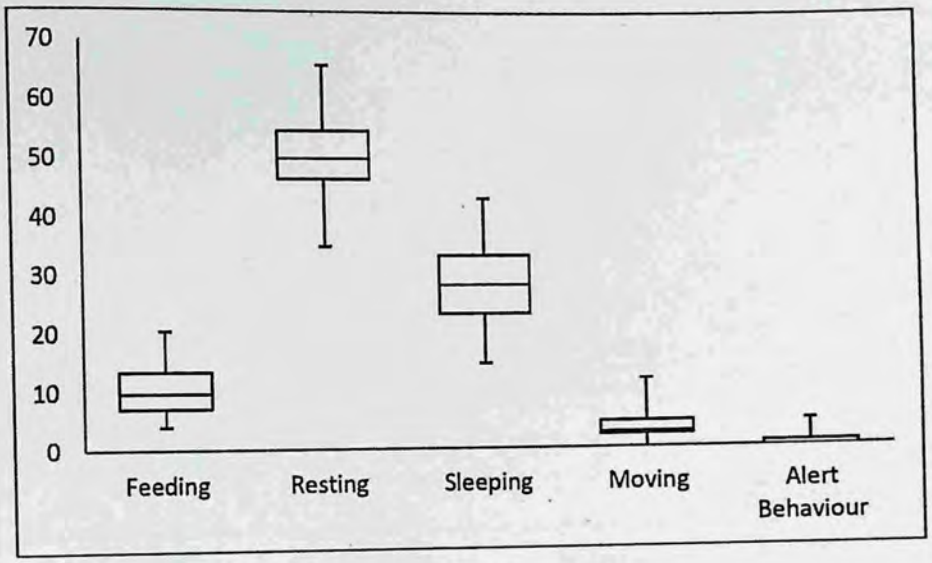


Figure 30: Box plots for major activities carried out by the adult free-ranging Phayre's leaf monkey (December 2014-March 2015).

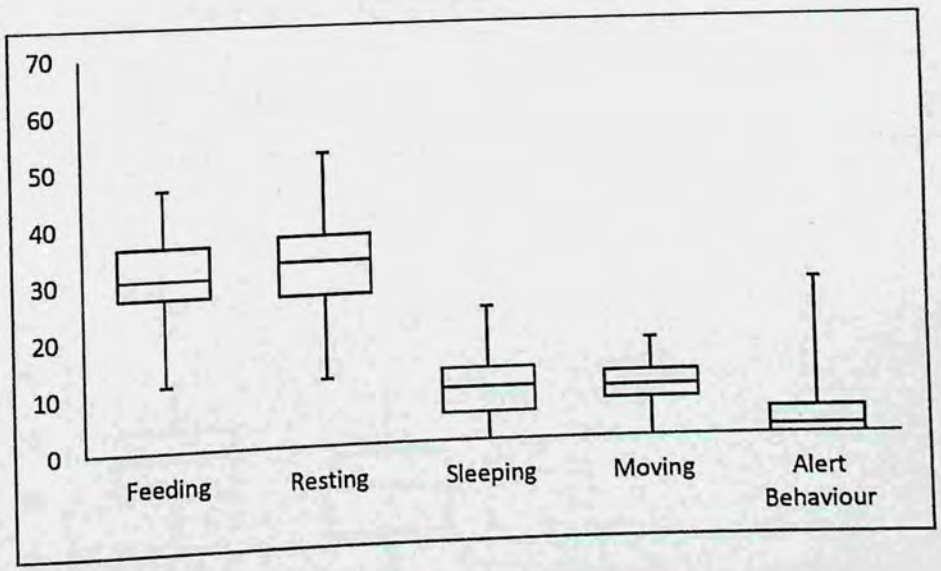


Figure 31: Box plots for major activities carried out by the sub-adult Phayre's leaf monkey in captivity (December 2014-March 2015).

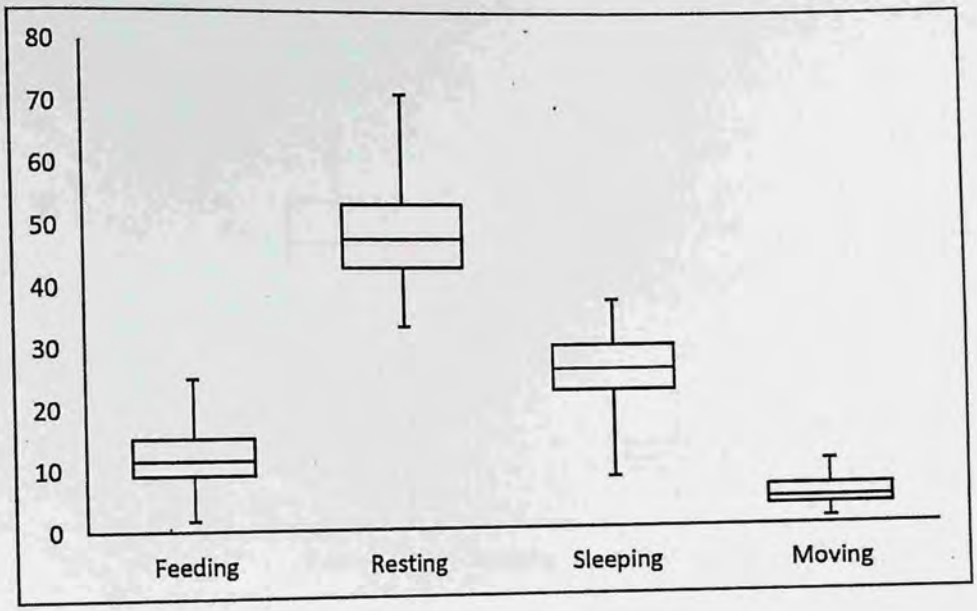


Figure 32: Box plots for major activities carried out by the sub-adult free-ranging Phayre's leaf monkey (December 2014-March 2015).

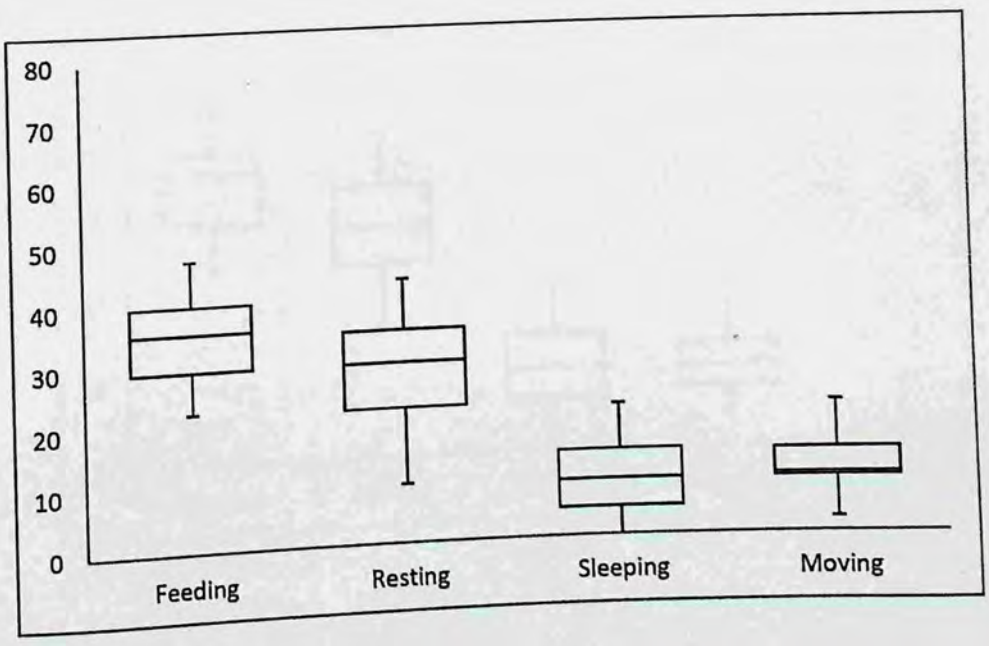


Figure 33: Box plots for major activities carried out by the juvenile Phayre's leaf monkey in captivity (December 2014-March 2015).

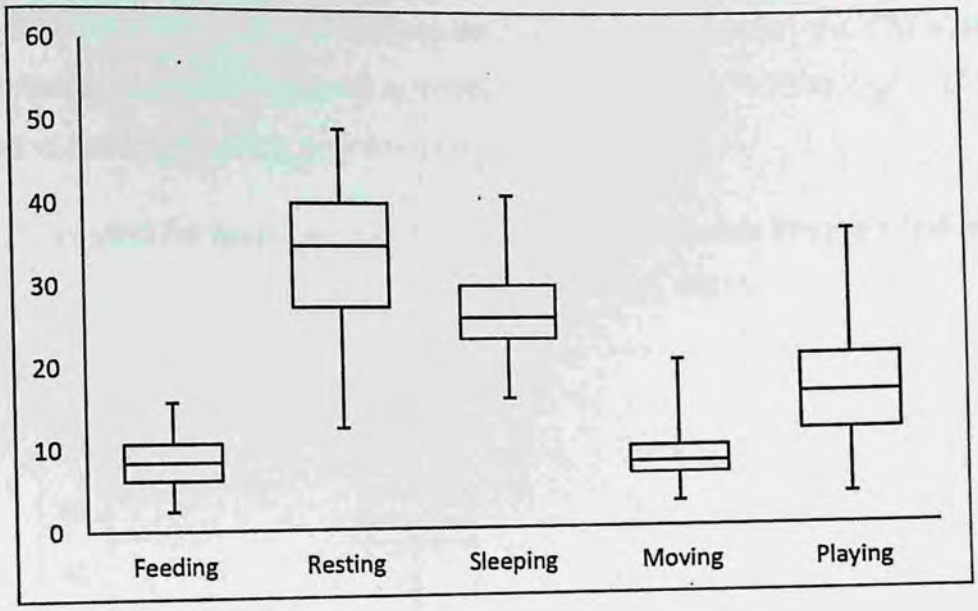
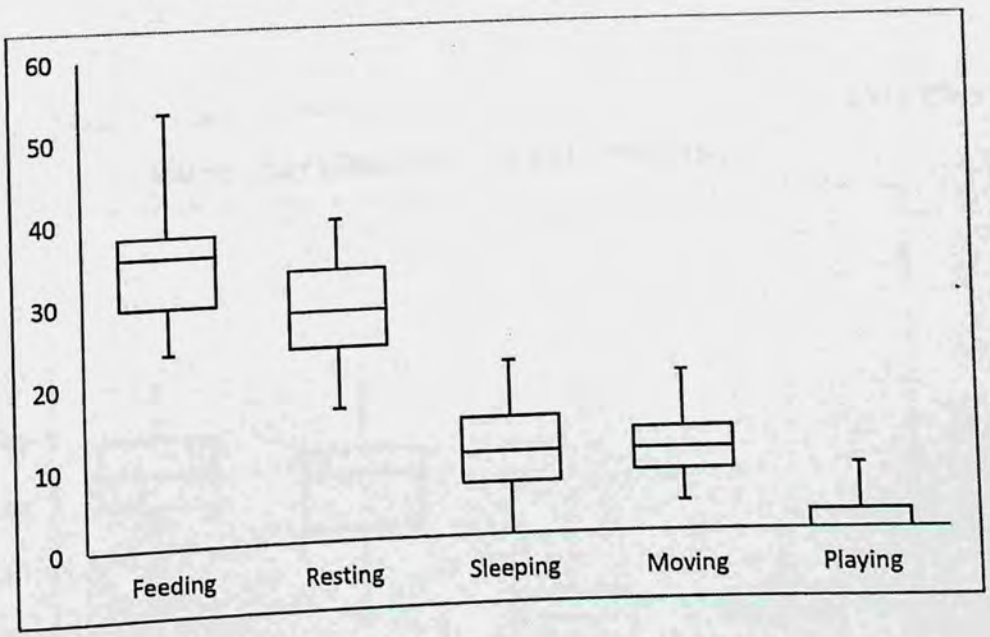


Figure 34: Box plots for major activities carried out by the juvenile free-ranging Phayre's leaf monkey (December 2014-March 2015).



SEX CLASSES

On the basis of sex classes (males and females) in the free-ranging and captivity conditions, a significant difference was observed between the major activities carried out. Chi square values were calculated in order to estimate the significance for females (χ^2 =1770.9, p=< 0.05) (Figure 35 and 36) and males (χ^2=630.2, p= <0.05) (Figure 38 and 39).

Figure 35: Box plots for major activities carried out by the female Phayre's leaf monkey in captivity (December 2014-March 2015).

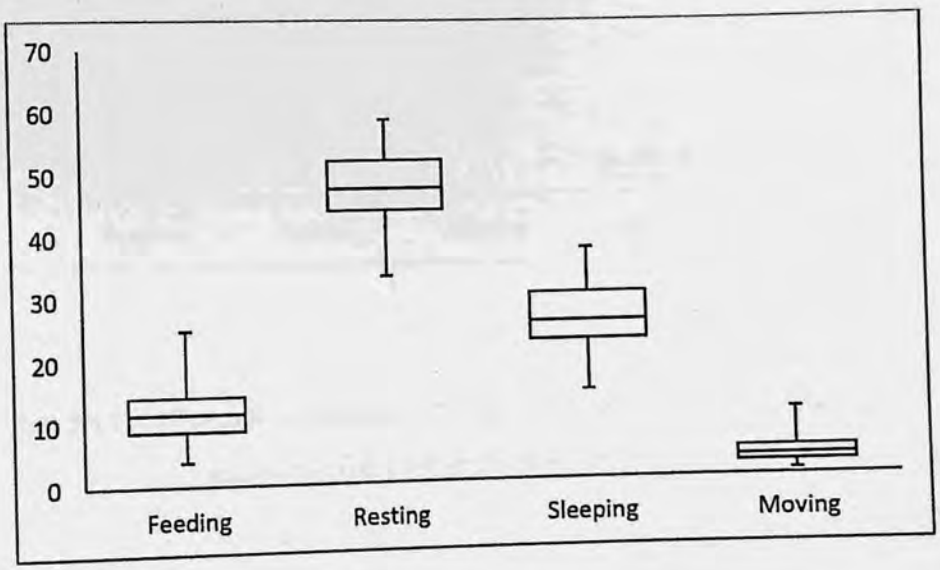


Figure 36: Box plots for major activities carried out by the female free-ranging Phayre's leaf monkey (December 2014-March 2015).

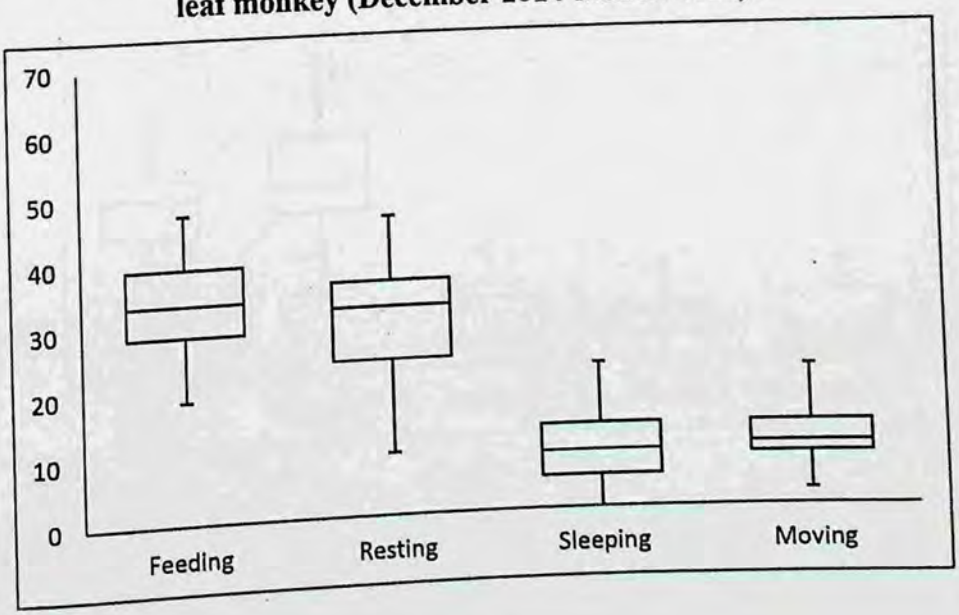


Figure 37: Box plots for major activities carried out by the male Phayre's leaf monkey in captivity (December 2014-March 2015).

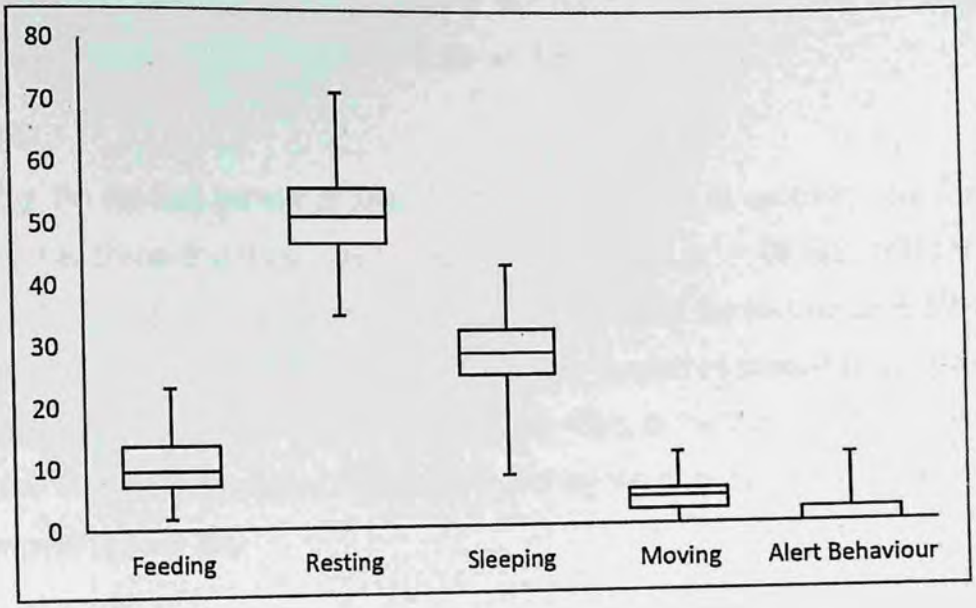
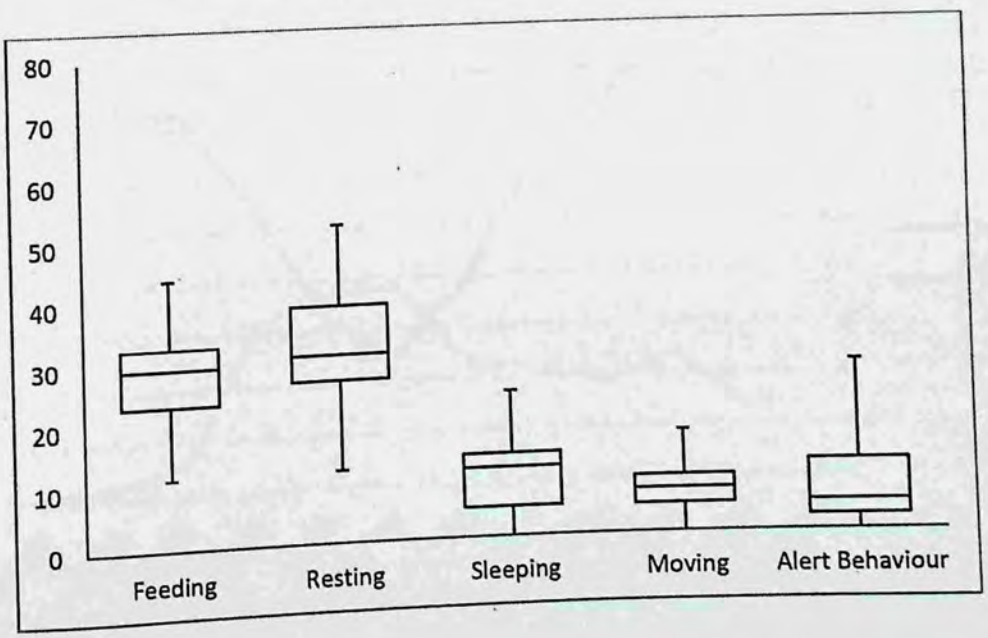


Figure 38: Box plots for major activities carried out by the male free-ranging Phayre's leaf monkey (December 2014-March 2015).



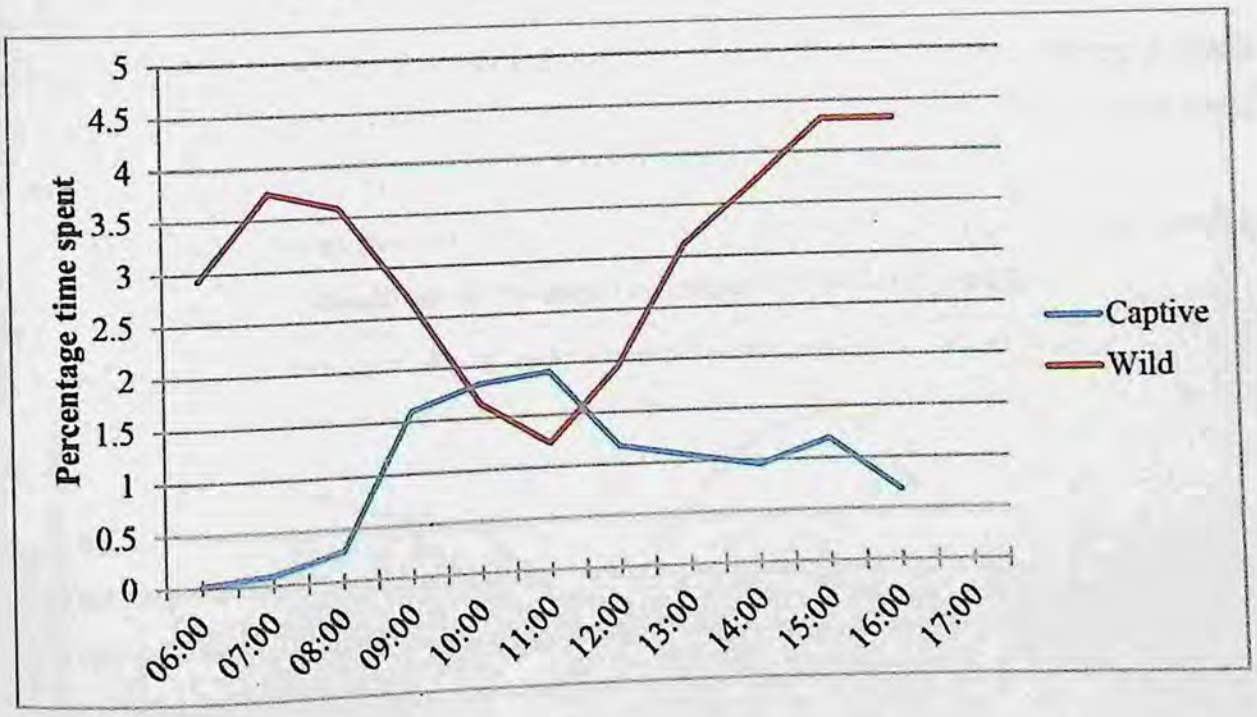
6.3.2 Activity Patterns

Taking into account the activity pattern or time spent carrying out major activities throughout the day (dawn to dusk) - feeding, sleeping, moving and resting were taken into consideration for comparative analysis between the captive and the wild troop.

1. FEEDING

On comparing the feeding pattern of the Phayre's leaf monkey in captivity and free ranging conditions, it was found that there was a significant difference ($\chi^2 = 987.12$, $p<0.05$) observed between both settings thereby rejecting the null hypothesis that the two separate troops would have similar activity patterns. The feeding pattern in both conditions seemed to be opposing each other with the captive troop showing a peak in feeding when the wild troop showed a dip (1000-1130 hrs). The wild troop displayed two peaks in feeding whereas the captive troop displayed a single major peak (Figure 39).

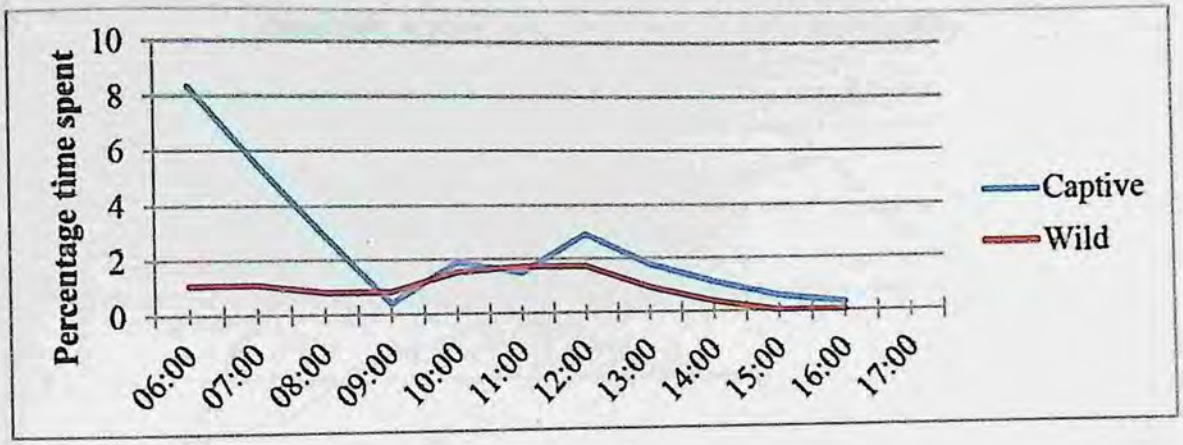
Figure 39: Feeding pattern of the Phayre's leaf monkey in captivity and free-ranging condition across time (December 2014-March 2015).



2. SLEEPING

Although resulting in a different χ^2value, the observed difference between the sleeping pattern in the two settings (captive and free-ranging) was found to be significantly different ($\chi^2 = 612.56$, $p=<0.05$). The captive troop seemed to be spending more time sleeping than the wild troop (Figure 40).

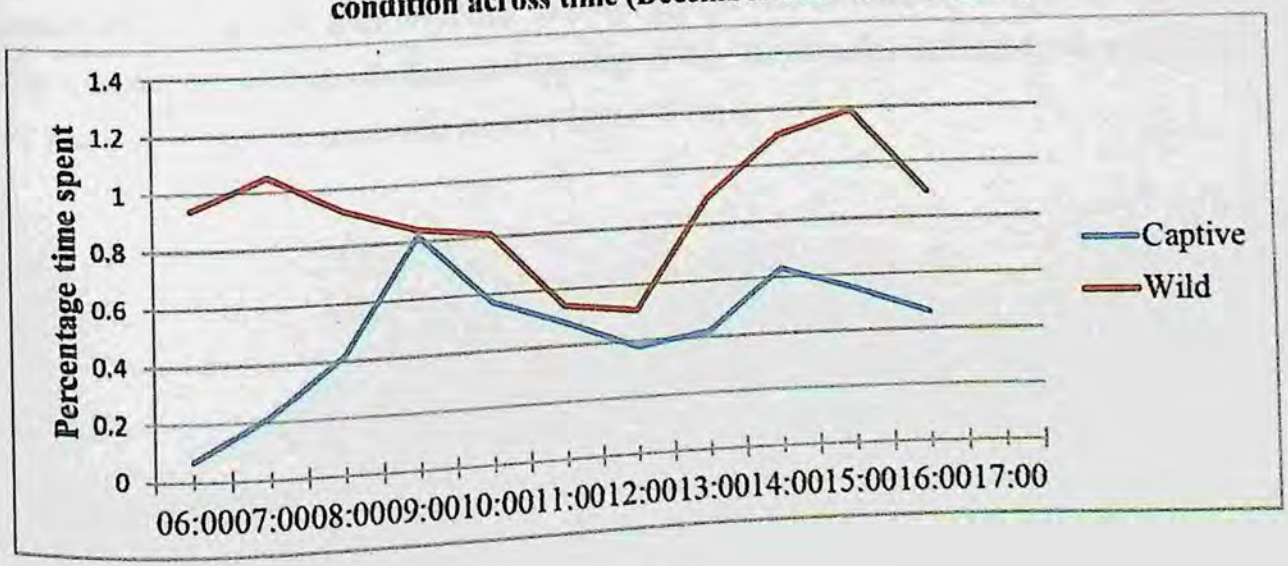
Figure 40: Sleeping pattern of the Phayre's leaf monkey in captivity and free-ranging condition across time (December 2014-March 2015).



3. MOVING

In terms of moving, neither of the patterns coincided among the two settings thereby giving a significant difference ($\chi^2 = 116.73$, $p=<0.05$). The wild troop seemed to be more active in terms of moving than the captive troop (Figure 41).

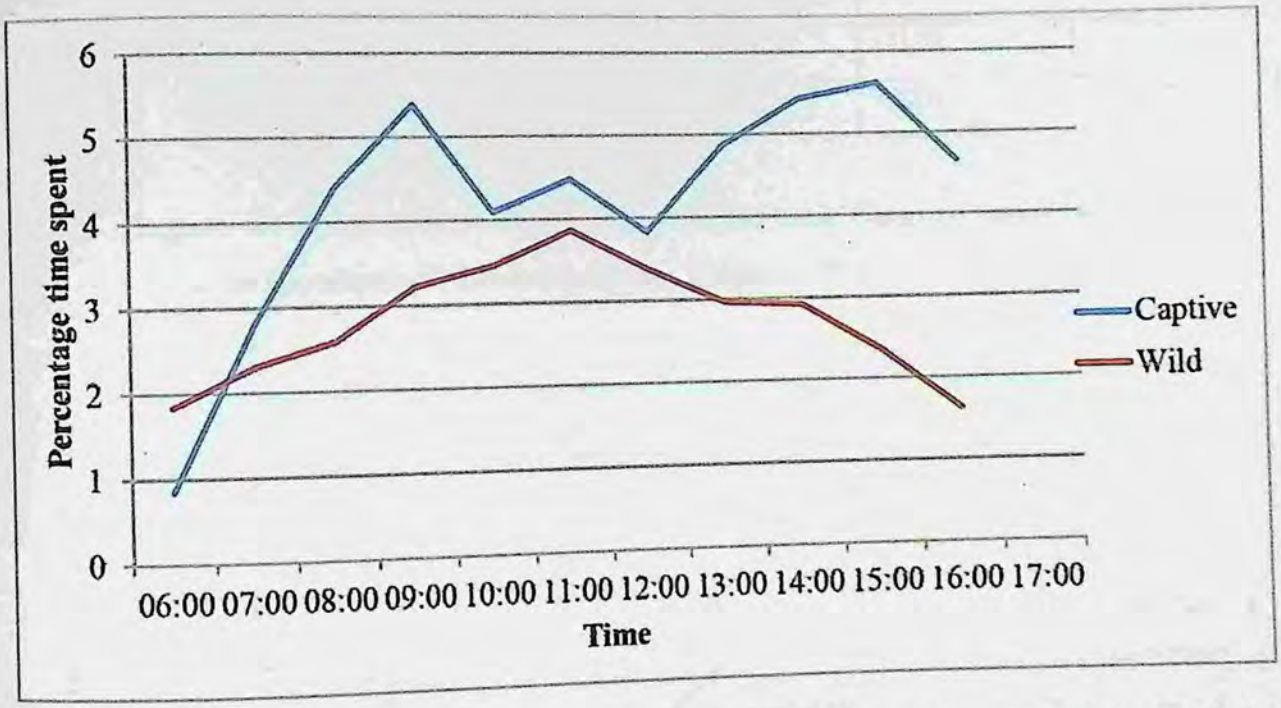
Figure 41: Moving pattern of the Phayre's leaf monkey in captivity and free-ranging condition across time (December 2014-March 2015).



4. RESTING

The wild troop displayed a single evident peak in resting during the noon whereas the captive troop showed three such peaks distributed throughout the day. The chi square test gave significant differences in time spent on resting by the two troops (χ^2 =286.09, p=<0.05) (Figure 42).

Figure 42: Resting pattern of the Phayre's leaf monkey in captivity and free-ranging condition across time (December 2014-March 2015).



Significant differences were obtained with chi square calculations for comparing the major activity patterns (feeding, sleeping and moving) of the Phayre's leaf monkey in the captive and wild settings across the same time period (0600-1700 hrs).

Table 7: Chi square values depicting significant differences in major activities across time, between members of the free-ranging and captive troops in Sepahijala Wildlife Sanctuary, Tripura (December 2014- March 2015).

Category	Sub-category	Feeding		Sleeping		Moving	
		χ^2	p value	χ^2	p value	χ^2	p value
Sex classes	Males	229.6	<0.05	134.34	<0.05	27.76	0.001
	Females	506.56	<0.05	301.42	<0.05	62.33	<0.05
Age classes	Adults	425.25	<0.05	338.95	<0.05	28.253	0.001
	Sub-Adults	279.19	<0.05	82.11	<0.05	31.61	0.000
	Juveniles	228.62	<0.05	183.66	<0.05	43.39	<0.05

Figure 43: Comparative feeding pattern of the male Phayre's leaf monkey across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

Figure 44: Comparative sleeping pattern of the male Phayre's leaf monkey across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

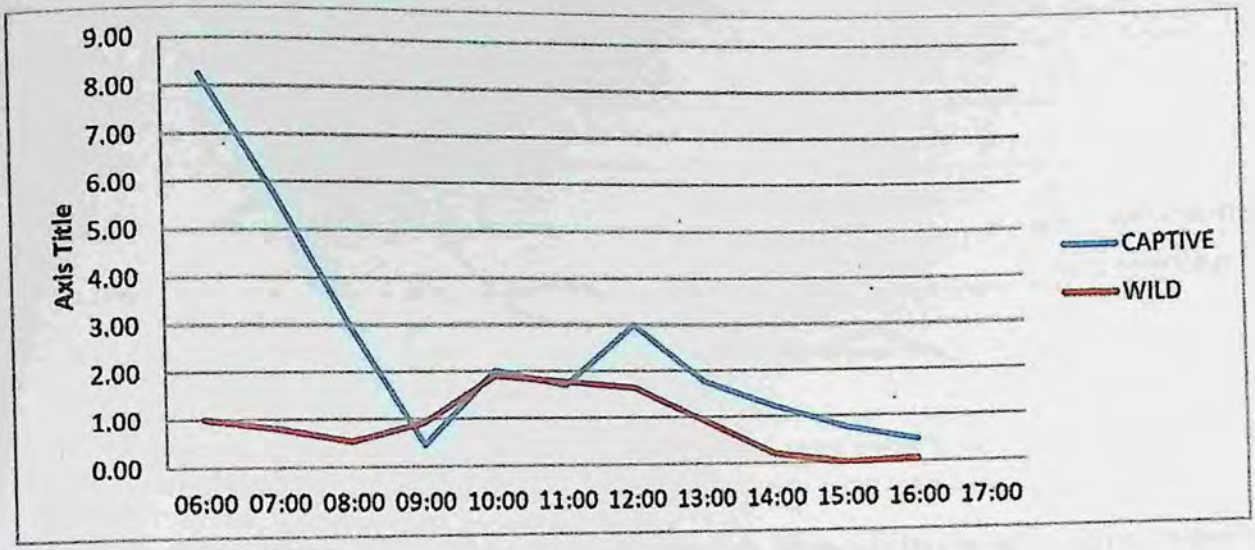


Figure 45: Comparative moving pattern of the male Phayre's leaf monkey across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

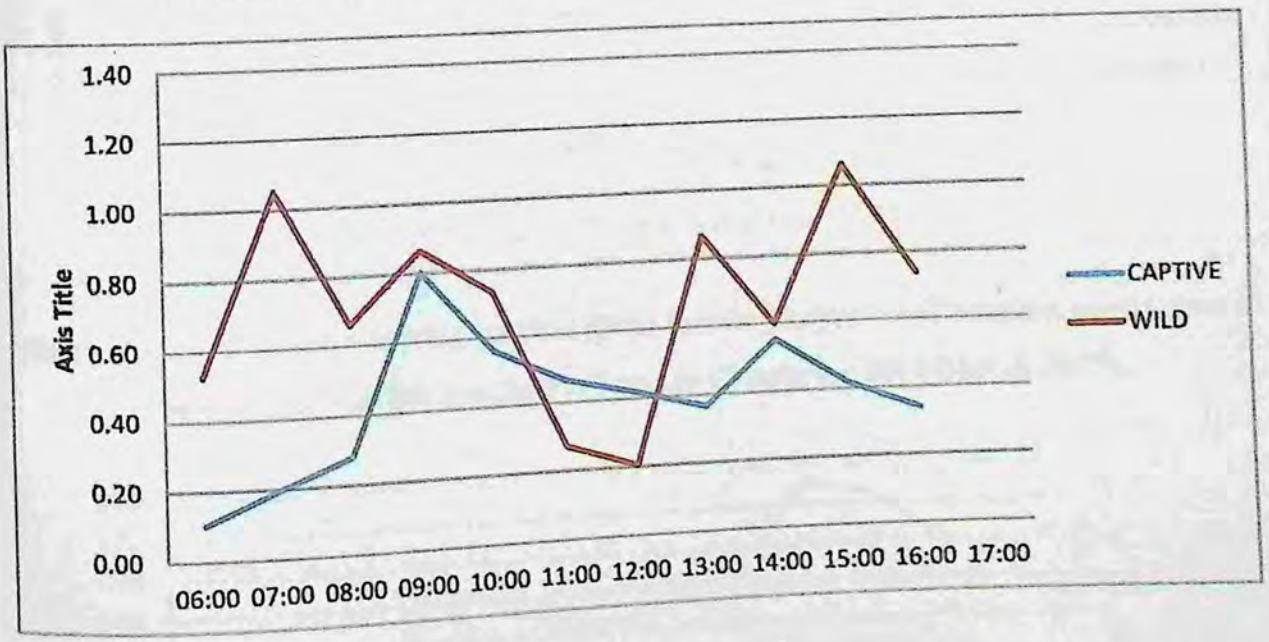


Figure 46: Comparative feeding pattern of the female Phayre's leaf monkey across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

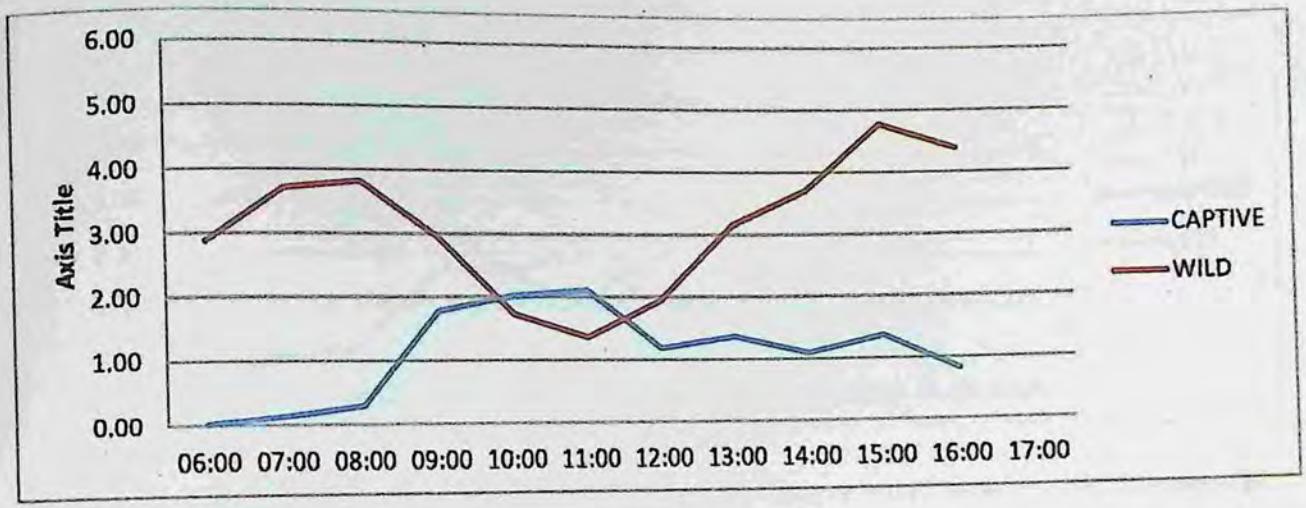


Figure 47: Comparative sleeping pattern of the female Phayre's leaf monkey across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

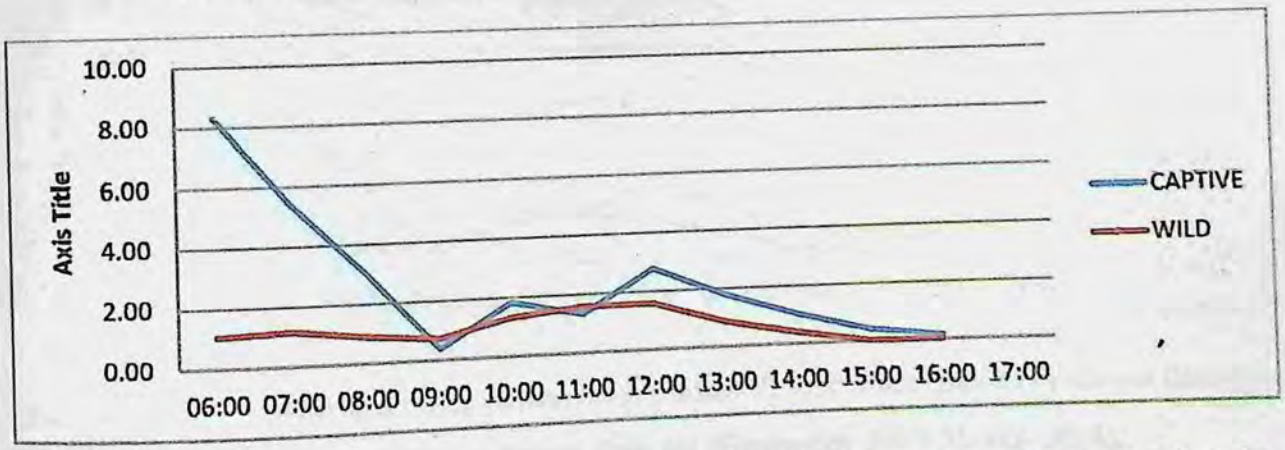


Figure 48: Comparative moving pattern of the female Phayre's leaf monkey across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

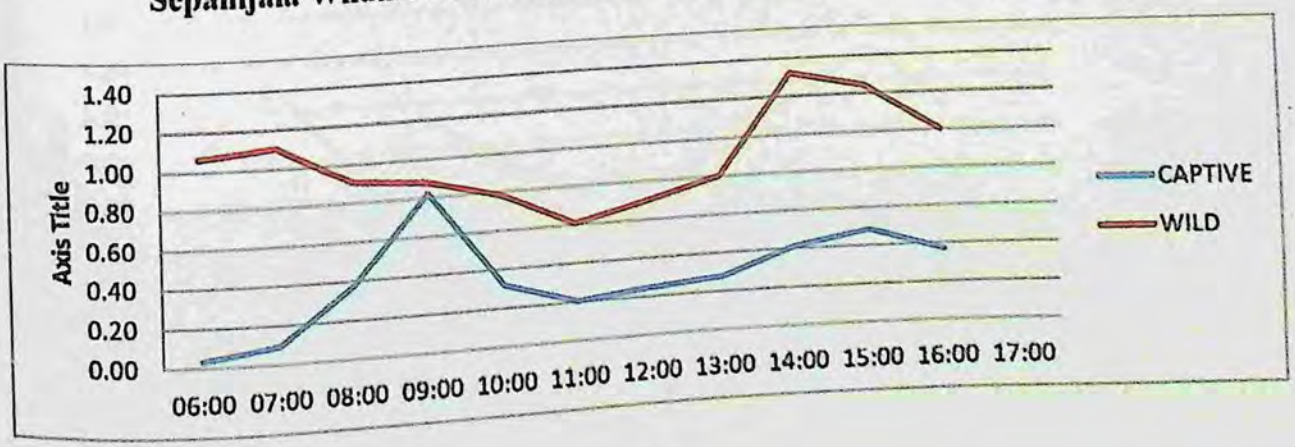


Figure 49: Comparative feeding pattern of the adult Phayre's leaf monkeys across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

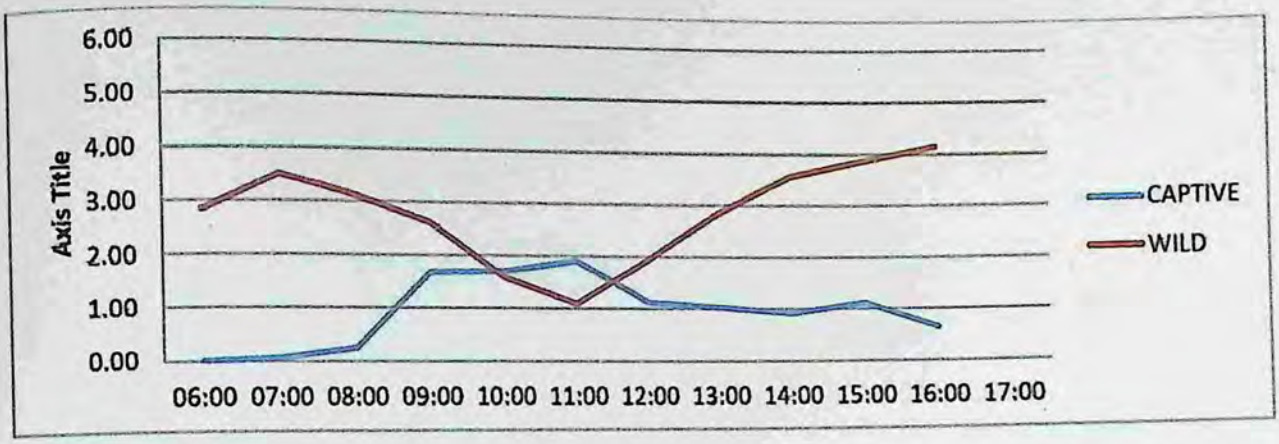


Figure 50: Comparative sleeping pattern of the adult Phayre's leaf monkeys across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

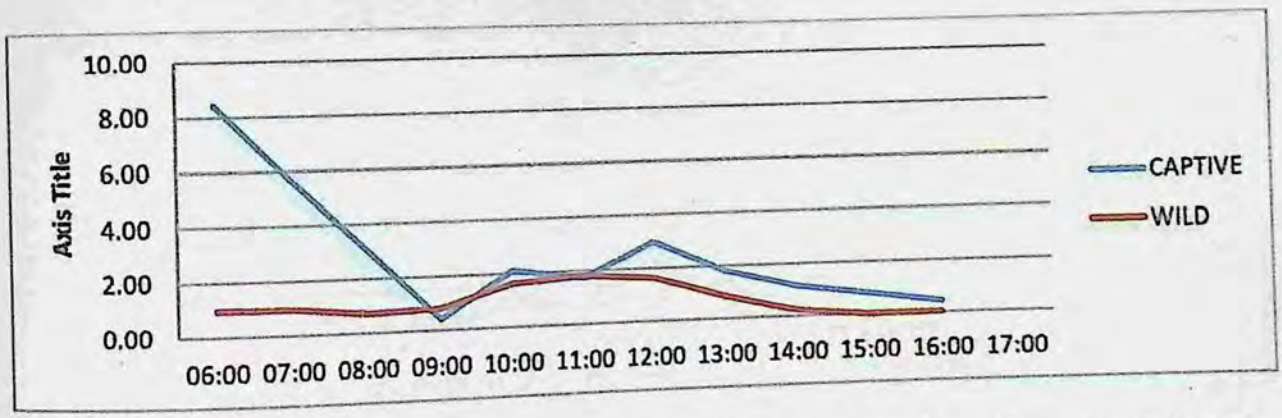


Figure 51: Comparative moving pattern of the adult Phayre's leaf monkeys across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

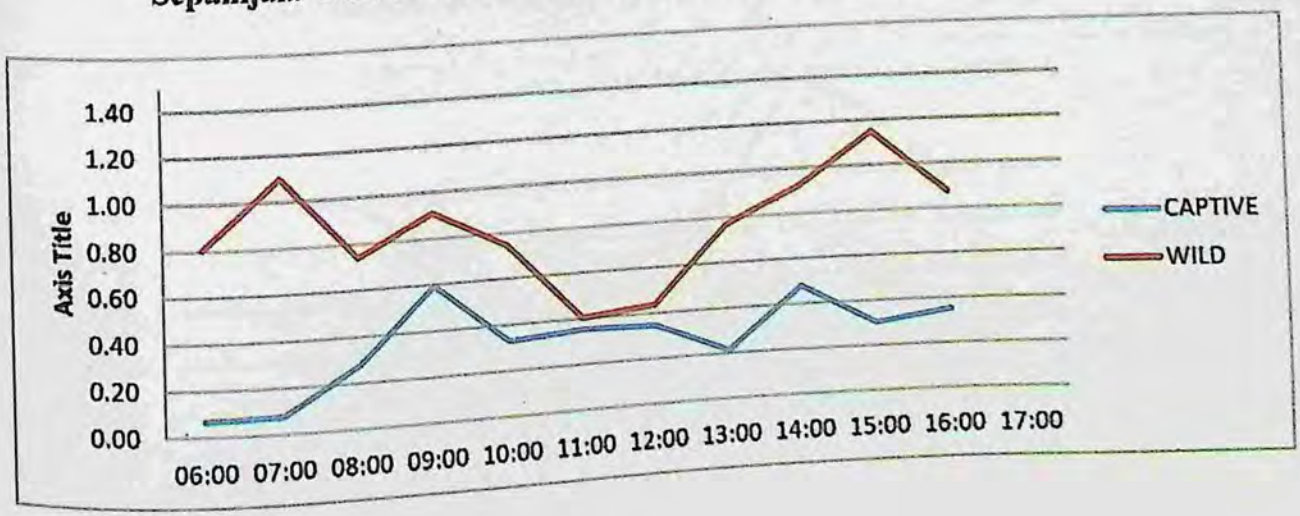


Figure 52: Comparative feeding pattern of the sub-adult Phayre's leaf monkeys across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

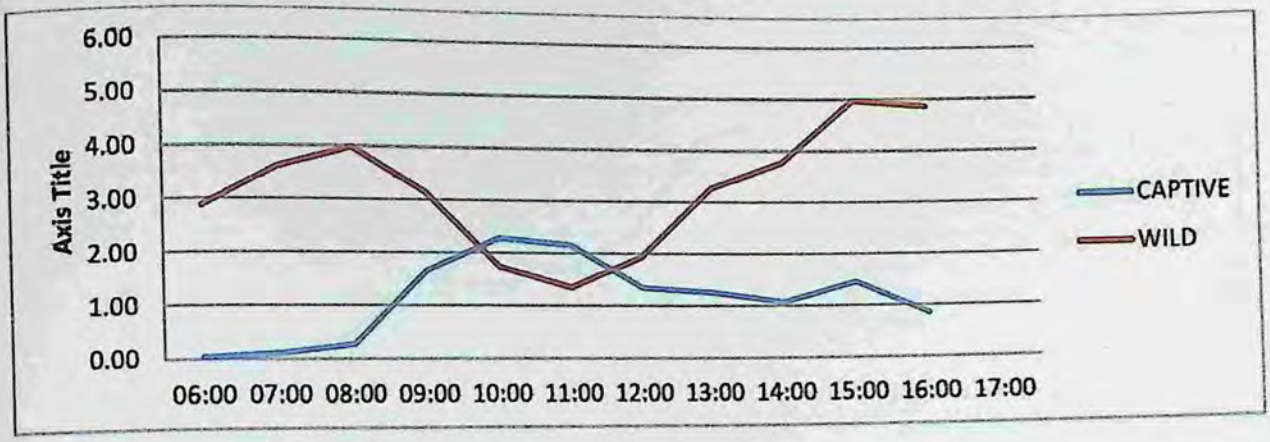


Figure 53: Comparative sleeping pattern of the adult Phayre's leaf monkeys across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

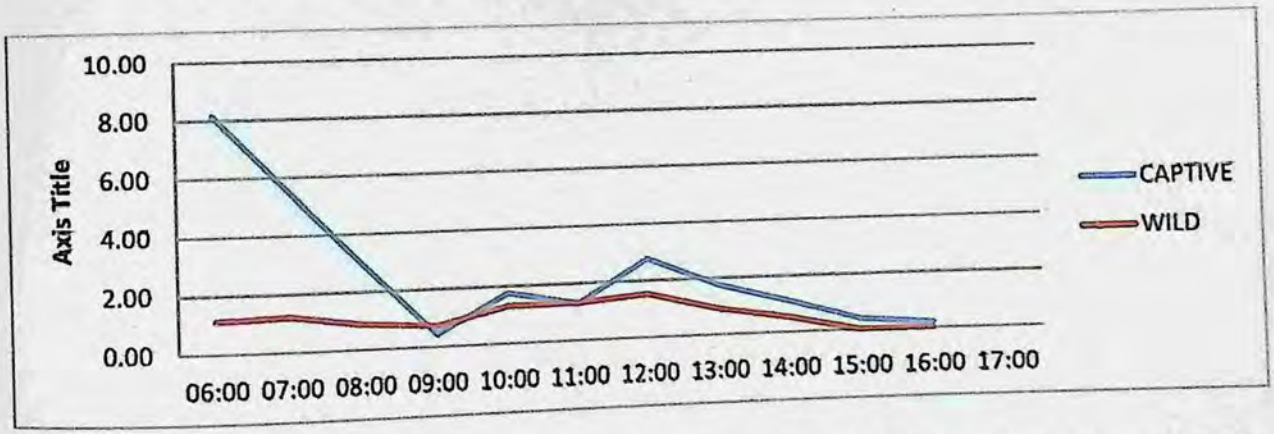


Figure 54: Comparative moving pattern of the adult Phayre's leaf monkeys across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

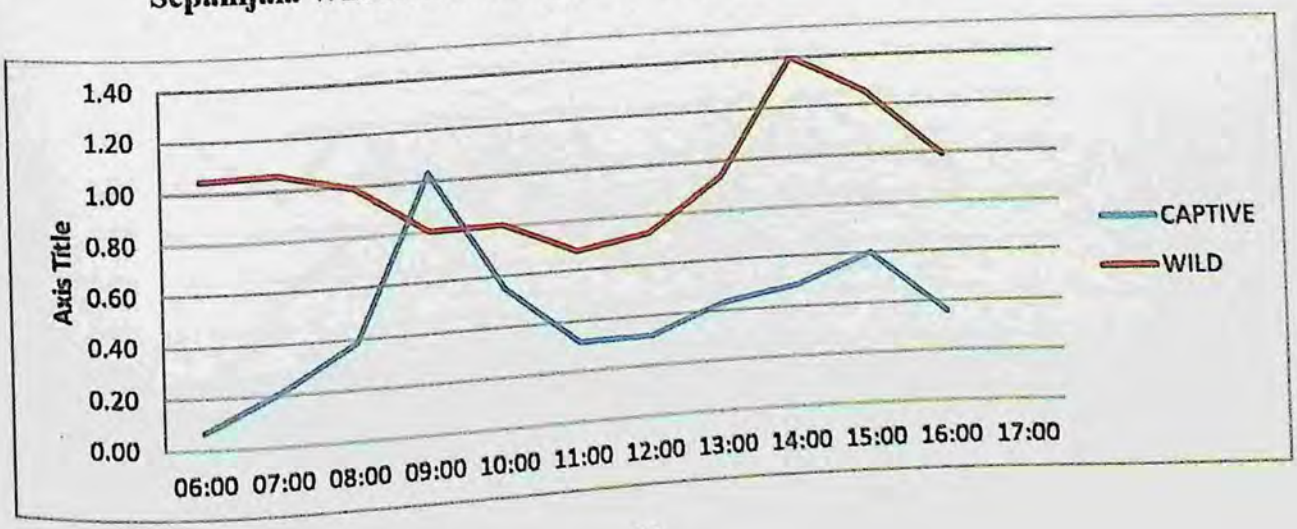


Figure 55: Comparative feeding pattern of the juvenile Phayre's leaf monkeys across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

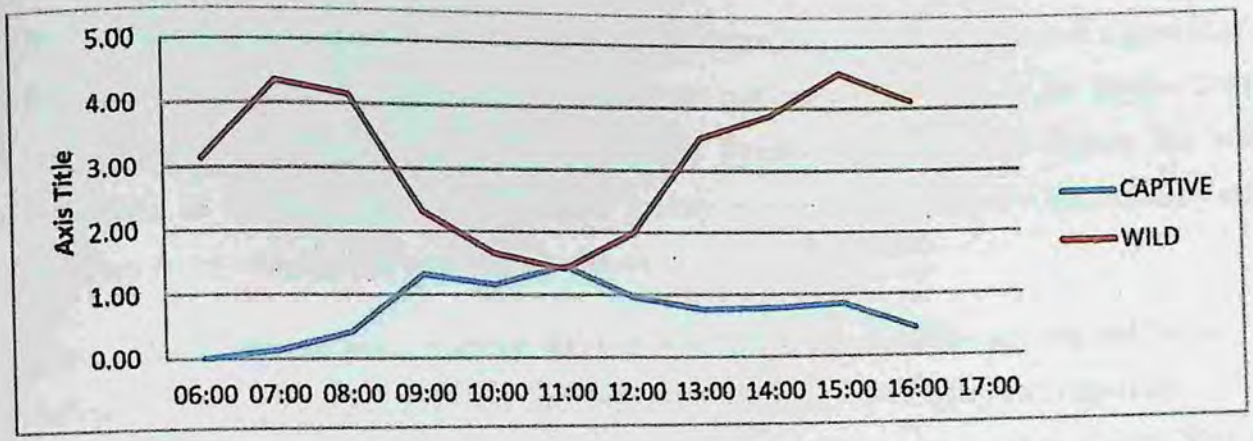


Figure 56: Comparative sleeping pattern of the adult Phayre's leaf monkeys across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).

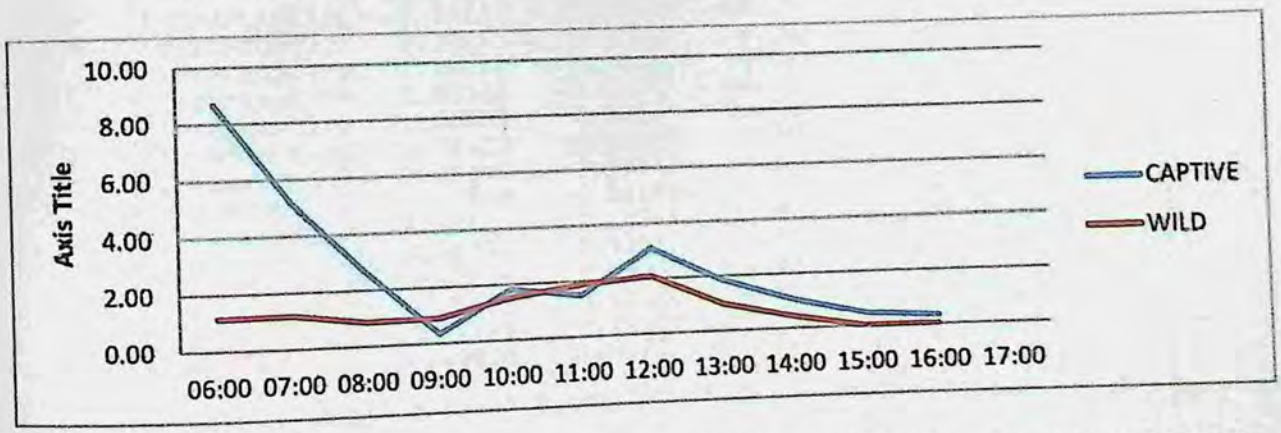
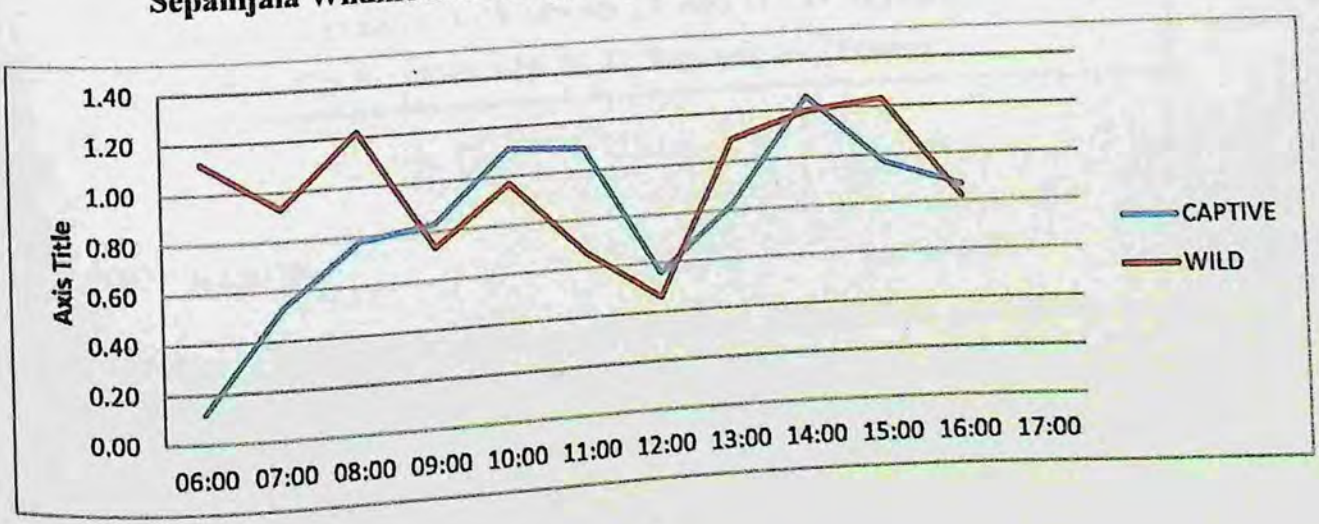


Figure 57: Comparative moving pattern of the adult Phayre's leaf monkeys across time in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015).



Using the R package VGAM (Yee, 2010), it was established that there was not much difference observed in activity patterns within the members of the same troop in the wild and in captivity. But on comparing the values of the activity patterns across the two troops, there was a significant difference observed which implies that the time spent carrying out activities by the captive troop was significantly different from that of the wild troop (Figure 58). This rejects the null hypothesis of the study thus stating that the activity patterns of the Phayre's leaf monkey are different in free ranging and captivity conditions.

Figure 58: R software using package VGAM showing significant differences in the 13 pre-defined activity patterns across the two different settings (Free-ranging and captivity conditions) in the Sepahijala Wildlife Sanctuary, Tripura (December 2014 to March 2015)

```
Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept):1 -1.59754    0.01839  -86.85   <2e-16 ***
(Intercept):2  0.21855    0.01517   14.40   <2e-16 ***
(Intercept):3  1.19167    0.01717   69.42   <2e-16 ***
(Intercept):4  1.69546    0.01957   86.64   <2e-16 ***
(Intercept):5  2.00083    0.02159   92.69   <2e-16 ***
(Intercept):6  2.21120    0.02326   95.08   <2e-16 ***
(Intercept):7  2.71444    0.02832   95.85   <2e-16 ***
(Intercept):8  2.97738    0.03165   94.08   <2e-16 ***
(Intercept):9  3.00553    0.03204   93.82   <2e-16 ***
(Intercept):10 3.01412    0.03216   93.74   <2e-16 ***
(Intercept):11 3.13676    0.03393   92.46   <2e-16 ***
(Intercept):12 5.60518    0.11020   50.87   <2e-16 ***
(Intercept):13 5.61734    0.11086   50.67   <2e-16 ***
GROUP[T.W]     0.49836    0.02285   21.81   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Number of linear predictors:  13

Dispersion Parameter for cumulative family:   1

Residual deviance: 4879.604 on 12 degrees of freedom

Log-likelihood: -2521.681 on 12 degrees of freedom
```

6.4 FOOD HABITS

The free-ranging Phayre's leaf monkeys were observed feeding on 38 plant species belonging to 24 families throughout the study period based on scan observations as well as casual observations (Table 8). The family Moraceae comprised majority of the species. The primates

were observed feeding on a range of food items such as stems, petioles, young leaves, mature leaves, flower buds, flowers, young fruits, mature fruits and seeds. The monkeys were also seen feeding on termites in four different occasions.

Table 8: List of food items and parts observed being consumed by the Phayre's leaf monkey in Sepahijala Wildlife Sanctuary (December 2014-March 2015).

S.No.	Scientific name	Family	Parts eaten
1	*Acacia auriculiformis*	Fabaceae	mature leaves
2	*Albizia procera*	Mimosaceae	seeds from pods
3	*Aquilaria malaccensis*	Thymelaeaceae	fruits
4	*Artocarpus chaplasha*	Moraceae	young leaves, inflorescence
5	*Artocarpus lakoocha*	Moraceae	leaf petiole
6	*Bombax ceiba*	Bombacaceae	flower buds (whole)
7	*Croton roxburghii*	Euphorbiaceae	young leaves
8	*Cymbidium aloifolium*	Orchidaceae	mature leaves
9	*Delonix regia*	Fabaceae	leaves
10	*Dillenia pentagyna*	Dilleniaceae	Flower buds
11	*Elaeocarpus floribundus*	Elaeocarpaceae	young leaves
12	*Beilschhmiedia spp.*	Elaeocarpaceae	young flowers, fruits and leaves
13	*Engelhardtia spicata*	Juglandaceae	young flowers
14	*Ficus fistulosa*	Moraceae	fruits
15	*Ficus nervosa*	Moraceae	young fruits
16	*Ficus racemosa*	Moraceae	young fruits (inner=white)
17	*Ficus spp.*	Moraceae	young fruits
18	*Ficus virens*	Moraceae	young leaves
19	*Hevea brasiliensis*	Euphorbiaceae	young leaves
20	*Lannea coromandalica*	Anacardiaceae	flowers
21	*Lindera nacusua*	Lauraceae	young fruits
22	*Litsea glutinosa*	Lauraceae	young leaves
23	*Litsea monopetala*	Lauraceae	young leaves

24	*Macrosolen cochinchinensis*	Loranthaceae	young leaves
25	*Merremia hirta*	Convolvulaceae	young leaves
26	*Meyna spinosa*	Rubiaceae	mature leaves
27	*Schima wallichi*	Theaceae	young leaves
28	*Spatholobus parviflorus*	Fabaceae	seeds
29	*Sterculia villosa*	Malvaceae	stalk of flowers
30	*Terminalia arjuna*	Combretaceae	mature leaves
31	*Terminalia bellirica*	Combretaceae	inner stem; fruits
32	*Tinosporia cordifolia*	Menispermaceae	inner stem
33	*Toona ciliata*	Meliaceae	young leaves
34	*Trema orientalis*	Ulmaceae	young and mature leaves
36	*Trichosanthes spp*	Cucurbitaceae	mature leaves
37	*Gynocardia odorata*	Bixaceae	young flowers, mature leaves, young leaves
38	*Stereospermum personatum*	Bignoniaceae	young leaves
39	Termites		

Based on scan observations, the plant species and part that was most consumed i.e. >5% of the total diet by the wild troop of the Phayre's leaf monkey are given in Table 9. The tree species *Gynocardia odorata* comprised major part of the diet of the wild troop (16.64%) with the flower buds and flower part mainly being consumed. This was followed by the mature fruits of *Terminalia belerica* (16.02%).

Table 9: Plants species most eaten (>5 times) by Phayre's leaf monkey

S.NO.	SPECIES	% FEEDING
1	*Gynocardia odorata*	16.64
2	*Terminalia belerica*	16.02
3	*Beilschmiedia spp.*	14.72
4	*Croton roxburghii*	6.62
5	*Ficus racemosa*	5.41
6	*Artocarpus chaplasa*	5.04

On comparing the nutritional parameters of the food items consumed by the Phayre's leaf monkeys in captivity and the wild, significant differences were established among five parameters out of the six evaluated. The six parameters considered for comparison were crude protein (CP), Neutral Detergent Fibre (NDF), Calcium, Phosphorous (P), Iron (Fe) and Zinc (Zn). The remaining parameters were not compared due to time constraints and lack of information on the same category of food items offered in captivity.

The independent samples t-test taking into account Levene's test for equality of variances was used to understand homogeneity of variance. Accordingly, the results were interpreted which implied that there were significant differences in the nutritional make-up of the food items in the two different set-ups (captive and wild). Calcium (t= -3.219, sig. two tailed=0.002), Iron (t= -5.458, sig. two tailed=0.000), Zinc (t= -4.942, sig. two tailed=0.000) and NDF (t= -8.237, sig. two tailed=0.000) gave significant differences when all the food items were considered both in the wild and in captivity. However, crude protein (t= -0.731, sig. two tailed=0.480) and Phosphorous (t= -2.316, sig. two tailed=0.030) did not seem to be significantly different between both the settings.

Figure 59: Box plots for Calcium(Ca) and Phosphorous (P) content in food items in wild and in captivity at Sepahijala Zoological Park, Tripura (December 2014- March 2015)

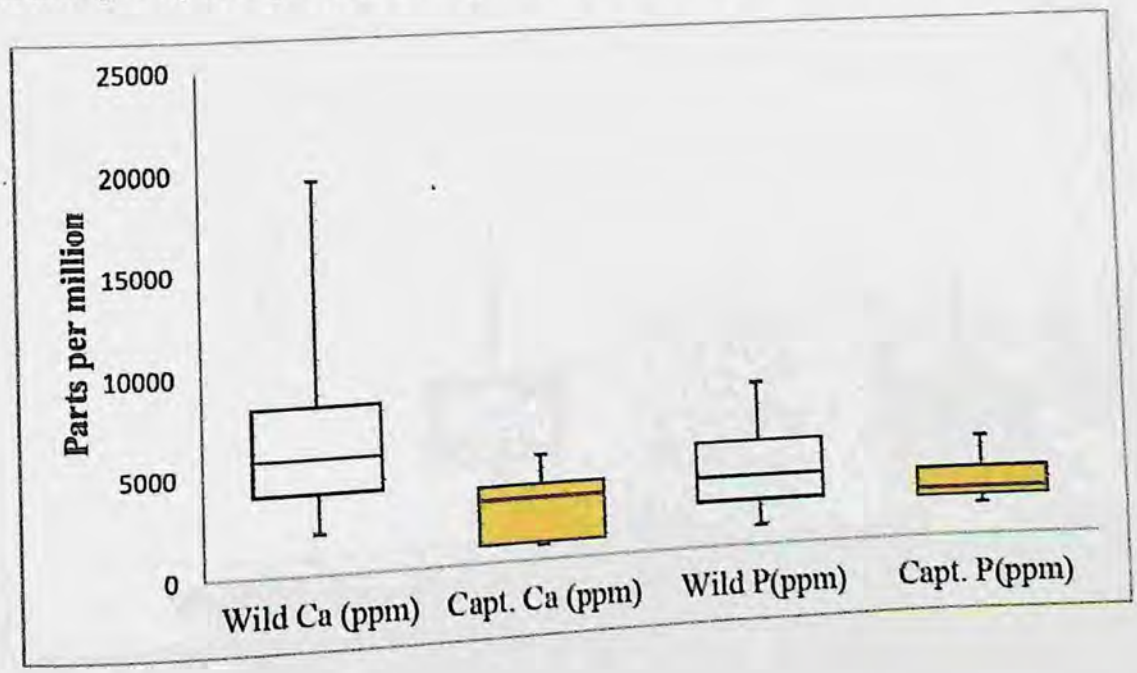


Figure 60: Box plots for Iron (Fe) and Zinc (Zn) content in food items in wild and in captivity at Sepahijala Zoological Park, Tripura (December 2014- March 2015)

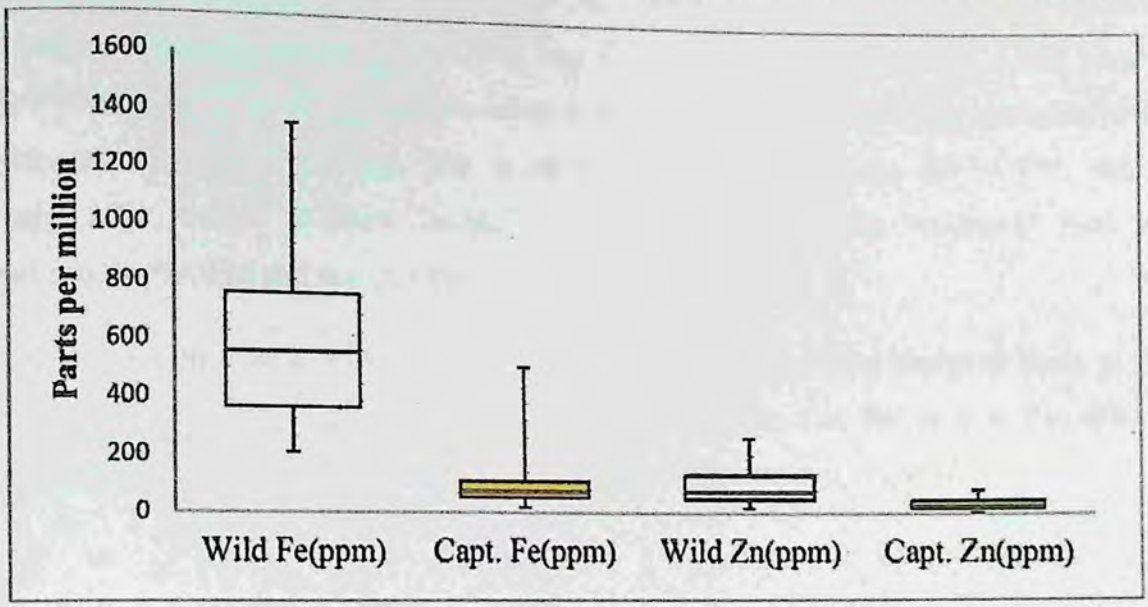
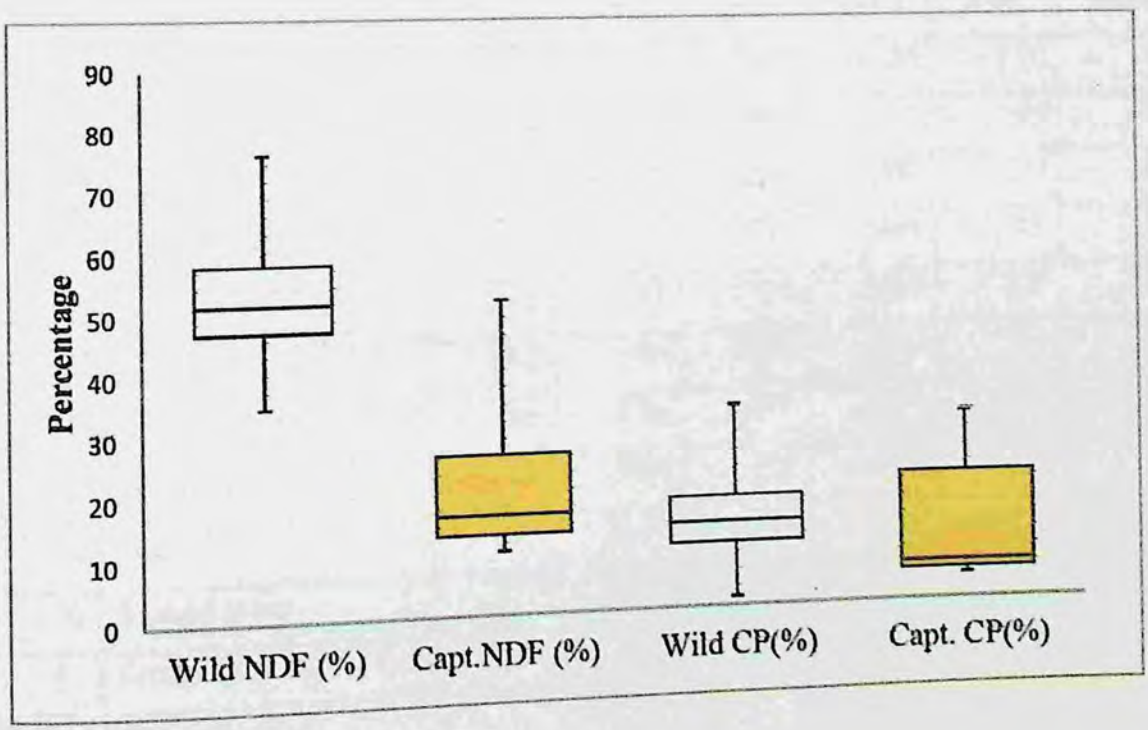


Figure 61: Box plots for Neutral Detergent Fibre (NDF) and Crude Protein (CP) content food items in wild and in captivity at Sepahijala Zoological Park, Tripura (December 2014- March 2015)



On comparing the same parameters with the top six plant species consumed in the wild (Table 11) and all the food items in captivity (Table 10), there were significant differences observed in the composition of Calcium (t= -4.492, sig. two tailed=0.000), Iron (t= -4.092, sig. two tailed=0.001), Zinc (t= -2.523, sig. two tailed=0.020) and NDF (t= -4.988, sig. two tailed=0.000). Crude protein (t= -0.388, sig. two tailed=0.706) and Phosphorous (t= -1.571, sig. two tailed=0.132) seemed to show insignificant differences across the variety of food items consumed in the wild and in captivity.

Therefore, barring crude protein and phosphorous, other parameters analysed seem to differ significantly in terms of nutrient composition which implies that the captive diet offered is significantly different or deficient in the nutrients than those eaten in the wild.

Table 10: Nutritional content of food items offered to the captive Phayre's leaf monkeys in Sepahijala Zoological Park (December 2014-March 2015)

S. No.	Food item	NDF (%)	CP (%)	Ca (ppm)	P (ppm)	Fe (ppm)	Zn (ppm)
1	Apple	17.5	4.99	900	1600	110	34
2	Banana	12.5	5.12	900	1700	60	25
3	Beans	22.5	26.47	5200	3300	110	51
4	Bottle gourd	36.4	4.11	4300	2400	85	32
5	Carrot	10.5	9.27	1800	2300	216	31
6	Cucumber	15.2	5.88	3100	1900	74	11
7	Grapes	NA	6.74	800	3600	42	8
8	Mosambi	13.2	5.04	800	2100	22	21
9	Pea	NA	25.23	3700	4400	74	49
10	Soaked gram	27.5	31.42	3500	2600	50	65
11	*Careya arborea* - YL	51.18	NA	3887.00	5000.00	513.90	84.40

*Source (Das et al. 2013)

Table 11: Nutritional content of food items consumed by the free-ranging Phayre's leaf monkeys in Sepahijala Wildlife Sanctuary, Tripura (December 2014-March 2015)

S. No.	Plant species	Plant part	NDF (%)	CP (%)	Ca (ppm)	P (ppm)	Fe (ppm)	Zn (ppm)	Na (ppm)	K (ppm)	Mg (ppm)	ADF (%)	Lignin (%)	Tannin (%)
1	*Acacia auriculiformis*	ML	51.22	8.87	13023.00	1750	652.20	23.70	286.00	2468.00	4155.00	39.24	13.81	11.01
2	*Albizia procera*	seeds	55.16	15.67	4596.00	5250	618.30	135.10	469.00	25920.00	5176.00	38.66	14.55	0.08
3	*Artocarpus chaplasha*	YL	41.21	12.96	7915.00	3000	343.70	23.00	327.00	20570.00	8139.00	46.38	15.56	2.50
4	*Artocarpus lakoocha*	petiole	51.33	4.28	18342.00	1000	932.80	223.40	318.00	8336.00	11620.00	46.44	13.22	3.00
5	*Artocarpus lakoocha*	inflorescence	47.19	12.59	2591.00	3500	529.20	48.60	145.00	14425.00	1482.00	44.27	10.06	0.50
6	*Beilschmiedia roxburghiana*	YL	47.65	19.81	4531.00	4500	802.40	266.40	286.00	11238.00	1752.00	47.62	14.12	7.50
7	*Beilschmiedia roxburghiana*	FL	54.21	17.11	6871.00	4250	429.40	74.80	194.00	11539.00	2269.00	40.02	17.65	6.00
8	*Beilschmiedia roxburghiana*	YF	51.64	13.78	4182.00	5250	449.00	67.60	130.00	15315.00	3498.00	43.12	14.76	4.50
9	*Bombax ceiba*	FB	58.21	18.12	8637.00	5250	1358.00	175.70	816.00	15930.00	3293.00	39.96	11.34	3.50

10	*Croton roxburghii*	YL	61.38	13.25	2610.00	2250	257.80	43.20	149.00	6141.00	2161.00	36.44	15.31	2.04
11	*Cymbidium aloifolium*	ML	42.38	1.51	12551.00	1000	758.90	108.00	410.00	7227.00	6257.00	42.38	13.21	0.04
12	*Delonix regia*	ML	41.17	23.50	19530.00	6750	885.50	46.10	1470.00	7880.00	3643.00	36.51	7.19	17.00
13	*Dillenia pentagyna*	FB	63.29	15.78	2873.00	4750	761.40	249.30	186.00	26360.00	2725.00	40.07	12.13	3.50
14	*Elaeocarpus floribundus*	YL	53.28	12.22	4434.00	3750	319.90	31.50	315.00	5667.00	2312.00	47.23	12.29	4.50
15	*Engelhardtia spicata*	FL	67.27	14.58	4330.50	5875	479.50	44.40	549.00	11571.50	2259.50	43.34	14.48	2.25
16	*Ficus nervosa*	YF	51.27	9.03	14730.00	3000	414.30	62.40	282.00	16825.00	4159.00	49.83	12.31	4.50
17	*Ficus racemosa*	YF	45.42	14.39	8104.00	7500.	320.70	69.10	643.00	24080.00	3902.00	41.96	16.19	2.50
18	*Ficus spp.*	YF	44.63	28.04	2882.00	5000	363.90	22.00	193.00	8997.00	2848.00	42.81	12.09	0.01
19	*Ficus virens*	YL	51.23	21.79	3165.00	7000	652.10	262.50	135.00	11264.00	2975.00	38.15	13.63	0.06
20	*Gynocardia odorata*	FB	43.69	18.20	9293.00	6000	287.50	64.70	546.00	15190.00	3717.00	43.13	31.65	0.50
21	*Gynocardia odorata*	YL	44.65	14.87	3778.00	3250	1087.00	91.50	212.00	9347.00	4270.00	35.79	15.59	0.05
22	*Gynocardia odorata*	ML	75.86	6.84	9065.00	1750	545.70	76.00	693.00	6519.00	2868.00	42.55	18.88	2.00

23	*Hevea brasiliensis*	YL	51.67	32.24	2845.00	8250	781.80	146.50	237.00	11744.00	2515.00	49.23	12.21	0.09
24	*Lannea coromandalica*	FL	58.23	12.11	2037.00	2500	207.00	53.00	166.00	6241.00	1696.00	41.73	15.73	3.50
25	*Lindera nacusua*	FR	44.86	15.75	6044.00	1750	305.00	49.80	671.00	8505.00	2406.00	47.11	11.96	9.50
26	*Litsea glutinosa*	YL	55.33	24.88	2903.00	6000	563.30	178.30	239.00	9219.00	1545.00	43.88	15.12	0.03
27	*Litsea monopetala*	YL	50.99	13.51	8360.50	2375	1003.80	101.10	413.50	9300.00	2461.50	43.33	17.35	20.51
28	*Merremia hirta*	YL	47.73	11.21	4289.00	1750	673.45	85.65	256.50	7873.00	3079.50	42.62	14.17	4.26
29	*Meyna spinosa*	ML	61.28	14.76	6946.00	1750	602.50	89.30	254.00	10407.00	4646.00	35.36	12.35	2.50
30	*Schima wallichi*	YL	76.28	17.69	4128.00	6750	402.60	147.20	553.00	14140.00	1783.00	35.27	7.79	4.50
31	*Spatholobus parviflorus*	seeds	58.24	29.64	4357.00	5750	924.60	54.10	900.00	7359.00	3228.00	46.84	16.92	10.00
32	*Sterculia villosa*	FL stalks	57.34	6.90	5727.00	2750	237.20	115.00	670.00	23270.00	4853.00	43.26	10.72	9.00
34	*Terminalia arjuna*	ML	53.12	3.94	7733.00	2250	588.90	93.20	232.00	13810.00	5839.00	41.69	15.73	7.50
35	*Terminalia bellirica*	YF	34.92	11.28	9272.00	3000	933.40	67.90	881.00	16135.00	1710.00	35.11	11.77	0.50
36	*Terminalia bellirica*	stems	68.11	9.50	10930.00	1500	269.70	183.70	826.00	9519.00	4032.00	42.54	17.38	BDL

37	*Tinosporia cordifolia*	stems	47.31	9.95	8220.00	3750	984.40	46.10	749.00	16115.00	2180.00	41.28	13.08	BDL
38	*Toona ciliata*	YL	51.88	18.32	4552.00	2750	558.90	50.20	191.50	6663.50	2698.50	47.30	12.19	0.28
39	*Trema orientalis*	YL	47.38	13.95	6904.00	2250	553.80	58.10	257.00	5985.00	3821.00	52.19	13.21	10.02
40	*Trichosanthes spp.*	ML	45.23	10.03	3736.00	2000	387.50	50.20	180.00	5322.00	2278.00	44.29	11.21	0.06
41	*Termites*		59.24	33.43	6282.00	5250	645.80	133.80	1605.00	20045.00	2518.00	68.73	9.77	BDL

*ML= Mature Leaf, YL= Young Leaf, FB= Flower Bud, FL= Flower, YF= Young Fruit, BDL= Below Detection Level

6.5 PHENOLOGY

Phenological behaviour of tree species:

1. *Acacia auriculiformis*

   An evergreen tree (*Akashmuni*), the species did not show any flowering or fruiting in the weeks that it was observed during the study period.

2. *Aquilaria malaccensis*

   Locally known as *Agar*, also an evergreen tree, the species showed no initiation of flowering or fruiting throughout the time span for observations.

3. *Artocarpus chaplasha*

   A deciduous tree, *A. chaplasa* locally known as *Chamal* displayed mature leaves for initial eight weeks of observation. The ninth week onwards, it began shedding and by week 10, it started flowering. Week 11 showed an increased growth and sprouting of new leaves.

4. *Bombax ceiba*

   Locally called *Semul*, The species had already shed for the season and displayed budding and flowering in the initial weeks of observation. It began fruiting from week 3 and towards the end of the study period, i.e. week 12, the fruits had begun to mature.

5. *Delonix regia*

   A deciduous tree, this species displayed mature leaves from the beginning of the observation period and gradually turned towards shedding although complete shedding of the leaves was not observed in the individuals marked. Locally called as *Krishnachura*, out of the six tagged individuals, only two showed matured fruits (pods) throughout the study period while the rest had already shed.

6. *Dillenia pentagyna*

   A tall deciduous species, commonly known as *Hargaza* in the local language, it was at its peak of shedding as the mature leaves were ready to shed. Week 9 marked the initiation of

shedding whereas by week 12 all leaves had shed. Flowering began in Week 9 of the observation period.

7. *Engelhardtia spicata*

A deciduous species, it had initiated flowering before the observations began. Week 4 marked complete flowering with mature leaves.

8. *Syzygium cumini*

S. cumini also locally called as *Jam*, an evergreen tree species displayed mature leaves till week 6 of ocular observations. Week 7 witnessed the sprouting of young leaves over the crown. Week 11 was marked by flowering.

9. *Terminalia bellirica*

Bohera as the locals call it is a tall deciduous tree. It bore mature leaves and semi- mature fruits which gradually shed over the weeks. By week 12, the species bore no fruits. Week 10 marked the shedding of the mature leaves whereas week 11 was observed sprouting new leaves.

10. *Gynocardia odorata*

An evergreen species, it began flowering in the second week of the observations (January 2015). Week 7 was marked by sprouting of new leaves and week 9 saw the flowering of the buds.

Phenology and environmental factors:

The minimum and maximum temperatures for the study area were recorded during January 2015 to April 2015. The temperature ranged from 35.2°C to 10°C during the study period. The relative humidity was ranged from 99% to 31%. The annual rainfall recorded for the study period (January 2015-April 2015) was 79.7 mm. April was the wettest month in the region. The eaten food plants and parts of Phayre's leaf monkeys in Sepahijala Wildlife Sanctuary were as per the available phenophases (vegetative and reproductive) of the monitored food plants.

7. DISCUSSION

The activity budgets of the Phayre's leaf monkey in general and all the age and sex classes in particular showed that the major activity in captivity was resting followed by sleeping and feeding. The juveniles showed heightened activity of playing in comparison to the other age classes. In terms of activity distribution through the day, all showed similar pattern in feeding as it was controlled.

There seemed to be no significant difference in the activity budgets of the captive Phayre's leaf monkeys during visitor and non-visitor days (χ^2 =0.365, p=1) thereby indicating that the animals were used to human presence.

There were often, instances of aggressive behavior amongst the sub-adult males and adult male as well as sub-adult male and adult females especially during times of feeding. Towards the end of the study period, a fight ensued between the captive sub-adult males rendering one of them a deep wound. The injured primate was isolated in order for his wound to heal. The adult male in the troop spent almost 32% of his time sleeping, highest among all the other individuals. Taking into account comments made by numerous studies, this could be the result of absence of proper environmental and social stimuli where the captive animals develop behavioral pathologies (Anderson and Chamove 1980, 1985; Chamove et al. 1984; Marriner and Drickamer 1994; Rendall and Taylor 1991). Another reason for such behaviour could also be attributed to abnormal compositions in group housing of the primates which give rise to abnormalities in their behavioral repertoire (Reinhardt et al. 1987; Rendall and Taylor 1991; Reinhardt et al. 1996).

In terms of the activity budgets of the monkeys obtained from the wild, the observations seemed to be similar to those obtained by Gupta and Kumar (1993) with respect to feeding. However, time spent resting was higher and time spent travelling was lower in the studied troop at Sepahijala Wildlife Sanctuary, Tripura. This could be attributed to the reason that the species was followed throughout a particular season only whereas the data compiled by Gupta and Kumar consist of all seasons (winter, summer and monsoon).

On comparing the activity budgets and patterns between the captive and free-ranging troop, significant differences were observed. This highlights the crux of the study which emphasizes the

conservation of wild-like behavior in captivity. A first line of defense, behavior of an animal indicates its response to any change in the environment. That is what the animals do in order to interact with, respond to, and control their environment (Mench 1998). Considering that the study species is being bred under the premises of a conservation breeding programme meant for eventual reintroduction (maybe subsequent generations) it is essential that the captive mammals be active at levels similar to those in the wild to meet the actual goal of the program (Kagan and Veasey 2010; McPhee and Carlstead 2010).

Fortunately, the captive leaf monkeys were observed to show no signs of any type of stereotypy during the study period which implies that the mammals have not yet reached a point of no return which highlights the potential to not let captivity cause irreversible damages.

Although the captive mammals observed were in an open moat it is well known that more than quantity of space offered, it is the quality that is more important (Hediger 1964; Mench and Mason 2000; Mallapur 2005; Maple 2007). Not only in terms of animal welfare but also as a measure to generate appreciation for the biological significance and need for conservation of a species, an animal's behaviour is the most powerful communicator (McPhee and Carlstead 2010).

In terms of addressing the problems usually faced while comparing the wild and captive mammals, this study successfully tackled most of the issues. Veasey et al. (1996) listed six such points namely, (1) wild animals avoiding humans which in turn would pose problematic to acquire an accurate time budget,(2) species' behavior being prone to temporal and geographic variation in relation to biotic and abiotic factors, (3) Many species being rare in the wild and in the zoo thereby making it difficult as a small sample size to locate the wild individuals in an area that truly represents their original range, (4) The observer having a considerable influence upon the results obtained (5) problems in obtaining genetically equivalent wild conspecifics, particularly with domesticated species and animals and finally (6) doubts regarding the validity of comparisons for the data of wild and captive animals been collected by different observers. In reference to the six points made, in the same order it can be said that points (1,2,4,5 and 6) have been addressed barring point (3). The free-ranging monkeys were successfully habituated and observed within their geographical range. The captive counterparts were part of the conservation

breeding initiative thereby maintaining genetic heterozygosity among themselves under the regulation of the zoo management and both the observations, in free-ranging and captivity conditions were carried out by the same observer.

The results obtained under food habits are consistent with the studies based on the feeding ecology of the Phayre's leaf monkey and other Asian colobine monkeys which talk about their dietary preferences (Curtin 1980; Davies et al. 1988; Bennett and Davies 1994; Gupta and Kumar 1994; Yeager and Kool 2000; Suarez 2013). The wild Phayre's leaf monkeys were mostly seen feeding on young leaves, fleshy immature fruits, seeds and flower parts. They were also occasionally recorded feeding on termites which contributed less than one percent of their diet throughout the study period.

Daily scans for feeding revealed that the tree species *Gynocardia odorata* comprised major part of the diet of the wild troop (16.64%) with the flower buds and flower part mainly being consumed. This was followed by the mature fruits of *Terminalia belerica* (16.02%).

In depth nutrient analysis of the food plants consumed, revealed a diverse range of composition of the positive and negative nutrients. In comparison to the data obtained for the food items offered in captivity, the wild diet showed minerals like Calcium ranging from 2037ppm (*Lannea coromandalica*) to19530 ppm (*Delonix regia*), Iron from 207ppm (*Lannea coromandalica*) to 1358 (*Bombax ceiba*) and Zinc from 22 ppm (*Ficus spp.)* to 266 ppm (*Beilschmieda roxburghiana).* This again suggests the variation in diet identifiable with the members of the genus *Trachypithecus* (Kirkpatrick 2011). Tannin ranged from 20.51% to 0.01% in the wild diet which justifies the genus' ability to break down hard-to-digest cellulose found in plants.

Apart from crude protein (CP) and phosphorous (P), other parameters (Neutral Detergent Fibre (NDF), Calcium (Ca), Iron (Fe) and Zinc (Zn)) analysed, differed significantly in terms of nutrient composition (in the captive and free-ranging setting) which implies that the captive diet offered is significantly different from that in the wild.

The captive monkeys were also observed feeding on tree barks and discarded food items such as banana peel, grape stems, orange peels and Pea pods. They were also observed foraging for plants or left-over food resources in the moated area which compelled them to feed on the ground, a phenomenon not commonly observed in the free-ranging counterparts. The times the

free-ranging Phayre's leaf monkeys were seen on the ground was only to cross-over to the other side. Both different instances of being on the ground are indicative that the captive animals may be requiring more frequent feeding than currently presented whereas the free-ranging animals may be at risk owing to discontinuity in habitat.

It is important to be familiar to the natural foods keeping in mind the conservation goal of breeding and reintroduction. Considering feeding as an example, in the first reintroduction of the golden lion tamarin (*Leontopithecus rosalia)* the captive- born animals were observed to be deficient in locomotor skills. They were neither able to orient themselves spatially nor were they able to recognize their natural foods, non-avian predators, and dangerous non-predaceous animals (Kleiman et al. 1986; Stoinski and Beck 2004). Similar problems were faced in the reintroductions of the black-and-white ruffed lemur, *Varecia variegata variegate* (Britt et al. 1999). Therefore, ability to recognize natural food and process it is of utmost importance.

Since detailed information about the range and composition of the diets of free-ranging wild animals is extremely limited (Jordan 2005) and often only generalized approximations of food items consumed is known that too derived from 'model' organisms, the present study holds an important stand to address needs of specialist feeders in both wild and captivity.

The phenological studies of the food plants of the Phayre's leaf monkey in SepahijalaWildlife Sanctuary, Tripura showed that among the species only the *Bombax ceiba* trees remained mainly leafless whereas *Acacia auriculiformis, Aquilaria malaccensis* and *Gynocardia odorata*, all evergreen species bore leaves throughout the year. Young flowers of *Gynocardia odorata* emerged in the early part of the study period (January) which formed a major food item of the leaf monkeys in the study area.

8. MANAGEMENT RECOMMENDATIONS

As in the case of the golden lion tamarins, pairing captive bred individuals with experienced wild-caught animals increased the survival rate of the reintroduced animals (Kleiman 1989) it emphasizes the importance of *in-situ* conservation in the study area, the Sepahijala Wildlife Sanctuary, Tripura. The advantage of being within its geographical area, a combined effort of conservation of the species in the wild will not only aid in the survival of the species in the wild but also in captivity.

For many, visiting the zoo will be the only opportunity to see such species. Therefore, a behaviourally healthy animal in a naturalistic enclosure doing what it does naturally in the wild like the eagle-spread fashion in which it leaps from one tree to another will help instill an appreciation for importance of conservation.

It is recommended that efforts be made to increase foraging behavior i.e. frequent ad-libitum feeding of natural food items spread throughout the enclosure which would not only keep the animals active but also increase locomotion and decrease aggressive behavior in acquiring food resources.

In terms of the wild counterparts, it would benefit them if the plant species identified are conserved or planted (as there are plans of replacing the rubber plantation as proposed in the Management plan of the study area) both in terms of availability of food resources and habitat contiguity.

As this study gives an understanding of the complexity of activities and foraging in free-ranging animals, the zoo management can increase their knowledge of the needs of the animals in captivity which in turn can enhance their expertise in conservation breeding and subsequent reintroduction in wild in its distributional ranges.

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APPENDIX I

(Standard errors for graphs plotted)

Activity pattern of major activities of the captive Phayre's leaf monkey (December 2014-March 2015).

TIME	FE	RE	SL	MO
6:00	0.01	0.11	0.11	0.02
7:00	0.03	0.27	0.28	0.09
8:00	0.04	0.45	0.17	0.10
9:00	0.09	0.39	0.04	0.10
10:00	0.21	0.33	0.17	0.15
11:00	0.13	0.34	0.16	0.17
12:00	0.09	0.30	0.12	0.06
13:00	0.14	0.40	0.06	0.12
14:00	0.08	0.43	0.08	0.16
15:00	0.12	0.29	0.14	0.12
16:00	0.08	0.37	0.10	0.10

Activity patterns of adult female in captivity (December 2014-March 2015)

TIME	FE	RE	SL	MO	AUG	ALG	ALB	AB	SB	UR.DE
6:00	0.00	0.22	0.25	0.04	0.00	0.05	0.00	0.00	0.00	0.00
7:00	0.07	0.38	0.45	0.04	0.08	0.09	0.02	0.00	0.02	0.00
8:00	0.10	0.35	0.36	0.07	0.10	0.16	0.07	0.00	0.00	0.00
9:00	0.25	0.25	0.12	0.15	0.08	0.09	0.08	0.03	0.00	0.04
10:00	0.24	0.28	0.32	0.06	0.05	0.12	0.11	0.02	0.00	0.03
11:00	0.22	0.34	0.26	0.10	0.08	0.10	0.04	0.02	0.00	0.02
12:00	0.18	0.32	0.36	0.07	0.05	0.14	0.09	0.02	0.00	0.00
13:00	0.18	0.27	0.28	0.07	0.10	0.17	0.00	0.03	0.00	0.00
14:00	0.15	0.28	0.24	0.08	0.05	0.14	0.00	0.00	0.02	0.02
15:00	0.22	0.25	0.14	0.10	0.08	0.15	0.02	0.00	0.00	0.02
16:00	0.13	0.30	0.10	0.09	0.07	0.12	0.05	0.00	0.00	0.03

Activity patterns of adult male in captivity (December 2014-March 2015)

TIME	FE	RE	SL	MO	AUG	ALG	ALB	SB	VO	DR	UR.DE
6:00	0.00	0.29	0.30	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7:00	0.00	0.44	0.44	0.06	0.07	0.07	0.00	0.00	0.00	0.00	0.00
8:00	0.14	0.43	0.39	0.13	0.17	0.07	0.11	0.00	0.00	0.00	0.00
9:00	0.32	0.35	0.19	0.20	0.09	0.00	0.11	0.00	0.00	0.00	0.09
10:00	0.32	0.38	0.42	0.16	0.00	0.00	0.07	0.00	0.00	0.00	0.00
11:00	0.35	0.39	0.31	0.18	0.00	0.09	0.00	0.00	0.00	0.00	0.00
12:00	0.26	0.38	0.39	0.19	0.07	0.11	0.09	0.00	0.07	0.00	0.00
13:00	0.19	0.42	0.39	0.11	0.00	0.13	0.00	0.06	0.07	0.00	0.00
14:00	0.25	0.36	0.27	0.19	0.00	0.07	0.00	0.00	0.00	0.00	0.07
15:00	0.26	0.39	0.26	0.13	0.06	0.29	0.00	0.00	0.00	0.06	0.00
16:00	0.24	0.47	0.21	0.14	0.07	0.07	0.00	0.00	0.07	0.00	0.00

Activity patterns of sub-adult female in captivity (December 2014-March 2015).

TIME	FE	RE	SL	MO	PL	AUG	ALG	ALB	AB	SB	VO	UR.DE
6:00	0.03	0.30	0.31	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00
7:00	0.09	0.38	0.49	0.06	0.05	0.12	0.03	0.00	0.00	0.00	0.00	0.00
8:00	0.11	0.36	0.37	0.13	0.05	0.09	0.09	0.08	0.00	0.00	0.00	0.00
9:00	0.29	0.30	0.16	0.19	0.06	0.10	0.06	0.08	0.03	0.00	0.00	0.05
10:00	0.33	0.35	0.35	0.12	0.03	0.07	0.10	0.07	0.00	0.00	0.00	0.03
11:00	0.22	0.31	0.24	0.06	0.03	0.12	0.11	0.06	0.00	0.00	0.03	0.03
12:00	0.22	0.25	0.36	0.10	0.06	0.08	0.15	0.06	0.00	0.03	0.00	0.03
13:00	0.26	0.30	0.31	0.11	0.10	0.07	0.15	0.00	0.00	0.00	0.00	0.08
14:00	0.21	0.29	0.26	0.12	0.11	0.11	0.16	0.00	0.00	0.00	0.00	0.05
15:00	0.26	0.26	0.12	0.12	0.06	0.12	0.13	0.03	0.00	0.00	0.00	0.06
16:00	0.17	0.32	0.09	0.11	0.11	0.10	0.12	0.00	0.00	0.00	0.05	0.00

Activity patterns of sub-adult male in captivity (December 2014-March 2015).

TIME	FE	RE	SL	MO	PL	AUG	ALG	ALB	AB	SB	UR.DE	VO	OS
6:00	0.03	0.35	0.40	0.08	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0
7:00	0.03	0.44	0.47	0.12	0.00	0.09	0.05	0.16	0.00	0.03	0.00	0.00	0
8:00	0.09	0.41	0.39	0.13	0.00	0.11	0.03	0.16	0.07	0.00	0.00	0.03	0
9:00	0.26	0.37	0.13	0.21	0.00	0.06	0.03	0.17	0.05	0.00	0.00	0.00	0
10:00	0.33	0.36	0.28	0.14	0.00	0.03	0.05	0.17	0.08	0.03	0.00	0.00	0
11:00	0.27	0.32	0.27	0.13	0.00	0.09	0.03	0.03	0.00	0.00	0.03	0.00	0
12:00	0.24	0.34	0.39	0.12	0.00	0.03	0.09	0.10	0.00	0.00	0.00	0.00	0.10
13:00	0.18	0.27	0.30	0.12	0.00	0.09	0.10	0.06	0.08	0.00	0.00	0.00	0
14:00	0.18	0.32	0.25	0.15	0.03	0.08	0.10	0.09	0.05	0.03	0.03	0.00	0
15:00	0.24	0.34	0.13	0.14	0.00	0.06	0.08	0.13	0.05	0.00	0.05	0.03	0
16:00	0.16	0.40	0.11	0.11	0.00	0.05	0.07	0.08	0.03	0.00	0.03	0.00	0

Activity patterns of juveniles in captivity (December 2014-March 2015).

TIME	FE	RE	SL	MO	PL	AUG	ALG	ALB	UR.DE	VO	DE
6:00	0.00	0.18	0.29	0.06	0.11	0.02	0.00	0.00	0.00	0.07	0
7:00	0.06	0.24	0.48	0.11	0.29	0.07	0.07	0.00	0.00	0.10	0
8:00	0.10	0.34	0.36	0.13	0.33	0.07	0.03	0.00	0.02	0.07	0.02
9:00	0.21	0.25	0.13	0.13	0.32	0.06	0.06	0.07	0.00	0.09	0
10:00	0.19	0.29	0.37	0.17	0.26	0.07	0.02	0.07	0.00	0.05	0
11:00	0.22	0.31	0.27	0.19	0.32	0.09	0.05	0.00	0.02	0.02	0
12:00	0.18	0.28	0.38	0.12	0.22	0.08	0.09	0.00	0.00	0.06	0
13:00	0.14	0.36	0.33	0.15	0.35	0.12	0.06	0.00	0.04	0.02	0
14:00	0.15	0.31	0.25	0.26	0.31	0.06	0.07	0.00	0.04	0.12	0
15:00	0.22	0.36	0.15	0.13	0.34	0.07	0.11	0.00	0.00	0.02	0
16:00	0.13	0.39	0.12	0.16	0.26	0.03	0.05	0.00	0.02	0.02	0

Activity pattern of major activities of the free-ranging Phayre's leaf monkey (December 2014-March 2015).

TIME	FE	RE	SL	MO
6:00	0.07	0.08	0.05	0.14
7:00	0.23	0.22	0.09	0.05
8:00	0.35	0.24	0.09	0.12
9:00	0.18	0.10	0.05	0.05
10:00	0.06	0.18	0.14	0.05
11:00	0.14	0.23	0.13	0.09
12:00	0.02	0.07	0.12	0.12
13:00	0.18	0.17	0.04	0.09
14:00	0.08	0.12	0.07	0.18
15:00	0.39	0.31	0.01	0.04
16:00	0.21	0.19	0.02	0.07

Activity patterns of adult female in wild (December 2014-March 2015).

TIME	FE	RE	SL	MO	AUG	ALG	ALB	OS	UR.DE
6:00	0.44	0.29	0.25	0.18	0.07	0.05	0.00	0.45	0.02
7:00	2.32	1.76	2.02	0.98	0.18	0.42	0.13	0.81	0.13
8:00	0.38	0.32	0.35	0.17	0.04	0.08	0.02	0.21	0.02
9:00	0.42	0.35	0.29	0.15	0.07	0.12	0.06	0.22	0.00
10:00	0.37	0.27	0.24	0.14	0.08	0.14	0.04	0.22	0.00
11:00	0.33	0.28	0.27	0.12	0.08	0.17	0.03	0.24	0.00
12:00	0.40	0.30	0.35	0.13	0.10	0.13	0.02	0.22	0.02
13:00	0.46	0.34	0.20	0.11	0.05	0.13	0.06	0.23	0.07
14:00	0.39	0.33	0.13	0.19	0.08	0.10	0.07	0.15	0.03
15:00	0.39	0.32	0.03	0.15	0.03	0.09	0.07	0.17	0.00
16:00	0.34	0.22	0.00	0.14	0.05	0.09	0.04	0.13	0.03

Activity patterns of free-ranging adult male (December 2014-March 2015).

TIME	FE	RE	SL	MO	AUG	ALG	ALB	AB	SB	UR.DE	VO	OS
6:00	0.50	0.40	0.32	0.19	0.00	0.06	0.14	0.00	0.00	0.00	0.06	0.59
7:00	0.49	0.43	0.34	0.22	0.00	0.06	0.24	0.07	0.00	0.07	0.06	0.29
8:00	0.47	0.42	0.26	0.18	0.11	0.11	0.30	0.07	0.00	0.06	0.11	0.35
9:00	0.44	0.31	0.30	0.22	0.06	0.07	0.29	0.00	0.00	0.00	0.11	0.28
10:00	0.33	0.36	0.44	0.23	0.11	0.07	0.23	0.00	0.00	0.00	0.11	0.35
11:00	0.27	0.38	0.36	0.16	0.12	0.14	0.26	0.00	0.00	0.07	0.11	0.26
12:00	0.49	0.43	0.36	0.11	0.12	0.00	0.26	0.00	0.00	0.00	0.07	0.38
13:00	0.40	0.48	0.27	0.22	0.00	0.09	0.26	0.00	0.00	0.00	0.00	0.33
14:00	0.47	0.47	0.11	0.20	0.16	0.00	0.28	0.00	0.07	0.07	0.11	0.16
15:00	0.45	0.37	0.00	0.24	0.00	0.09	0.29	0.00	0.00	0.06	0.11	0.26
16:00	0.49	0.32	0.07	0.23	0.00	0.00	0.10	0.07	0.00	0.00	0.00	0.09

Activity patterns of free-ranging sub-adult female (December 2014-March 2015).

TIME	FE	RE	SL	MO	PL	AUG	ALG	ALB	VO	OS	UR.DE
6:00	0.51	0.34	0.37	0.24	0.06	0.06	0.09	0.00	0.00	0.50	0.00
7:00	0.42	0.37	0.39	0.28	0.00	0.06	0.09	0.09	0.00	0.17	0.18
8:00	0.51	0.45	0.29	0.27	0.00	0.09	0.07	0.06	0.06	0.29	0.00
9:00	0.48	0.39	0.30	0.19	0.00	0.11	0.18	0.11	0.00	0.27	0.00
10:00	0.37	0.42	0.35	0.21	0.00	0.06	0.09	0.11	0.00	0.40	0.00
11:00	0.37	0.49	0.30	0.28	0.07	0.17	0.13	0.00	0.00	0.42	0.09
12:00	0.45	0.45	0.44	0.25	0.00	0.16	0.09	0.07	0.00	0.34	0.00
13:00	0.50	0.44	0.28	0.24	0.00	0.13	0.00	0.00	0.07	0.26	0.07
14:00	0.47	0.35	0.21	0.26	0.00	0.00	0.09	0.06	0.07	0.26	0.00
15:00	0.43	0.34	0.00	0.27	0.00	0.15	0.13	0.06	0.00	0.35	0.07
16:00	0.46	0.26	0.00	0.26	0.00	0.00	0.09	0.00	0.00	0.11	0.06

Activity patterns of free-ranging juveniles (December 2014-March 2015).

TIME	FE	RE	SL	MO	PL	AUG	ALG	ALB	UR.DE	VO	OS
6:00	0.53	0.29	0.25	0.19	0.07	0.05	0.03	0.05	0.00	0.034014	0.474662
7:00	0.42	0.29	0.33	0.17	0.12	0.10	0.05	0.00	0.05	0.083324	0.112755
8:00	0.42	0.28	0.35	0.20	0.09	0.05	0.05	0.00	0.00	0.140855	0.241473
9:00	0.35	0.35	0.32	0.16	0.15	0.10	0.15	0.03	0.03	0.032468	0.216335
10:00	0.31	0.32	0.32	0.19	0.18	0.03	0.07	0.03	0.06	0.034014	0.249755
11:00	0.37	0.34	0.32	0.16	0.14	0.12	0.10	0.00	0.07	0.102222	0.267509
12:00	0.40	0.33	0.42	0.14	0.10	0.05	0.06	0.03	0.03	0.034014	0.310679
13:00	0.49	0.37	0.25	0.16	0.06	0.05	0.03	0.03	0.03	0.09478	0.262862
14:00	0.39	0.35	0.19	0.20	0.09	0.06	0.06	0.05	0.07	0.076079	0.089177
15:00	0.37	0.27	0.00	0.20	0.10	0.06	0.06	0.03	0.05	0.119545	0.224277
16:00	0.42	0.33	0.00	0.20	0.06	0.06	0.03	0.03	0.07	0.055437	0.055856

APPENDIX II

(PICTURES)

Free-ranging Phayre's leaf monkey feeding on stem of *Terminalia belerica*

Free-ranging Phayre's leaf monkey (Adult male) resting

Free-ranging Phayre's leaf monkey (Adult male) allo-grooming the female

Captive Phayre's leaf monkey (Adult female) allo-grooming the juvenile

Structure provided to the captive Phayre's leaf monkey during the study period

Open moat enclosure of the observed captive troop of Phayre's leaf monkey

APPENDIX III

(Data sheets)

Activity patterns and food habits of Phayre's leaf monkey (*Trachypithecus phayrei phayrei*) in free-ranging and captive conditions in Sepahijala Wildlife Sanctuary, Tripura.

Scan sampling datasheet (Captive troop)

Place: **Total no. of individuals:** **Date:** **Time:**

SCAN	DETAILS OF INDIVIDUALS											REMARKS
	1	2	3	4	5	6	7	8	9	10	11	

FE-Feeding, PL- Playing, SL-Sleeping, SI-Sitting, RE-Resting, MO-Moving, AUG-Auto grooming, ALG- Allo grooming, AB-Aggressive behaviour, SB-Sexual behaviour, DE-Defecating, UR-Urinating, VO- Vocalization, ALB- Alert behaviour, OS- Out of sight, ST-Abnormal behaviour

Activity patterns and food habits of Phayre's leaf monkey (*Trachypithecus phayrei phayrei*) in free-ranging and captive conditions in Sepahijala Wildlife Sanctuary, Tripura.

Tree/Shrub Phenology

Plant species: **Date:**

S.No.	Tag No.	Vegetative Phase			Reproductive Phase				Remarks
		YL	ML	NL	FB	FL	YF	MF	

YL=Young leaf, ML=Mature leaf, NL=No leaf FB=Flower bud, FL=Flower, YF=Young fruit, MF=Mature fruit

Activity patterns and food habits of Phayre's leaf monkey (*Trachypithecus phayrei phayrei*) in free-ranging and captive conditions in Sepahijala Wildlife Sanctuary, Tripura.

Scan sampling datasheet (Wild troop)

Place: **Total no. of individuals:** **Date:** **Time:**

SCAN	DETAILS OF INDIVIDUALS							REMARKS
	1	2	3	4	5	6	7	
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								
13.								
14.								
15.								
16.								
17.								
18.								

FE-Feeding, PL- Playing, SL-Sleeping, SI-Sitting, RE-Resting, MO-Moving, AUG-Auto grooming, ALG- Allo grooming, AB-Aggressive behaviour, SB-Sexual behaviour, DE-Defecating, UR-Urinating, VO- Vocalization, ALB- Alert behaviour, OS- Out of sight, ST-Abnormal behaviour