BEHAVIOURAL PATTERNS AND FOOD HABITS OF RE-INTRODUCED GAUR (*BOS GAURUS GAURUS*) IN BANDHAVGARH TIGER RESERVE, MADHYA PRADESH.

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Certificate

This is to certify that the thesis entitled **"Behavioural Patterns and Food Habits of reintroduced gaur (*Bos gaurus gaurus*) in Bandhavgarh Tiger Reserve, Madhya Pradesh" in Wildlife Institute of India, Dehradun** submitted for the award of the **Doctor of Philosophy** in Wildlife Science to Saurashtra University, Rajkot is a record of original and independent research work carried out by **Mr. Manas P. Manjrekar** under our guidance. No part of this thesis has been submitted to any other university or institution for the award of any degree and it fulfills all the requirements laid down by the Saurashtra University.

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I also certify that the research work was appreciated by all who remain present and there was no comments made for this research work/comments made are incorporated in the thesis.

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EXECUTIVE SUMMARY

The Bandhavgarh Tiger Reserve (BTR), situated in Central India, supported a small population of gaur (35-38 individuals). This gaur population became extinct by 1998 and the reason for the same is attributed to the disruption of the migratory corridor between the forests of Bandhavgarh and Ghunghuti and Amarkantak. Even after the local extinction of gaur from Bandhavgarh it continued to be an excellent habitat for gaur and hence it was decided to reintroduce gaur in BTR as it would be a major conservation initiative for this vulnerable species. The gaur population of Kanha Tiger Reserve, situated in Central India, was selected as the source population for this reintroduction programme. The reintroduction programme was carried out in two phases wherein 19 gaur were translocated to BTR in January 2011 and 31 gaur were translocated in March 2012 and of this total reintroduced population of 50 animals, 27 were radio-collared.

The present study was designed to study the behavioural patterns and food habits of the reintroduced gaur population in Bandhavgarh Tiger Reserve. The study was carried out from March 2012 to February 2014 covering all the seasons in a year, summer (March - June), monsoon (July - October) and winter (November - February). For the collection of data on the behavioural patterns of gaur the scan sampling technique was used and 13 distinct activities of gaur were identified *viz*. feeding, moving, resting, standing, autogrooming, allogrooming, sexual behaviour, aggressive behaviour, drinking, salt licking, vocalising, defecating/urinating and alert behaviour. In a month the activity data on gaur was collected from 0600 hrs in the morning to 1800 hrs in the evening. For the present study, gaur were classified

into seven different age and sex classes *viz*. adult cow, sub-adult cow, sub-adult bull, brown bull, black bull, yearling and calf.

The percentage time spent in each activity was calculated for all the seven different age and sex classes of gaur for all the seasons. The data for all the age and sex classes was pooled together to calculate the percent time spent in different activities by gaur in general. The annual and seasonal activity patterns and activity budgets were calculated for all the age and sex classes of gaur and for gaur in general. For the analysis of activity patterns the entire day (0600-1800 hrs) was divided in six time frames of two hours each *viz*. 0600-0800, 0800-1000, 1000-1200, 1200-1400, 1400-1600 and 1600-1800 hrs. The statistical package SPSS was used for data analysis and since the data was found to be non-normal, the non parametric Kruskal-Wallis test was used to analyse the data. Percent time spent on activities like feeding, moving, resting and alert behaviour by each age and sex class of gaur was tested for significant seasonal difference. Also the time spent in these activities in each season and annually was tested for significant difference across the different age and sex classes of gaur. Percentage frequency occurrence and event rates were calculated for the social interactions (allogrooming, aggressive behaviour and sexual behaviour) and other behaviours like drinking, leadership and vocalisations.

The data on the food plants and parts eaten by gaur was also obtained from the scan sampling technique and during the scans whenever an individual was observed feeding, the plant species and plant parts eaten by the individual were recorded. Samples of the eaten food plant parts were collected for each season (summer, monsoon, winter) and these samples were later subjected to nutritional analysis

(crude protein, minerals, fibre and tannins) in the laboratory at Wildlife Institute of India. Fresh dung samples of gaur were collected for each season (at least 50 samples per season) and these samples were analysed for the percentage frequency occurrence of monocot and dicot plant fragments (monocot : dicot ratio). Also the percentage frequency occurrence of the plant fragments of major food plants of gaur was calculated simultaneously with the monocot : dicot ratio for each season. Phenological study of the major tree, shrub and grass species in the study area was carried out. Changes in the phenology of the marked trees and shrubs were quantified based on ocular estimation in terms of percentage availability of vegetative phases (young leaves, matured leaves, no leaves) and reproductive phases (buds, flower, young fruit and mature fruit) every fortnight. Phenological data for the major grass communities (1 sq.m plots) was recorded in terms of percentage availability of vegetative phase (mature and young shoots), reproductive phase (flowering and seeding) and changes in the grass colour (green, green yellow, yellow, yellow brown, brown) every week.

A multispectral (LANDSAT 7 ETM+), high-resolution (30 m) satellite imagery from the Global Land Cover Facility (GLCF) was used to generate the landuse/landcover (LULC) map of the study area. For the quantification of vegetation (tree, shrub and ground layer) in Bandhavgarh Tiger Reserve (BTR), the digitized map of BTR was gridded (2 km X 2 km) in a GIS domain and systematic vegetation plots were laid in field for vegetation quantification. A ten metre radius plot was laid to enumerate tree density, shrub density was enumerated in a five metre radius plot and the point intercept method was used to estimate the percentage ground cover (grass, herb, bare soil, leaf litter and rock) in 1 sq.m. plot. The food

plants of the captive elephants in Bandhavgarh Tiger Reserve were also recorded throughout the study period to get an understanding of the overlap between the food plants of gaur and elephant in the study area.

The percentage time spent feeding on different plant species and plant parts by gaur was estimated for each season. For the estimation of percentage time spent feeding on major food plants annually by gaur the feeding records obtained during the entire study period (six seasons) were pooled together. It was hypothesized that food selection by gaur was related to the nutritional composition of the food items and hence the time spent feeding was correlated with the values of the different nutritional components of the food plants of gaur. Since the data was non-normal, Spearman's rank correlation was used as the correlation test. Compositional analysis was performed to determine the selection of the major food items by gaur in the different seasons.

A total of 17,330 scan records were obtained for gaur (taking all the age and sex classes of gaur together). The annual activity budget of gaur showed that feeding (38.8%), moving (24.4%) and resting (20.4%) constituted the major activities throughout the year. Standing accounted for 10.8% of the time and 5.6% time was spent on other activities like alert behaviour, autogrooming, social interactions, drinking and salt licking. The seasonal activity budgets of gaur showed that the time spent in feeding was highest in summer (42.5%) compared to monsoon (34%) and winter (39.7%) and the difference in the percentage time spent for feeding across the seasons was found to be significant (Kruskal Wallis: $\chi^2 = 11.352$, $p<0.05$). Gaur spent 28.3% of the time moving in winter as compared to 19.4% in summer and

25.6% in monsoon (K.W: χ^2 = 45.310, p<0.05). The time spent resting by gaur in winter (14.7%) was significantly lower as compared to summer (23.8%) and monsoon (22.9%) (K.W: χ^2 = 38.277, p<0.05). Time spent feeding annually by gaur was found to differ significantly between the different age and sex classes (K.W: χ^2 =44.425, p<0.05). Annually the time spent feeding was highest for sub-adult bull (45.1%) and was lowest for calf (29.6%). No significant difference was observed in the time spent moving and resting by different age and sex classes of gaur.

The seasonal activity budgets of different age and sex classes of gaur showed that feeding was the only activity in which the time spent by different age and sex classes of gaur varied significantly in all the seasons (summer: χ^2 = 27.472, p<0.05; monsoon: χ^2 = 23.878, p<0.05; winter: χ^2 = 18.268, p<0.05). No significant difference was observed in the time spent in moving and resting by different age and sex classes of gaur in any of the seasons. Time spent in feeding did not differ much for summer and winter but it showed a significant decline in monsoon for all the age and sex classes of gaur. The reason for this pattern could be an increased availability of forage of higher nutritional value in monsoon as compared to summer and winter in the study area of Bandhavgarh Tiger Reserve. The seasonal activity budgets for all the age and sex classes of gaur showed that the time spent resting was highest in summer followed by monsoon but was significantly low in winter. The mean monthly temperature in winter ranged from 10.2˚C to 19.1˚C which was considerably lower than that in summer (range: 27˚C – 43.8˚C) and monsoon (range: 23.8˚C – 33.3˚C) which probably resulted in gaur spending overall less time resting in winter.

The diurnal annual activity patterns of gaur for the major activities like feeding, moving and resting showed that feeding activity peaked in the early morning hours (0600-0800 hrs) and in the late afternoon and evening hours (1600-1800 hrs). Time spent feeding by gaur was observed to be lowest in the time frame of 1000-1200 hrs after which it steadily increased. Gaur moved most in the early morning hours (0600-0800 hrs) after which the time spent moving showed a decline till 1200 hrs and then did not show much variation thereafter. Resting activity was observed to peak in the time frame of 1000-1200 hrs whereas it was minimal during the early morning and evening time frames.

The seasonal activity patterns for the major activities of gaur showed that the time spent for feeding by gaur in summer and monsoon was highest in the time frame of 1600-1800 hrs whereas in winter the time spent feeding was highest in the 0600-0800 hrs time frame. Time spent moving by gaur in summer and monsoon showed a similar pattern wherein it was highest for the time frame of 0600-0800 hrs after which it steadily declined in the mid-day hours and then increased again. In winter, the time spent moving by gaur was higher in the mid-day hours as compared to that in the early morning and evening hours. In all the seasons, the resting activity occurred mainly in the mid-day hours but in winter, the time spent resting in the mid-day hours was considerably lower as compared to summer and monsoon. Overall the observations on activity pattern indicated synchronisation of the annual activity pattern for feeding, moving and resting among different age and sex classes of gaur in Bandhavgarh.

In the present study the social interactions among the members of a gaur herd were classified as allogrooming, dominance-subordination interactions and sexual behaviour. During the study period a total of 316 allogrooming interactions were recorded. It was observed that adult cows initiated the highest percentage of allogrooming interactions (44%) followed by sub-adult cows (17.7%) whereas calves received the highest percentage of allogrooming interactions (37.7%) followed by adult cow (30.1%). Most of the allogrooming interactions initiated by adult cow, sub-adult cow and yearling were directed towards calf. Adult cows and sub-adult cows also directed considerable number of allogrooming interactions towards their own age and sex class. Calves groomed adult cow the most followed by their own age class. Black bull, brown bull and sub-adult bull directed majority of their allogrooming interactions towards adult cow.

Four types of dominance-subordination interactions were recorded among gaur during the study period in Bandhavgarh. These were chasing, threatening, head-butting and head to head fighting. A total of 205 records have been made of these rank indicating gestures during the study period. It was observed that among the dominance-subordination interactions, the occurrence of head to head fighting was the highest (47.8%) whereas that of the threatening behaviour was the lowest (13.7%). The most number of records for chasing, threatening and head butting were made for adult cow (34, 18 and 20 respectively) whereas that of head to head fighting were found to be highest for sub-adult cow (n=45). It was observed that among all the age and sex classes of gaur, black bull showed the highest frequency for threatening, head to head fighting and head butting behaviours (0.01, 0.021 and 0.004 per scan record respectively) whereas the frequency of chasing behaviour was

highest for adult cow (0.005 per scan record) followed by brown bull (0.004 per scan record).

During the present study four types of activities by gaur males were grouped under the display of sexual behaviour *viz*. flehmen, tending, rutting call and mounting. A total of 74 records of the activities grouped under sexual behaviour were made during the study period. Among the different age classes of gaur males the event rate for the display of sexual behaviour was found to be highest for black bull (0.07/scan record). Among the different seasons, the event rate for the display of sexual behaviour was found to be higher for summer (0.033/scan record) as compared to monsoon and winter. During the study period gaur were observed to drink water in all the four time frames of the day (0600-0900, 0900-1200, 1200-1500 and 1500-1800 hrs) and the event rate of the drinking activity was found to be highest in the time frame of 1500-1800 hrs (0.17/hr) and lowest in the time frame of 0600-0900 hrs (0.06/hr).

During the study period four types of vocalisation were identified for gaur and a total of 86 instances of gaur vocalisations were recorded. These were communication calls, alarm calls, rutting calls and threatening vocalisation. It was observed that among the different age and sex classes of gaur, adult cow had the most number of records for communication calls (n=40), alarm calls (n=5) and threatening vocalisation (n=10). Rutting calls were only recorded for black bulls (n=3) and brown bulls (n=2). Annually, the percent time spent in alert behaviour was found to be highest for adult cow (2.5%) followed by sub-adult bull (2.2%) and sub-adult cow (1.8%). The difference in the time spent in alert behaviour annually by

different age and sex classes of gaur was found to be significant (K.W: $\chi^2 = 42.380$, $p<0.05$).

Adult cows had to care for their calves which might be the reason for more time spent in alert behaviour by adult cow as compared to other age and sex classes of gaur in the present study. Also mostly adult cows lead a group and while leading a group the individual leading was observed to be more alert than others which could explain the observed high time spent in alert behaviour for adult cow in the present study. After adult cow, the age class with more time spent in alert behaviour was the sub-adult age class. The reason for this pattern might be that most of the rank indicating gestures were directed by the adult gaur towards sub-adult individuals and hence they may need to be more alert than the other age classes. The other reason could be that sub-adults were more vulnerable to predation and hence were more alert. Yearlings and calves are also vulnerable to predation but since these individuals tend to stay close to the mother cow they probably spent less time spent in alert behaviour.

During the study period a total of 82 species of food plants belonging to 29 families were recorded which comprised of 34 tree species, 8 shrub species, 14 herb species, 23 grass species and 3 climber species. A total of 6,724 feeding records were collected for gaur in Bandhavgarh Tiger Reserve during the study period through the scan sampling technique. Overall, the major food items identified for gaur in Bandhavgarh Tiger Reserve based on the percent time spent feeding by gaur were bamboo leaves (*Dendrocalamus strictus* leaves), grasses, herbs, *Shorea robusta* leaves, *Butea superba* leaves (climber) and *Chloroxylon swietenia* leaves. Annually

these food items combined to constitute about 93% of the total time spent feeding by gaur in the study area. Annually the time spent feeding on bamboo leaves was the highest (45.3%) followed by grasses (30.2%), herbs (8.3%), *Shorea robusta* leaves (3.9%), *Butea superba* leaves (2.6%) and *Chloroxylon swietenia* leaves (2.5%). The percent time spent feeding by gaur in summer was highest for grasses (45.9%) whereas in monsoon and winter it was highest for bamboo leaves (32.9% and 63.9% respectively).

Annually the percent time spent grazing by gaur was 84.9% whereas that spent browsing was 15.1%. The time spent grazing by gaur was observed to be highest in monsoon (89.7%) followed by winter (84.8%) and summer (81.9%) but the difference across the seasons was found to be non-significant (K.W. χ^2 = 2.439, $p>0.05$). In summer the crude protein content was found to be highest in herbs (9%) whereas for monsoon and winter it was found to be the most in *Butea superba* leaves (11.6% and 6.9% respectively). The NDF content was observed to be highest for herbs (71.3%), young bamboo shoots (70.2%) and *Chloroxylon swietenia* leaves (69.7%) in summer, monsoon and winter respectively. In summer the ADF content was highest for *Chloroxylon swietenia* leaves (48.2%) whereas in monsoon and winter it was found to be highest for herbs (52.4% and 52.6% respectively). The lignin content in summer was found to be highest in *Chloroxylon swietenia* leaves (14.2%) whereas in monsoon and winter the lignin content was highest in *Shorea robusta* leaves (15.3% and 15.9% respectively). In all the seasons the tannin content was found to be the highest in *Chloroxylon swietenia* leaves (summer: 4.0 g/100g catechine equivalent, monsoon: 5.8 g/100g c.e., winter: 4.0 g/100g c.e.).

The correlation analysis between percent time spent feeding and different nutritional parameters of the major food items of gaur during the present study showed that lignin content and tannin content were a good predictor for food selection by gaur since the correlations between percent time spent feeding by gaur and lignin and tannin content were found to be negative in all the seasons. The correlations between time spent feeding and lignin and tannin content were found to be significant in summer whereas they were non-significant in monsoon and winter. In the present study it was observed that the crude protein content of the bamboo leaves and grasses which formed the major food items of gaur was highest in monsoon as compared to summer and winter and the seasonal activity budgets of gaur showed that the percentage time spent feeding by gaur in monsoon (34%) was the lowest compared to summer and winter (42.5%, and 39.7% respectively). Thus gaur in Bandhavgarh seem to compensate for the lower crude protein contents in their main food items (bamboo leaves and grasses) in summer and winter by increasing their feeding time in summer and winter as compared to monsoon.

A total of 301 dung samples were analysed during the study period. It was observed that the percentage frequency occurrence of monocot plant fragments in the gaur dung samples was high in all the seasons (summer: 84.8%, monsoon: 90.3%, winter: 92.2%) as compared to that of the dicot plant fragments (summer: 11.3%, monsoon: 5.5%, winter: 4.8%). The percentage frequency occurrence of bamboo fragments was observed to be highest in winter (30.5%) as compared to summer (20.2%) and monsoon (17.1%). Percentage frequency occurrence of the fragments of the grass *Saccharum spontaneum* was observed to be 30% in summer, 6.8% in monsoon and 10.6% in winter. The Ivlev's selectivity index (IVI), calculated for the major food

items of gaur in different seasons in Bandhavgarh showed that the utilisation of bamboo leaves as a food item by gaur was higher than its availability in all the seasons. The utilisation of grasses as a food resource was observed to be more than its availability in summer whereas it was lower than its availability in monsoon and winter. The utilisation of herbs by gaur as a food item was observed to be proportional to its availability in monsoon whereas it was found lower than its availability in summer and winter. Compositional analysis showed that in summer, grasses were the most preferred food item of gaur whereas in monsoon and winter bamboo leaves was the most preferred food item of gaur in the study area.

It was observed from the land use/land cover map of Bandhavgarh Tiger Reserve that the mixed forest was the most dominant vegetation type which covered an area of 40.2% whereas the area under plantation covered the lowest percent area (0.2%). In addition, the bamboo forest covered an area of 12.6%, grasslands 6.5%, whereas Sal forest covered about 13.1% area in the entire Tiger Reserve. Between 2011 and 2013 three villages (Kallwah, Kumarwah and Magdhi) have been relocated from the core area of Bandhavgarh Tiger Reserve and the village relocated sites have been transformed into grasslands having mainly species like *Saccharum spontaneum* and *Vetiveria zizanoides*. These grasslands (on the relocated sites) have been observed to be used extensively by gaur during the study period and have become important feeding sites for gaur in the study area.

A total of 62 food plants eaten by the captive elephants in Bandhavgarh Tiger Reserve were identified during the study period. Of the 62 species of food plants eaten by the captive elephants in the study area, 59 species were eaten by gaur. Thus,

of the 82 food plants recorded for gaur in the present study, 59 were common for gaur and the captive elephants. Hence, in terms of species of food plants eaten by captive elephants, an overall overlap of 72% with the species of food plants of gaur was observed. In summer, of the 52 food plants recorded for gaur, 24 were observed to be common between gaur and captive elephants showing an overlap of 46.2% in terms of species of food plants. Similarly, the overlap observed in terms of food plants species between gaur and captive elephants in monsoon was 69.8% and in winter was 66%.

Chapter I

Introduction

CHAPTER I: INTRODUCTION

1.1: BACKGROUND

Ungulates are a diverse group of mammals, most of which are hoofed animals. The even toed ungulates belonging to the order Cetartiodactyla are the most successful group of large herbivores on earth today (Thenius 1990). The Bovidae is a family among the order Cetartiodactyla which encompasses a diverse group of the extant ungulates that are distributed mainly in the Old World with a few species being present in North America (Vairavel 1998). The family Bovidae includes cattles, buffaloes, antelopes, sheeps and goats. The present classification scheme for bovids recognizes eight subfamilies subdivided into two clades, the Boodontia which comprises of a single subfamily, Bovinae and Aegodontia comprising of all other bovid subfamilies (Thomas 1984). Eurasia and Africa have been the centres of radiation for almost all the bovids (Gentry 1992). It has been suggested by Kingdon (1997) that a continental divide between Africa and Eurasia may have been responsible for the early divergence of the Boodontia (Eurasian in origin) and the Aegodontia (which continued evolving in Africa). The rejoining of the two continental land masses (after these two clades had become distinct) at the Arabian peninsula removed this geographic barrier which allowed both the groups to expand into the other's homeland.

The subfamily Bovinae represents an early offshoot of the family Bovidae. It diverged from the Aegodontids approximately 25 million years ago. Based on the fossil evidence, the Bovinae appear to have arisen in Asia with the first fossils

appearing around 18.5 million years ago (Hernandez-Fernandez and Vrba 2005). The modern Bovinae have attained large body sizes compared to any other bovid subfamilies which might have happened because of the cooler climates prevalent in Eurasia (Hernandez-Fernandez and Vrba 2005). Presently three tribes are recognised within the subfamily Bovinae *viz.* Bovini (cattle, buffalo, bison and saola), Boselaphini (nilgai and four-horned antelope) and Tragelaphini (spiral-horned antelope). The Bovini tribe includes five genera containing ten species and 21 subspecies. The five genera include Asiatic buffalo (*Bubalus*), African buffalo (*Syncerus*), Bison (*Bison*), true cattle (*Bos*) and Saola (*Pseudoryx*). The Gaur (*Bos gaurus*) is a wild cattle belonging to the genus *Bos*.

1.2: STUDY SPECIES

The gaur (*Bos gaurus*) is the largest living Bovine confined to the Oriental bio-geographic region. It has been classified as follows:

1.2.1: Classification

Kingdom : Animalia

Phylum : Chordata

Class : Mammalia

Order : Cetartiodactyla

Family : Bovidae

Scientific name : *Bos gaurus*

Species authority : C.H. Smith, 1827

Traditionally three subspecies of gaur (*Bos gaurus*) have been recognized *viz*. *Bos gaurus readei* (Myanmar and Cambodia), *Bos gaurus hubbacki* (Thailand south of the isthmus kra and west Malaysia) and *Bos gaurus gaurus* (India and Nepal). However, the National Research Council (1983) recognizes only two subspecies, *Bos gaurus gaurus* of India and Nepal and *Bos gaurus laosiensis* of Myanmar, Thailand, Laos, Vietnam, Cambodia and Malaysia. In North-eastern India a domestic form of gaur (Mithun, Mithan or Gayal) occurs which has arisen through breeding between wild gaur and domestic cattle. The scientific name of this subspecies is *Bos frontalis*.

1.2.2: General characteristics and ecology

Gaur is a large herbivore with the bulls weighing around 600-1000 kg and the cows about 300-700 kg. The shoulder height for gaur bulls is around 1.6 to 1.9 m whereas for cows it is about 10 cm shorter than the males (Sankar *et al*. 2001). Horns are present in both sexes but they are larger with more swath in the males (Sanderson 1968). There is a high bulging forehead ridge between the horns referred to as *Bos*. Adult males have two prominent dewlaps, a small one at the chin and a large one hanging below the throat. There is a shoulder hump which is more pronounced in the males. Newly born calves are light golden yellow in colour. The colour darkens with age, and adult females are dark brown whereas adult males are black. Both hind legs and forelegs are white to tan below the knees. Gaur reach sexual maturity at three years of age and usually produce one and rarely two calves after a gestation period of 275 days. The maximum recorded life span for captive female gaur has been 24 years (Crandall 1964) and that for captive male gaur has been 23.6 years (Ahrestani *et al*. 2011).

Plate 1.1: Adult gaur cow.

Plate 1.2: Adult gaur bull.

Plate 1.3: Gaur calf.

Gaur is a group living animal. The group structure is very fluid and dynamic. The group size in gaur may range from two individuals to more than 20 individuals. A typical group usually consists of adult cows, some calves, one or two adult bulls and a few sub adult animals. Sometimes gaur bulls also form bachelor herds (all male herds). Gaur bulls (mainly adult bulls) also roam solitary and may join different herds for short periods of time. Gaur is known to be a mixed feeder (Schaller 1967). It mainly grazes in the monsoon but is known to browse in dry seasons. Their diet mainly consists of shoots and leaves of bamboo, grasses, herbs, trees and shrubs. Fruits of *Aegale marmalos*, *Bauhinea* spp., *Cassia fistula*, *Cordia myxa*, *Diospyros melanoxylon*, *Phyllanthus emblica*, *Gmelina arborea*, *Terminalia bellerica* and *Randia dumetorum* are also eaten (Brander 1923, Schaller 1967, Krishnan 1972, Sankar *et al*. 2001) Gaur also feed on bark of trees like *Adina cordifolia*, *Tectona*

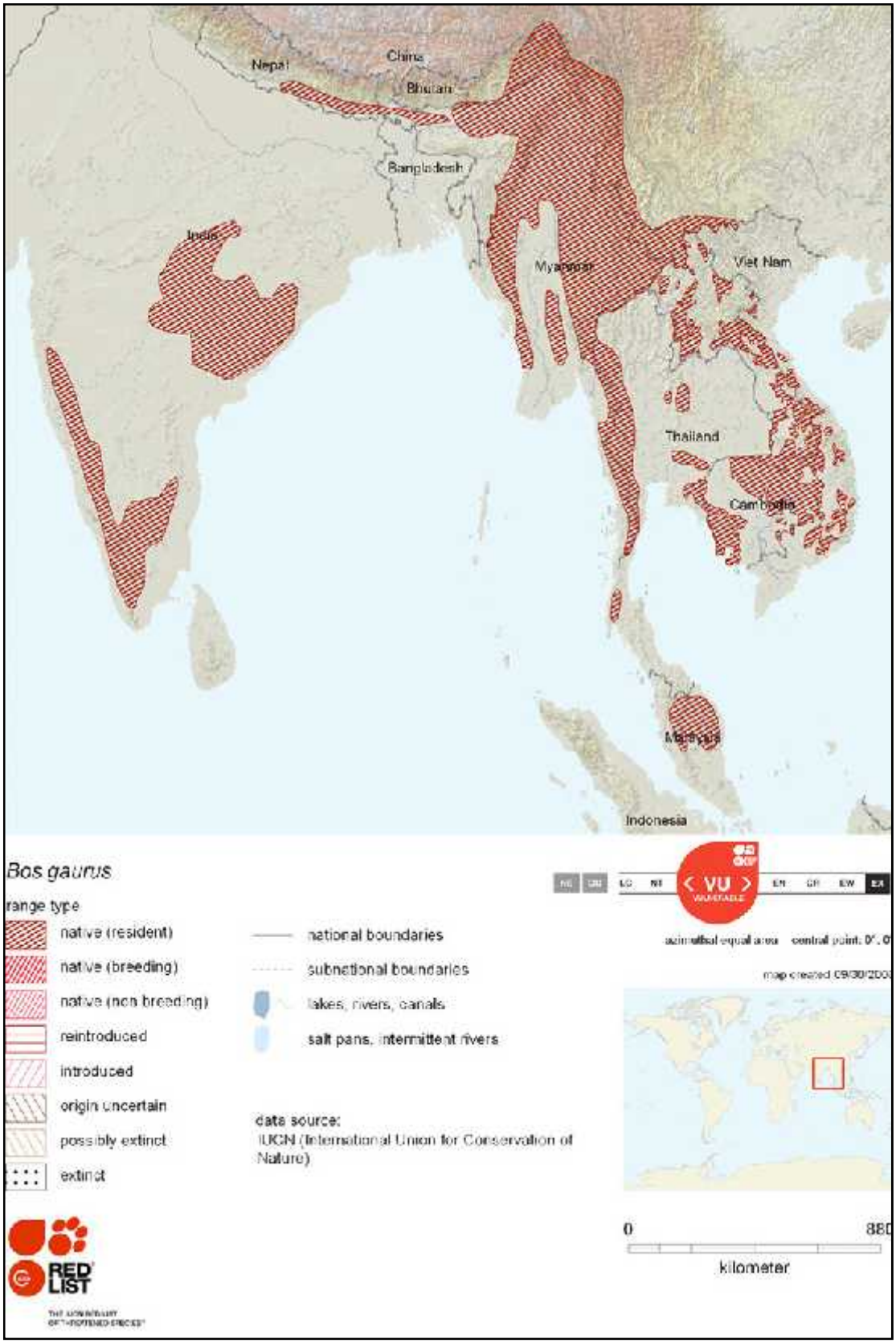
grandis, *Wendlandia natoniana* and *Phyllanthus emblica* (Pasha *et al*. 2004). Feeding mainly occurs during early morning hours and late afternoon and evening hours.

During the hottest periods of the day gaur are seen resting in thick tree cover. The mating season of gaur varies through the entire distributional range (Prater 1971), while in some areas definitive peaks have been observed. Brander (1923) reported December-January as the peak mating season for gaur in central India. In south India, this may range from November to March (Morris 1937). An unsynchronized pattern in parturition of gaur indicates that calves are born throughout the year and some mating occurs in all months of the year (Schaller 1967, Vairavel 1998, National Research Council 1983). The main predator of gaur is the tiger (*Panthera tigris*) and leopard (*Panthera pardus*) is also known to predate upon calves and yearlings of gaur (Sankar *et al*. 2001).

1.2.3: Global distribution of gaur

Historically, the distribution of the gaur covered the entire mainland of South and South-east Asia and Sri Lanka (Duckworth *et al*. 2008). The current distribution is restricted to scattered pockets in India, Nepal, Bhutan, Cambodia, China, the Lao PDR, peninsular Malaysia, Myanmar, Thailand and Vietnam (Figure 1.1).

Fig.1.1: The distributional range of gaur in South and South-East Asia (Pabla *et al.* 2011).



Gaur in Nepal is found in the Royal Chitwan National Park and Parsa Wildlife Reserve. In Bhutan, the presence of gaur has been reported all over the southern foot-hill zone, notably in Royal Manas National Park, Phipsoo Wildlife Sanctuary and Khaling Wildlife Sanctuary (Choudhury 2002). In Bangladesh a few gaur were thought to occur in the Chittagong Hill tracts, Sylhet and Mymensingh areas in the early 1980s (Sarker and Sarker 1984), but are probably now extinct. Status and distribution of the sub species *Bos gaurus readei* and *Bos gaurus hubbacki* in Thailand has been well investigated (Lekagul 1952, Suchart *et al.* 1976, Sayer 1981, Kutintara and Pongumphai 1982, Dobias 1982 and 1985, Supmee 1986, Sukavanich 1988, Nakhasathien 1989, Paliphod 1989, Climo 1990, Midas 1993). After a detailed study on the status of different gaur subspecies in different ranges and its occurrence it was reviewed that no gaur sighting was reported outside Thailand's Protected Areas (Srikosamatara and Suteethorn 1995). Srikosamatara and Suteethorn (1995) had estimated a population of about 915 gaur in Thailand. A 60% decline in the gaur population in Thailand has been reported in the last 20 years (Srikosamatara and Suteethorn 1995). Blower (1982) and Yin (1993) have reported the distribution and declining status of the species in Myanmar. Rabinowitz *et al*. (1995) made a rough estimation of about 100-200 gaur in the Tamanthi Wildlife Sanctuary in Myanmar. The current status of gaur in Myanmar is threatened due to the high level of trade in wild cattle trophies along the Thailand-Myanmar border (Rabinowitz *et al*. 1995, Slater 1983).

In Vietnam, the species is distributed in Yok Don Nature Reserve, Huai Kha Khaeng Wildlife Sanctuary (Laurie *et al.* 1989, MacKinnon *et al.* 1989), Nam Cat Tien National Park (Hoe and Quy 1991) and Nui Bi Doup (Canh 1995). However, there is

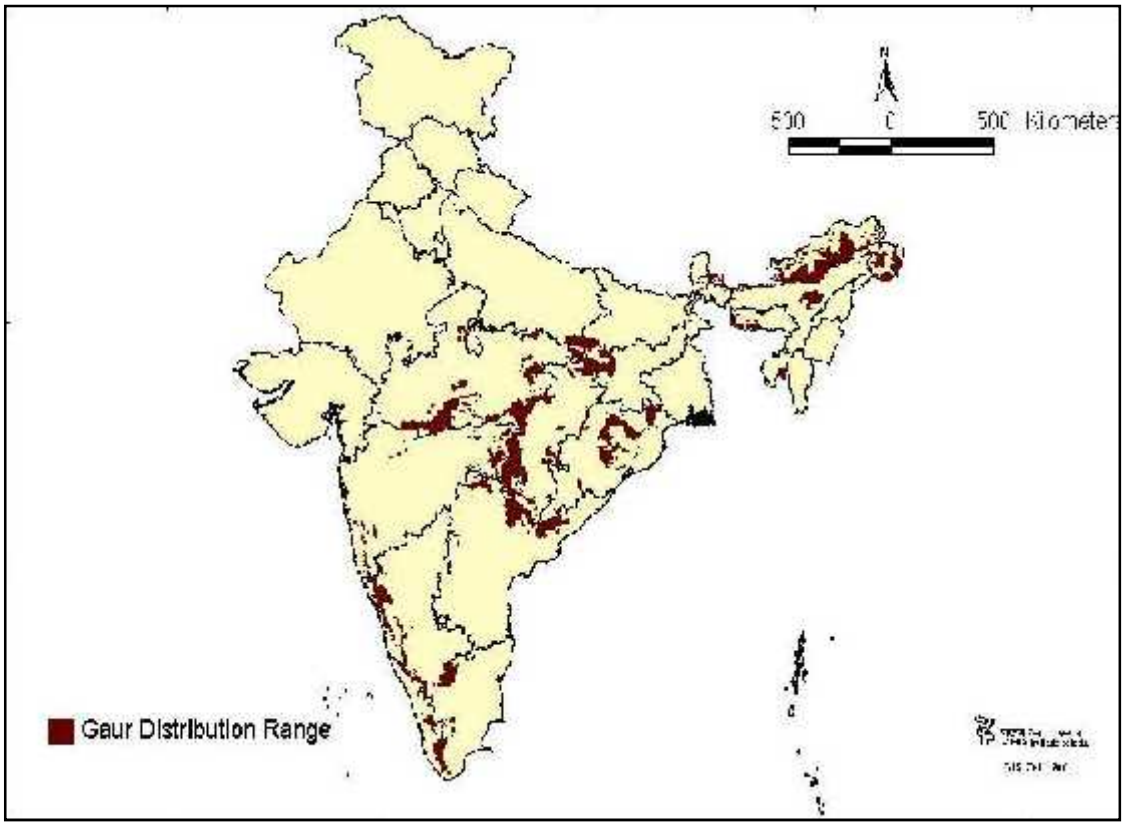
no published information on the estimated population of gaur in any of these areas. In Cambodia the most substantial gaur population of the country was found in eastern Cambodia centered on Mondulkiri province, where in the late 1990s potentially several hundred to a thousand gaur individuals may have survived in a forested landscape of over 15,000 km² (Timmins and Ou 2001, Tordoff *et al*. 2005). Political unrest, hunting and habitat destruction have been the main causes of decline in the gaur population in Cambodia and Vietnam (Dang 1986, Oliver and Woodford 1994).

The presence of gaur has been documented in the southern and central parts of Lao PDR (Salter *et al.* 1990, Salter 1993, Duckworth *et al.* 1994). In Malaysia the destruction of lowland rainforest has led to the decline of gaur population (Dolan 1967). Gaur has been exterminated from most of the areas in China (Xiang and Santiapillai 1993). A remnant population has been reported to be crossing back and forth along the Chinese-Myanmar border (Ma *et al*. 1994). The global population of gaur is estimated at 13,000-30,000 animals (Duckworth *et al*. 2008).

1.2.4: Gaur distribution in India

In India the gaur population is distributed mostly in isolated pockets largely corresponding to the major mountain systems of the Western Ghats, the Central Indian Highlands and the North-eastern Himalayas, including the hills south of Brahmaputra. Gaur is also found in the forests of Bihar, West Bengal and parts of the south-eastern peninsula (Figure 1.2.).

Fig.1.2: Distributional range of gaur in India (Sankar *et al*. 2001).



Based on the present distribution of gaur, Schaller (1967) stated that in the past the distribution of gaur should have extended to the plains since to reach central India gaur had to traverse the Gangetic plains and in order to reach southern India they had to cross the upland plateau. Gaur occurs in diverse habitats ranging from tropical wet, semi-wet evergreen and bamboo forests in the North-east to Tropical Moist Deciduous forests in the Western Ghats to Tropical Dry Deciduous forests in Central India to Shola forests and Tropical Thorn forests on the eastern slopes in the Western Ghats.

Sankar *et al*. (2001) reported that the Wayand-Nagarhole-Mudumalai-Bandipur complex in the Western-Ghats landscape is one of the most extensive extant

strongholds of gaur. In the Central Indian landscape the most important units for gaur population are the Satpura-Melghat landscape and Achanakmar-Kanha-Pench landscape (Jhala *et al*. 2011). In the Terai-Arc landscape gaur has been reported only from the Valmiki Tiger Reserve in Bihar which shares connectivity with the Chitwan National Park in Nepal (Jhala *et al*. 2011). The gaur habitat in North-east India is contiguous with the state of West Bengal in the west, Myanmar in the east, Bangladesh in the south and with Bhutan in the north (Sankar *et al*. 2001). Tropical moist deciduous and tropical dry deciduous forests are the dominant vegetation types within the present distribution limits of gaur (Sankar *et al*. 2001). The Western Ghats and Central Indian Landscape hold about 75% of the present gaur population in India. The gaur range represents approximately 7.12% of the geographical area and 30% of the forested area of India (Sankar *et al*. 2001).The estimated population of gaur in India is between 12,000 and 22,000 (Ranjitsinh 1997). Sankar *et al*. (2001) estimated the gaur population in India to be approximately 23,500.

1.2.5: Threats

Gaur populations are under many different kinds of threats in their entire distributional range. The principal threats to gaur are habitat degradation, poaching and disease. Gaur is hunted for its meat, crop protection, medicinal uses and as trophies (Pasha *et al*. 2004). Habitat loss and fragmentation are the most serious threats. In North-east India the species is threatened with habitat degradation brought about by shifting cultivation (Choudhury 2000, Imam 1985). In the rest of the gaur distributional range, conversion of forest areas to agricultural use or commercial plantations is another serious threat. Poaching and sport hunting in the past, and

habitat degradation are mainly responsible for the decline in the gaur population and it has also lead to the extinction of small local gaur populations (Sankar *et al*. 2001).

The Central Indian landscape which harbours about one fourth of the gaur population in India (Sankar *et al*. 2001) has witnessed quite a few local extinctions of gaur population in the past couple of decades. The gaur population has gone extinct from Bandhavgarh Tiger Reserve in Madhya Pradesh and from Kanger Valley National Park in Chhattisgarh (Sankar *et al*. 2001). The species is also possibly extinct in Sanjay National Park, in eastern Madhya Pradesh, which earlier had a gaur population connected with the populations in Chhattisgarh and Jharkhand. Brander (1923) had reported the extensive presence of gaur in the Betul and Khandwa districts of Madhya Pradesh at the beginning of the 20th century; the species is either extinct or unrecorded there at present. Apart from Central India the disappearance of gaur population has also been reported from Thattekad Wildlife Sanctuary in Kerala (Sankar *et al*. 2001).

The species is closely related to domestic livestock and is vulnerable to all the diseases that infect cattle. Past records indicate that populations of gaur have succumbed to epidemics of foot and mouth disease (FMD), rinderpest and anthrax in many areas of distribution. Several subpopulations of gaur in Bandipur-Mudumalai area were nearly destroyed as a result of rinderpest in 1968 (Choudhury 2002). Among the diseases reported for gaur, FMD has been found to be the most prevalent disease in the gaur populations in India (Sankar *et al*. 2001). Insurgency in some of the states of Northeast India and Central India has also affected the gaur habitat in

these regions (Choudhury 2002). The increased habitat fragmentation and anthropogenic pressures in gaur habitat could effectively reduce the genetic diversity of gaur populations as a result of inbreeding and expose those isolated populations to environmental and biological stocasticities.

1.2.6: Conservation Status

The global population of the gaur is estimated at 13,000-30,000 animals of which, only 5200-18,000 are reproductively active individuals (Duckworth *et al*. 2008). The population has declined overall by at least 30% during the last three generations. As a consequence, the gaur is categorized as Vulnerable (criteria A2cd+3cd+4cd ver. 3.1) in the IUCN Red List of Threatened Species (Hilton-Taylor 2000). It is listed in Schedule I of the Indian Wildlife (Protection) Act of 1972 and is included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

1.2.7: Literature review

Though gaur is the largest bovid in the world, long term ecological studies on this species have been few. The studies done by Brander (1923), Hubback (1937), Wharton (1968), Krishnan (1972) present only a sketchy account about the general ecology of gaur. In India detailed ecological studies on gaur have been carried out by Schaller (1967) and Chandiramani (1984) in Kanha Tiger Reserve, Vairavel (1998) in Parambikulam Tiger Reserve, Sankar *et al*. (2001) in Pench Tiger Reserve, Ashokkumar *et al*. (2004) in Mudumalai Tiger Reserve and by Gad (2011) in Bhagwan Mahaveer Wildlife sanctuary and Mollem National Park in Goa. Bhattacharya *et al*. (1997) conducted the status survey of gaur in North Bengal

region. The activity pattern and feeding behaviour of gaur was studied by Moorthy (1989) in Kodaikanal hills and by Prabhakar (1992) in the Indira Gandhi National Park. Ahrestani *et al*. (2012) studied the diet and habitat-niche relationships of gaur with other large herbivores in Bandipur and Mudumalai Tiger Reserves. Lad and Gopal (1992) conducted a short study on the gaur population in Bandhavgarh Tiger Reserve. Choudhury (1999) studied gaur in Dibang valley district of Arunachal Pradesh. Choudhury (2002) has also given information about the distribution and conservation of gaur in the Indian subcontinent. Ahrestani *et al*. (2011) studied the life history traits of gaur in wild and captivity and the age and sex determination of gaur has also been studied by Ahrestani and Prins (2011) in captivity.

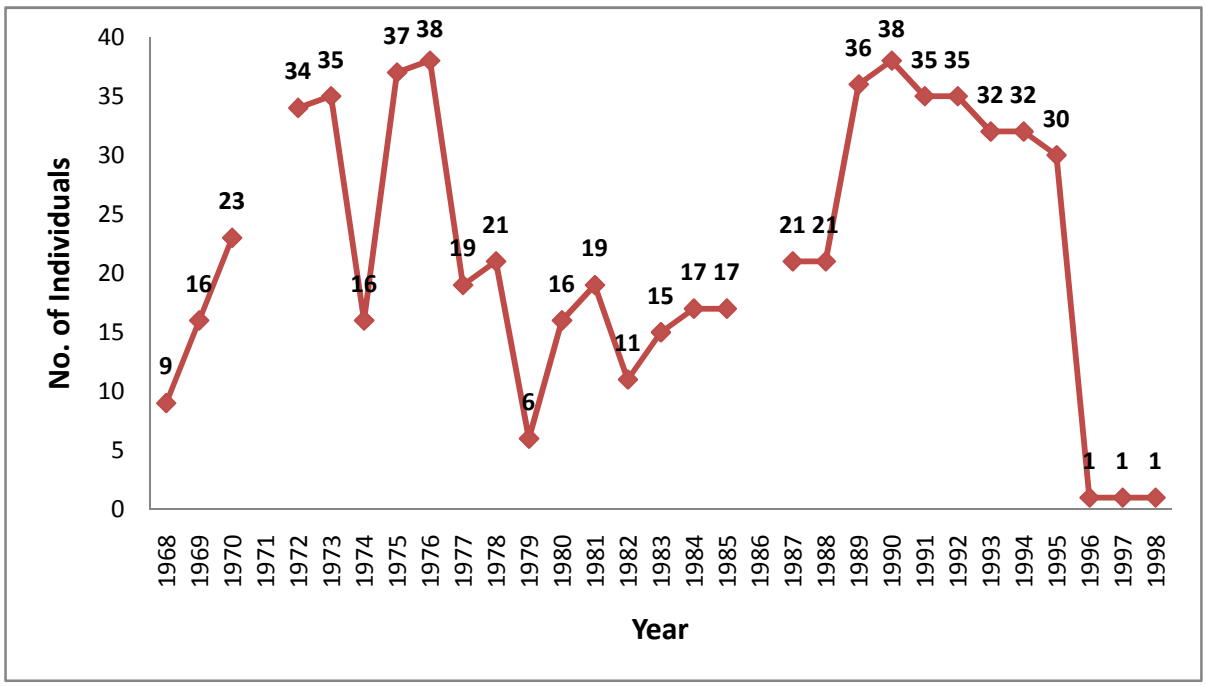
A lot of observations on gaur have been published as short notes (Cameron 1929, Brander 1935, Blackburn 1935, Morris 1937, 1938a, 1938b, 1948a, 1948b, 1952, 1954a and 1954b, Biddulph 1936, Mustill 1938, Russel 1938 and 1940, Rynjah 1950, Hutton 1951). A few of the published notes have dealt with the observations on the morphology of gaur (Cameron 1929, Morris 1930 and 1947, Biddulph 1936, Robinson 1942, Hundley 1951, Pillai 1951). Morris (1948b) and Kurt (1974) have briefly mentioned about the disease aspects of gaur. Some information about the gaur in North-eastern India can be found in short notes published by Choudhury (1987, 1992, 1993, 1994a, 1994b, 1995, 1996a, 1996b, 1996c, 1997a, 1997b, 1998a, 1998b, 1999 and 2000), Wegge (1976) and Gupta and Mukherjee (1994). Some studies on gaur in Central India and Southern India are discussed in Basappanavar (1985), Imam (1985), Balakrishnan and Easa (1986), Davidar (1986), Karanth (1986), Dwivedi (1987), Samant (1990), Rao (1991), Karanth and Sunquist (1992 and 1995). Conry (1989) studied the habitat use and movement patterns of gaur in

Malaysia. Information on gaur in Malaysia has been also given by Duckworth and Hedges (1998). Srikosamatara and Suteethorn (1995) have studied gaur in Thailand. Johnsingh (1998) has given information about gaur in Chitwan National Park, Nepal.

1.3: GAUR IN BANDHAVGARH TIGER RESERVE

Historically Bandhavgarh Tiger Reserve (BTR) had a small gaur population. According to the management plan prepared by Sonakiya (1993), the gaur population of BTR was considered to be threatened. A short study on the small gaur population of Bandhavgarh Tiger Reserve was carried out by Lad and Gopal (1992). Lad and Gopal (1992) reported that the gaur population of BTR in 1989 was 36 individuals and that it was distributed in three herds. Estimates of the gaur population in BTR from 1968 to 1998 are shown in Figure 1.3.

Fig.1.3: Estimates of gaur population in Bandhavgarh Tiger Reserve from 1968 to 1998 (Pabla *et al*. 2011).



* Estimates for years 1971 and 1986 are not available.

Lad and Gopal (1992) mentioned in their study that selective predation on gaur calves by tiger and wild dog was responsible for the stagnation of the gaur population in Bandhavgarh Tiger Reserve. It was generally believed that the gaur herds migrated to the Ghunghuti and Amarkantak forest areas (south-west of Bandhavgarh) during the monsoon season (Pabla *et al*. 2011). Lad and Gopal (1992) also reported about the occasional migration of some herds to the Ghunghuti forests in North Shahdol Forest Division. But on some occasions gaur were also recorded within the park area during the monsoon (Pabla *et al*. 2011). Thus it is not clear whether the migration of gaur outside of Bandhavgarh Tiger Reserve during monsoon was regular or occasional. According to the management plan prepared by Prakasam (2006), the last gaur, a male, was seen in Bandhavgarh in 1998.

The disruption of the migratory route of gaur owing to developmental activities in that region has been put forth as a major reason for the extinction of the gaur population in BTR. The other factors which have been considered are the outbreak of any livestock disease in the region during the relevant period or an accident in the form of a natural calamity (Pabla *et al*. 2011). But there is no record of any epidemic of anthrax, rinderpest or any other livestock disease in the region during the period corresponding to the disappearance of gaur from BTR. Since it was believed that gaur in BTR migrated during the monsoon, the small gaur population being wiped out in a flood on the migratory route has also been considered. Since there was no regular monitoring system for the gaur population in Bandhavgarh, the exact cause of the disappearance of gaur from Bandhavgarh is not known; but the disappearance of gaur from Bandhavgarh showed that small, isolated populations are vulnerable to local extinctions (Pabla *et al*. 2011).

1.3.1: Reintroduction of gaur in Bandhavgarh Tiger Reserve

Even after the local extinction of gaur from Bandhavgarh Tiger Reserve it continued to be an excellent habitat for the species and could therefore support a reasonable gaur population. So as a part of active management and conservation initiative, a proposal was prepared to reintroduce gaur in Bandhavgarh Tiger Reserve from Kanha Tiger Reserve by Madhya Pradesh Forest Department in 2007. Subsequently Wildlife Institute of India performed a Population Viability Analysis (PVA) and based on the analysis it was proposed to reintroduce 50 gaur (Male : Female ratio was 1:3) so as to achieve the overall population growth rate of 5% along with probability of survival as 99% (Pabla *et al.* 2011).

It was proposed to reintroduce 20 gaur (15 adult females and 5 adult males) in the first year and after careful monitoring of the initial population stock, the supplementation of 30 more individuals was to be undertaken within two years so as to maintain a viable population of approximately 50 animals in Bandhavgarh (Pabla *et al*. 2011). The gaur population of Kanha Tiger Reserve was selected to be the source population for Bandhavgarh since Kanha was the nearest area to Bandhavgarh with a sufficiently large gaur population. Both the Tiger Reserves are situated in the same climatic belt and have similar vegetation types. Kanha also has high predator densities and has the same species of predators as that found in Bandhavgarh, namely tiger, leopard and wild dog. The two Protected Areas are only around 200 km apart, which was a convenient distance for the transportation of the animals.

Since there was not much experience in capture and translocation of large herbivores in India, technical help from a South African game management company, 'Conservation Corporation of Africa' (Now renamed '& Beyond') was enlisted for the reintroduction programme (Pabla *et al*. 2011). The reintroduction programme was carried out in two separate phases. The first phase was conducted in January 2011 when 19 gaur were translocated from Kanha to Bandhavgarh Tiger Reserve. The second phase was carried out in March 2012 in which another 31 gaur were translocated to Bandhavgarh. For the purpose of intensive monitoring of this reintroduced gaur population, 27 individuals out of the total 50 animals were radio collared. Both VHF (Very high frequency) and satellite/GPS collars were used for the radio collaring purpose. In Bandhavgarh a 50 hectare forest area with ample forage was selected in the Magdhi range and was power fenced so that a soft release

of the translocated gaur individuals could be carried out. This was done in order to let the gaur acclimatize to their new environment. Artificial waterholes were created in this 50 hectare enclosure so as to take care of the water requirements of the gaur. In both the phases of the reintroduction programme the gaur were kept in this enclosure for about a month. During this period the behaviour and herd formation within the gaur population was closely monitored. After about a month the enclosure was opened which allowed the gaur to range freely in Bandhavgarh Tiger Reserve.

Plate 1.4: Immobilised gaur being carried on a stretcher.

Plate 1.5: Radio-collaring of gaur.

Plate 1.6: Transportation truck specially designed for translocation of gaur.

Plate 1.7: Gaur in the enclosure at Bandhavgarh Tiger Reserve.

1.4: JUSTIFICATION OF THE STUDY

In any reintroduction programme the monitoring and undertaking of ecological studies of the reintroduced species is of vital importance (IUCN 1998). Undertaking ecological studies of a reintroduced species provides an understanding as to how the species is interacting with its new environment. Studying behavioural patterns of a species gives an insight into the allocation of time for different activities by the species annually and seasonally which in turn leads to a better understanding of its general ecology. Survival of any species depends on the success in searching and finding the usable food which varies in time and space, hence study of food habits provides an understanding about the food utilisation and preference by the species. Thus both the above mentioned ecological aspects would lead to a better

understanding of the ecology of these reintroduced animals which in turn would aid in their long term conservation.

This study was designed with the following objectives:

1. To study the behavioural patterns of the reintroduced gaur.

2. To study the food habits of reintroduced gaur.

3. To map the abundance and distribution of major food plants of gaur in Bandhavgarh Tiger Reserve.

The study was carried out for two years i.e. from March 2012 to February 2014. Each year was divided into three seasons such as summer (March-June), monsoon (July-October) and winter (November-February). Data collection was carried out in all the seasons. This study on the behavioural patterns and food habits of the reintroduced gaur in Bandhavgarh Tiger Reserve will help the park management in making informed decisions and interventions (if and when necessary) which will aid in the long term conservation of this reintroduced population. Also since long term ecological studies on gaur have been few in the country, this study will add to the ecological understanding of this mega herbivore.

Chapter II

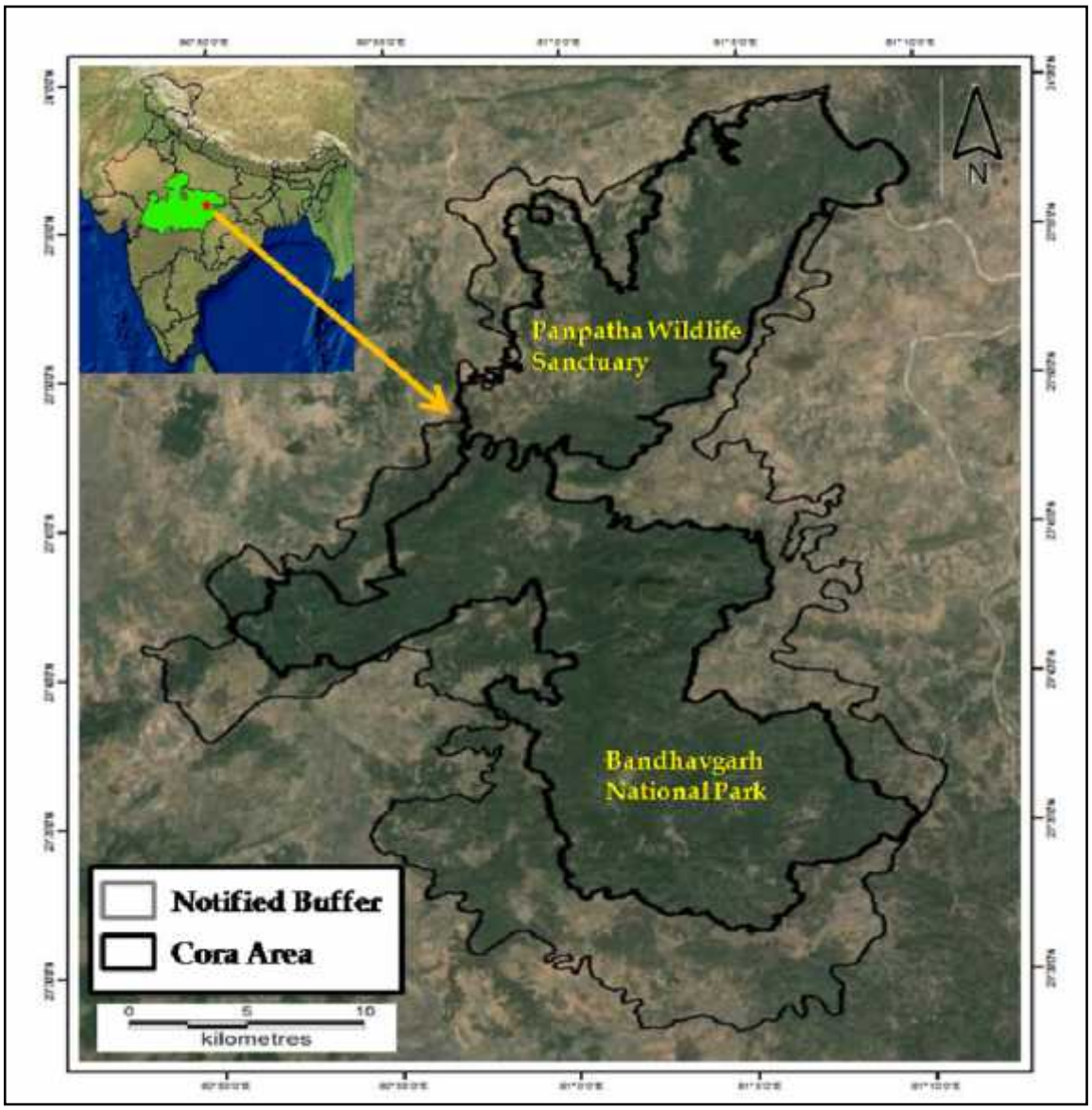
Study area

CHAPTER II: STUDY AREA

2.1: LOCATION AND GENERAL INFORMATION

The study was conducted in the Bandhavgarh Tiger Reserve (BTR) situated in the state of Madhya Pradesh in India (fig. 2.1). According to the Bio-geographic classification of India, Bandhavgarh Tiger Reserve falls in the zone 6E- Deccan plateau-Central highlands (Rodgers and Panwar 1988). It is located between the Vindhyan and the eastern flanks of Satpura hill ranges and the reserve lies between 23^0 30' 08" to 23^0 57' 01" North latitude and 80^0 47' 05" to 81^0 11' 43" East longitude. Bandhavgarh Tiger Reserve comprises of the core area (716.46 km^2) and the buffer area (820.15 km^2) and the total area of the reserve is 1536.7 km^2. The core area of the Tiger Reserve is further divided into two conservation units *viz*. Bandhavgarh National Park (448.84 km^2) and Panpatha Wildlife Sanctuary (264.28 km^2). The majority of the core area of BTR lies in the Umaria Forest Division (521.30 km^2) and the remaining portion lies in the Katni Forest Division (Prakasam 2006). The reserve has a diverse assemblage of flora and fauna (Gopal 1991). The headquarters of BTR is situated in Umaria town and the nearest cities are Katni (63.3 km), Shahadol (69.8 km) and Jabalpur (139 km).

Fig.2.1: Location of Bandhavgarh Tiger Reserve, Madhya Pradesh, Central India.



2.2: HISTORICAL AND LEGAL STATUS

Bandhavgarh Tiger Reserve has a very old history and ruins of the bygone era are scattered all over the tiger reserve. In Bandhavgarh, monuments of historical significance are the Bandhavgarh fort, caves, rock paintings and carvings. The Bandhavgarh fort is considered to be approximately 2000 years old (plate 2.1) and there are references to it in the ancient texts like the *Narad Panch* and the *Shiv*

Samhita Puranas (Sonakiya 1993). Legend has it that the fort was gifted by *Lord Ram* to brother *Lakshman* so as to keep a watch on Lanka and hence it acquired the name Bandhavgarh (Bandhav – brother, Garh – fort). The fort is surrounded by as many as 32 hillocks (Sonakiya 1993). There are many caves named after saints and Hindu gods, with oriental inscriptions. Large tanks cut in sand stone, wells and huge sculptures, symbolizing some of the incarnations of *Lord Vishnu* are seen on the Fort plateau. The most famous sculpture of Bandhavgarh is a sand stone carving of *Lord Vishnu* reclining on the serpent (sheshnaag) over a perennial water tank known as *Sheshshaiyya* (plate 2.2).

Plate 2.1: Bandhavgarh fort.

Plate 2.2: *Lord Vishnu* reclining on the serpent (*Sheshshaiyya*).

There has been human civilisation around the fort since 300 A.D. or even earlier and various dynasties have ruled the fort over the course of time (Sharma 1997). The earliest available historical data about the fort and its rulers is from the *Bhimsen Satvat* (Sonakiya 1993) in 300 A.D. when the fort was under the *Bharhivas Vekatak Dynasty*. The *Sangure Kings* captured the fort in the 5th century A.D. and it was later taken over by the *Kalchuri Rajput Kings*. Subsequently the fort was given over in dowry to the kings of the *Baghel* clan. It remained under the *Baghel* rulers till 1494 A.D. when it was captured by the *Kuruvanshee Kings*. In 1535 the *Baghel* kings regained the control of the fort and since then the Bandhavgarh fort remained under the rule of the *Baghel* kings as a part of the princely state of Rewa until Indian

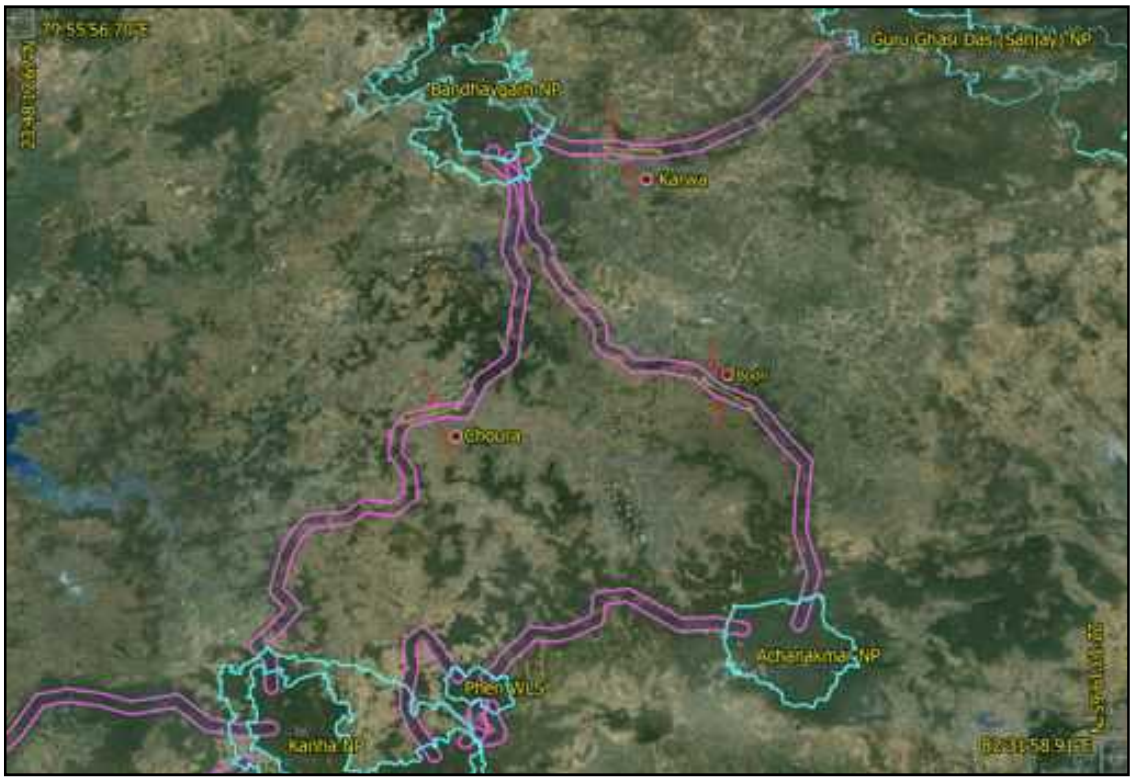
independence in 1947 (Nath 2000). The area enjoyed considerable protection under the *Baghel* rule as it was maintained as a shooting reserve for the royal family and hence there were rigid laws controlling the illegal felling of trees and poaching of animals (Nath 2000). In 1617, the capital of the Baghel kings was shifted to Rewa and the fort and its surroundings were gradually deserted. The *Baghel* king, late HH Martand Singh, handed over this hunting reserve to the government of India and in 1968 the Bandhavgarh National Park, comprising an area of 105 km^2 was established. In 1982 the area of the Bandhavgarh National Park was increased to 448.84 km^2. In 1983, an adjacent forest area of 264.28 km^2 to the east of the Park, was declared as the Panpatha Wildlife Sanctuary and subsequently the entire area was declared as Bandhavgarh Tiger Reserve under Project Tiger in the year 1993 (Prakasam 2006). On the fort there is a temple dedicated to *lord Ram* known as the *Bandhavadheesh* temple. The famous poet saint *Kabir Das* also lived on the fort and there is a temple and cave where he is supposed to have lived. These sites are important pilgrimage centres for people following the teachings of *Kabir* known as *Kabir Panthis*. On the occasions of the festivals of *Ramnavami*, *Krishna Janmashtami* and *Kabir jayanti* about 4000 to 10000 people visit *Bandhavadheesh* temple and the *Kabir* cave on foot (Prakasam 2006).

2.3: CONSERVATION SIGNIFICANCE

The Central Indian Landscape comprises of some of the most important and threatened habitats of tigers in India (Jhala *et al*. 2011). Bandhavgarh is one of the major source populations of tigers in this landscape and the forest corridor connectivity of Bandhavgarh with other protected areas like Sanjay-Dubri, Achanakmar and Kanha (fig. 2.2) is of vital importance for the movement and

maintenance of meta-populations of tigers in this landscape (Jhala *et al*. 2011). Apart from tiger conservation, Bandhavgarh is also important with regard to the conservation of avian fauna as it not only provides suitable habitat for resident birds but also provides wintering grounds for many waterfowl (Sonakiya 1993). Among the avian fauna, Bandhavgarh also harbours good populations of four species of vultures *viz*. long billed vulture (*Gyps indicus*), white-rumped vulture (*Gyps bengalensis*), red headed vulture (*Sarcogyps calvus*) and Egyptian vulture (*Neophron percnopterus*) (Prakasam 2006). Besides tiger and birds, the reserve harbors quite a few faunal species which figure prominently in the IUCN Red List like *Cuon alpines* (dhole), *Melursus ursinus* (sloth bear) and *Panthera pardus* (leopard) (Sonakiya 1993).

Fig.2.2: Corridors connecting Bandhavgarh Tiger Reserve with Sanjay-Dubri, Achanakmar and Kanha Tiger Reserves (Jhala *et al*. 2011).



2.4: TOPOGRAPHY AND GEOLOGY

Topographically, Bandhavgarh is extremely rugged with small hillocks interspersed with grassy swamps (Gopal 1991). The highest part of this landscape is the Bandhavgarh fort, which lies at an altitude of 810 m above msl (mean sea level) while the lowest point is the village of Tala at an altitude of 440 m above msl (Nath 2000). The area of Panpatha Wildlife Sanctuary is mostly plain though some parts have undulating hillocks and the highest point of the Sanctuary is 500 m above msl (Sonakiya 1993). The Bandhavgarh Tiger Reserve contains some of the oldest rocks in the world – the Gondwana rocks (Nath 2000). The rocks in the Bandhavgarh region belong to the Gondwana Super group of the South Rewa Basin (Sonakiya 1993) and the rock formations in Bandhavgarh mainly comprise of sandstone.

2.5: PHYSICAL FEATURES

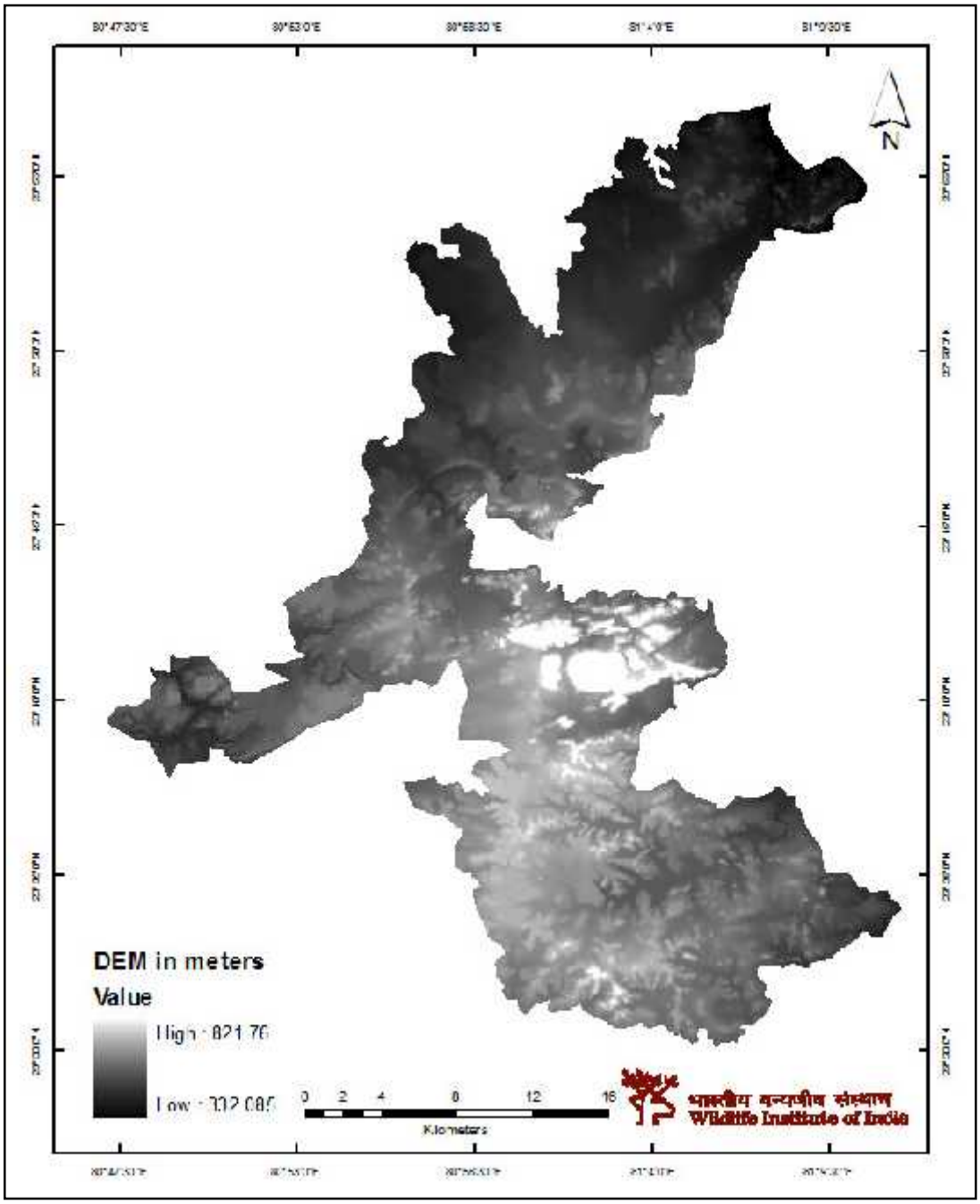
2.5.1: Soil

The various rock formations and local topography have played an important role in the formation of soil in Bandhavgarh. The Gondwana sandstone is a poor source for good quality soils. The soil in the region is mainly sandy or sandy loam (Nath 2000). Richer clay and black cotton soils are also found in the park but their distribution is restricted to the areas of Badrehal and Pathari beats and the surrounding areas in the park (Sonakiya 1993). The pH of the soil in the park is around 20 and the composition of the chloride is 13 (Roy *et al.* 1992). The soil is usually poor in nitrogen and organic matter and fairly rich in potash.

2.5.2: Slope

The slope categories in BTR have been identified into eight classes *viz*. 330-390 degrees, 391-450 degrees, 451-520 degrees, 521- 580 degrees, 581- 640 degrees, 641-700 degrees, 701- 760 degrees and 761- 820 degrees (figure 2.3). Most of the protected area falls into flat to gentle slope class (330- 640 degrees). Part of Tala range has a rugged terrain with steep slopes (701- 820 degrees).

Fig.2.3: Digital Elevation Model map of Bandhavgarh Tiger Reserve.

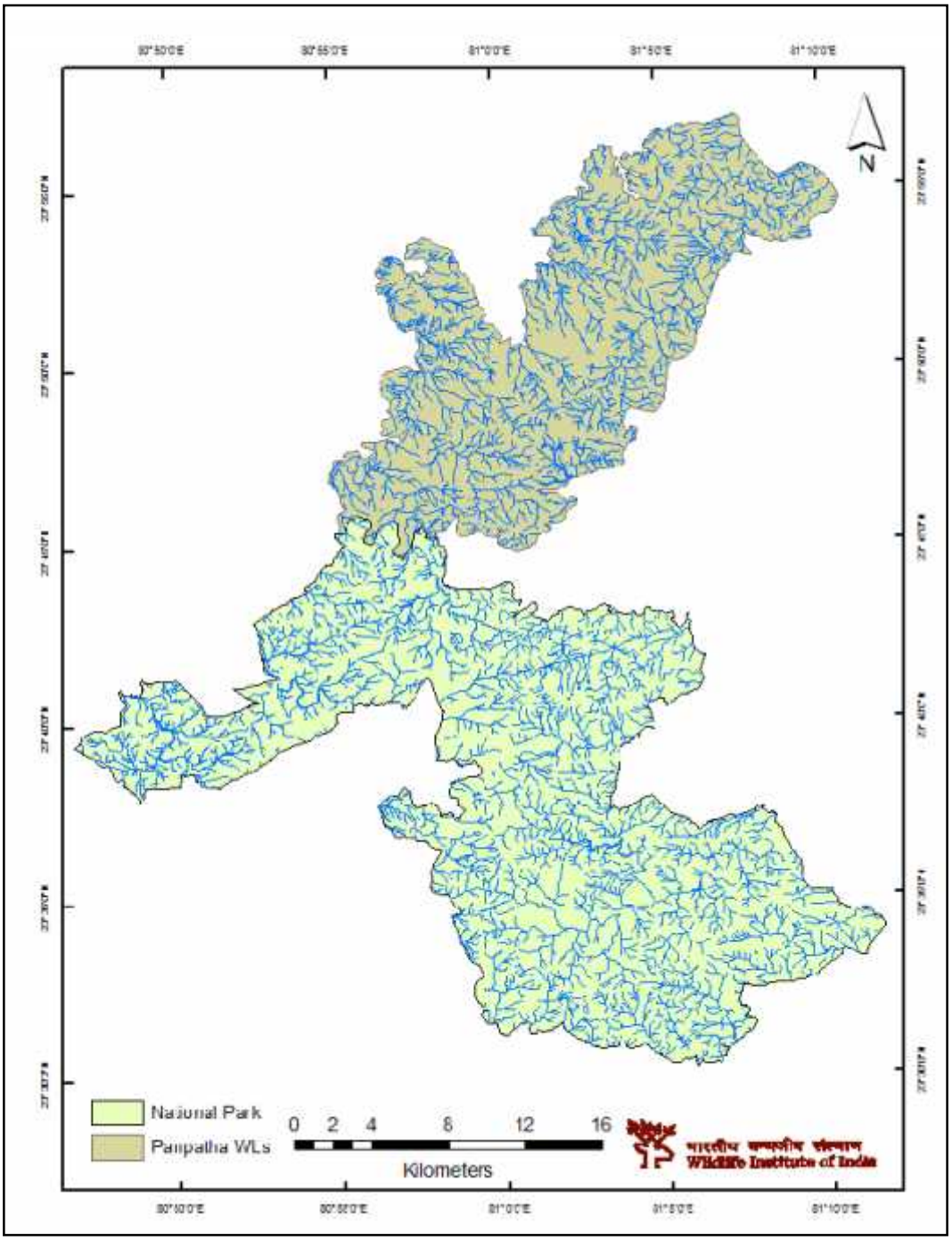


2.6: DRAINAGE PATTERN AND WATER AVAILABILITY

In Bandhavgarh Tiger Reserve the rock formations comprise mainly of sandstone which is a well-known aquifer as it is characterized by porosity and permeability (Prakasam 2006). Being permeable, sandstone is capable of high recharge and

discharge making it as a storehouse of ground water which has resulted in some areas of the park having a very high water table. The Tiger Reserve has a number of seasonal and perennial streams and nullas (Lad and Gopal 1992). The major perennial rivers are Umarar, Damnar, Janad, Johila, Charanganga and seasonal nalas are Bhadar, Chachahi and Chamkuli (Prakasam 2006). The river Son flows in the north eastern direction along the boundary of Panpatha Wildlife Sanctuary. A large number of perennial springs originate on the slope of Bandhavgarh fort, the most important being Charanganga which flows as a major river outside the park area (Pabla 1998). The river Janad runs year round and flows in North-East region of the park, which originates from Magdhi range and flows into Kallwah range and joins the Son river running along the buffer boundary. In Sanctuary area the main rivers are Halphal, Jaruwahi Nala and Bagaiha Nala. The major waterholes in the park are Rajbehra dam, Devkhanni talab, Andhiyari jhiriya, Adhawal, Bamera dam, Damdama talab, Jhurjura dam, Mahaman dam, Bodha talab, Charakava talab and Sukha dam (Prakasam 2006). Many water holes in the park dry up during summer and hence the park management supplies water in these water holes through tankers, solar pumps and hand pumps. The drainage pattern of the Tiger Reserve is shown in figure 2.4.

Fig.2.4: Drainage pattern of Bandhavgarh Tiger Reserve.



2.7: CLIMATE

The Tiger Reserve lies within the tropical zone, having three distinct seasons *viz*. summer (March-June), monsoon (July-October) and winter (November-February).

2.7.1: Summer

The summer sets in the month of March and lasts till around mid June when the area receives the first showers of the Southwest monsoon. Generally, the months of May and June are the hottest, with the temperature rising up to 46°C (Prakasam 2006). During the study period the highest mean monthly temperature was recorded in the month of May at 43.8 ^{0}C (fig. 2.5). Summer is usually dry, but instances of rains, hailstorms and thunder do occur in the month of March and April. The relative humidity in the early afternoon is as low as 15-20%. During this period many water holes dry up and the park area is prone to fires.

2.7.2: Monsoon

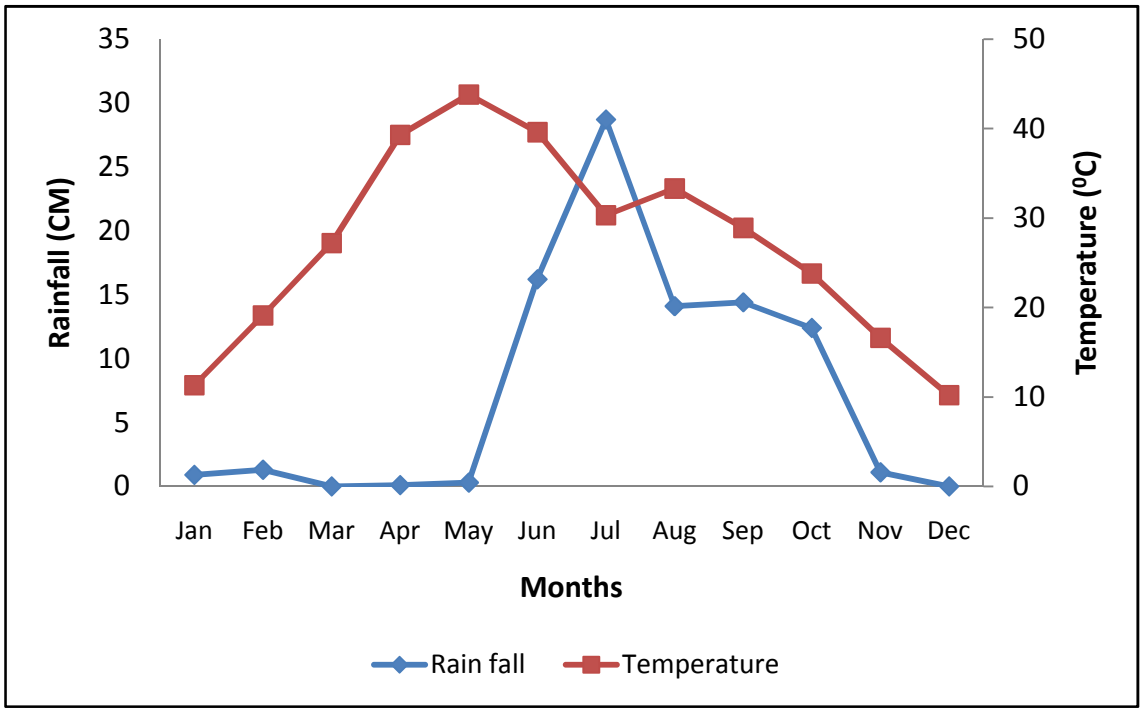
The area receives pre-monsoon showers by the mid of June and the regular southwest monsoon starts in the first week of July. More than 80% of the total precipitation in the year is received during July to September (Sonakiya 1993). Occasional winter rains occur during December to February from northeast monsoon constituting 5% of annual rainfall in this area (Prakasam 2006). During the study period the highest mean monthly rainfall was recorded in July at 28.7 centimetres (fig. 2.5).

2.7.3: Winter

The winter begins in November and lasts till February, December and January being the coldest months. In severe winters, the night temperature comes down very low, mercury dropping even to sub-zero temperatures and severe ground frost occurs in the meadows and valleys (Prakasam 2006). During the study period the lowest mean monthly temperature was recorded in December at 10.2 ^{0}C (fig. 2.5). Occurrence of

fog in the early morning hours is common in winter. The relative humidity reaches 100% during the night, and the incidence of dew is heavy.

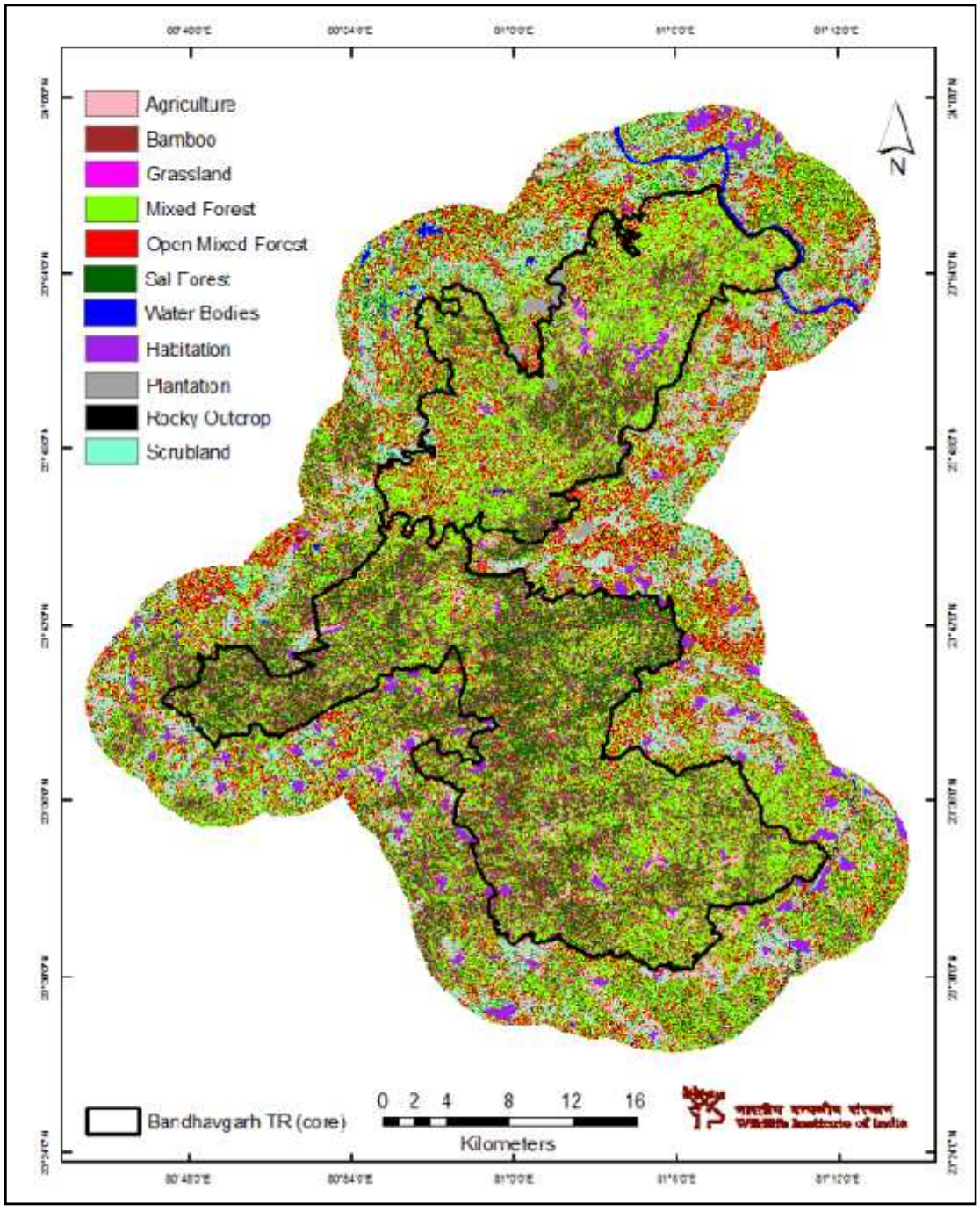
Fig.2.5: Mean rainfall and temperature in Bandhavgarh Tiger Reserve (January 2012 to December 2013).



2.8: FLORA

Vegetation of Bandhavgarh Tiger Reserve falls under five categories (Champion and Seth 1968) such as Moist peninsular low level Sal forest (3C/C2e), Northern dry mixed deciduous forest (5B/C2), Dry deciduous scrub (DS1), Dry grassland (5/DS4) and West Gangetic moist mixed deciduous forest (3C/C3a). The land use and land cover map of Bandhavgarh Tiger Reserve is given in figure 2.6.

Fig.2.6: Vegetation and land cover map of Bandhavgarh Tiger Reserve.



A) Moist peninsular low level Sal forest (3C/C2e)

Sal typically forms a high forest in which it constitutes about 60 - 80% of the top canopy, which is 25–40 m high. The undergrowth is abundant with the presence of climbers. The main associates are *Terminalia tomentosa, Pterocarpus marsupium,*

Anogeissus latifolia, Madhuca indica, Phyllanthus emblica, Buchanania lanzan, Diospyros melanoxylan, Terminalia Chebula, Kydia calycina, Ougeinia oojeinensis, Bridelia retusa, Bauhinia retusa and *Phoenix acaulis.* Sixty percent of the Tiger Reserve area comprises of Sal forests and its associates (Dwivedi 1987).

B) Northern dry mixed deciduous forest (5B/C2)

The upper canopy in this forest type is usually light, open and irregular, the trees having relatively short bole and poor form and a height rarely over 10 m. The canopy is made entirely of deciduous trees. The main species found are *Anogeissus latifolia, Acacia catechu, Butea monosperma, Buchanania lanzan, Acacia leucophloea, Syzygium cumini, Mangifera indica, Aegle marmelos, Soymida febrifuga, Cassia fistula, Flacourtia indica, Capparis decidua and Dendrocalamus strictus.* The undergrowth is comprised of *Ziziphus mauritiana, Ziziphus oenoplia, Ziziphus nummularia, Carissa opaca, Holarrhena antidysenterica, Bauhinia vahlii, Aristida depressa, Cynodon dactylon, Cymbopogon martinii, Heteropogon contortus, Themeda quadrivalvis* and *Cassia tora.*

C) Dry deciduous scrub (DS1)

This forest type represents a degradation stage of the dry deciduous forest and has been brought into existence by adverse biotic factors like cattle grazing, lopping and forest fires. In spite of sufficient rains, moisture retention is poor and the type has now become a stable edaphic climax. The main species found are *Butea monosperma, Diospyros melanoxylon, Cassia fistula, Anogeissus latifolia* and the undergrowth mainly comprises of *Woodfordia floribunda* and *Flacourtia indica.*

D) Dry grassland (5/DS4)

Grasslands, locally called as *bah*, are a common feature of the valleys in the park. Most of the large grasslands in the park have been created at the areas from where villages have been relocated outside of the park. The grassland communities are complex. Tall, coarse grasses are found in the marshy areas. Species which commonly occur in these grasslands include *Themeda quadrivalvis, Aristida setacea, Heteropogon contortus, Saccharum spontaneum, Vetiveria zizanoides* and *Phragmites karka.*

E) West Gangetic moist mixed deciduous forest (3C/C3a)

In this type of forest the canopy is comparatively open allowing good percentage of grass and herb to grow. The main species found in this type are *Lagerstroemia parviflora, Anogeissus latifolia, Adina cordifolia, Terminalia chebula, T. Bellerica, T. arjuna, Diospyros melanoxylon, Bauhinia retusa, Lannea coromandelica, Mitragyna parvifolia, Cassia fistula, Kydia calycina, Bauhinia racemosa, B. variegata, Phyllanthus emblica, Aegle marmelos, Grewia tiliaefolia, Bridelia retusa, Casearia esculenta, Gardenia turgida, G. latifolia, Holarrhena antidysenterica, Garuga pinnata, Buchanania lanzan, Butea monosperma, Helicteres isora* and *Dendrocalamus strictus* (Lall 1988). Bamboo occurs as undergrowth which are heavily browsed and become bushy. New culms of bamboo grow during November–December. These forests are highly prone to fire.

2.9: FAUNA

The Tiger Reserve supports a diverse assemblage of herbivores such as chital (*Axis axis),* sambar (*Rusa unicolor*) nilgai (*Boselaphus tragocamelus*), wild pig (*Sus scrofa*), barking deer (*Muntiacus muntjac*), four-horned antelope (*Tetracerus quadricornis*) and chinkara (*Gazella bennettii*). Primates such as Rhesus macaque (*Macaca mulatta)* and common langur (*Semnopithecus entellus)* are found in the park. The area supports a wide variety of large, medium and small sized carnivores such as tiger (*Panthera tigris*), leopard (*Panthera pardus*), dhole (*Cuon alpinus*), sloth bear (*Melursus ursinus*), jackal (*Canis aureus*), jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*), common palm civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*), grey mongoose (*Herpestes edwardsii*), ruddy mongoose (*Herpestes smithii*) and stripe necked mongoose (*Herpestes vitticollis*). The presence of wolf (*Canis lupus*), striped hyena (*Hyaena hyaena*), and Indian fox (*Vulpes bengalensis*) has also been recorded from the fringes of the park. The Indian porcupine (*Hystrix indica),* blacknaped hare (*Lepus nigricollis nigricollis*), three stripped squirrel (*Funambulus palmarum*) and Indian pangolin (*Manis crassicaudata*) also occur in Bandhavgarh Tiger Reserve. Domestic livestock (cattle, buffalo and goat) occur in the village areas present inside the National Park and Sanctuary (Prakasam 2006).

Around 250 species of birds have been identified in the Reserve (Prakasam 2006). The prominent birds of Bandhavgarh are the Indian peafowl (*Pavo cristatus*), red jungle fowl (*Gallus gallus*), Indian grey hornbill (*Ocyceros birostris*), Malabar pied hornbill (*Anthracoceros coronatus*), common teal (*Anas crecca*), lesser whistling teal (*Dendrocygna javanica*), crested serpent eagle (*Spilornis cheela*), lesser adjutant

stork (*Leptoptilos javanicus*), long billed vulture (*Gyps indicus*), red headed vulture (*Sarcogyps calvus*), white-rumped vulture (*Gyps bengalensis*) and Egyptian vulture (*Neophron percnopterus*) (Sonakiya 1993).

2.10: TOURISM

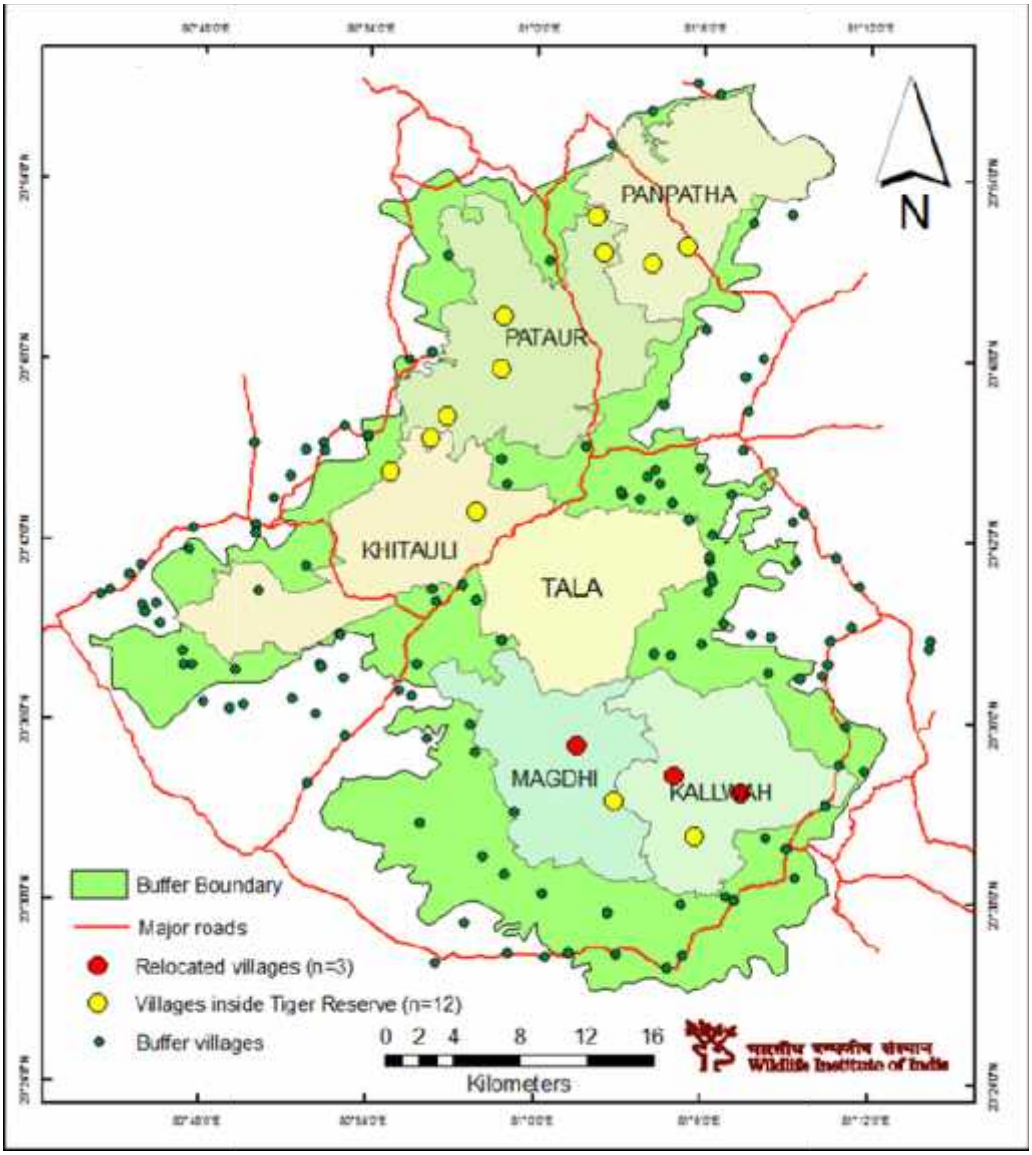
The park provides very good sighting opportunities of tiger and other wild animals (Tyabji 1991). The park remains open from mid of October to June end and tourists are allowed entry for four hours in the morning and three hours in the evening. Because of the easy sighting of tigers, around 1,00,000 tourists visit the park every year of which around 35% are foreigners (Choudhary 2013). The wildlife tourism activities are restricted only to an area of 146 km^2 which comprises of around 20% of the total core area of BTR. The tourism area in BTR is further divided into three zones among the ranges of Tala, Magdhi and Khitauli (Choudhary 2013).

2.11: HUMAN SETTLEMENTS

At the start of 2011 there were 15 villages located inside the Tiger Reserve, of which seven were located in the notified Bandhavgarh National Park and eight in the Panpatha Wildlife Sanctuary (Choudhary 2013). The villages inside the core area are due for relocation in a phase-wise manner and between 2011 and 2013 three villages, Kallwah, Kumarwah and Magdhi were relocated from the core area of Bandhavgarh (figure 2.7). Soon after relocation many herbivore species like chital, nilgai, chinkara, wild pig and gaur have been observed to use these relocated sites intensively (Sankar *et al*. 2013, Choudhary 2013). Also there are 96 villages within a five kilometer radius of the outer boundary of the core area of Bandhavgarh Tiger Reserve. The total human population of these villages is estimated to be around

45,000 heads (Choudhary 2013). Agriculture is the main occupation in these villages and the major crops are wheat, ragi, cauliflower, cabbage and beans. Some villagers also work with the forest department as fire watchers, choukidars, elephant caretakers and mahout, grass cutters and as a part of antipoaching team. The livestock mainly includes a large number of buffaloes and a few cows along with some goats (Prakasam 2006).

Fig.2.7: Location of villages in the core and buffer area of Bandhavgarh Tiger Reserve.



Chapter III

Behavioural patterns of reintroduced gaur

CHAPTER III: BEHAVIOURAL PATTERNS OF REINTRODUCED GAUR

3.1: INTRODUCTION

Translocation and reintroduction of wild animals which have become rare or have gone locally extinct due to natural catastrophes or human induced activities has become an important tool for conservation in recent years. In any reintroduction programme the monitoring and undertaking of ecological studies of the reintroduced species is of vital importance (IUCN 1998). Undertaking ecological studies of a reintroduced species provides an understanding as to how the species is interacting with its new environment. A single species may show different behavioural patterns in different environmental conditions (Delany and Happold 1979). Studying behavioural patterns of a species gives an insight into the allocation of time for different activities by the species annually and seasonally which in turn leads to a better understanding of its general ecology. The behavioural patterns and activity budgets are expected to differ according to the age and sex of the animal. Information on the behavioural pattern of a species helps in understanding the foraging and survival strategies of that species in their habitat (Vairavel 1998). The study of behavioural patterns also leads to an understanding of the social interactions of the animals with the members of their own species and other species.

There are a number of studies which have reported the activity pattern of different ungulate species. Activity patterns of black buck (Chattopadhyay and Bhattacharya 1986), impala (Jarman and Jarman 1973), warthog (Clough and Hassan 1970), mountain reed buck (Irby 1982), Thomson's gazelle (Walther 1973), lesser kudu

(Mitchell 1977), generuck and giraffe (Leuthold and Leuthold 1978), elephant (Mckay 1973, Santiapillai *et al*. 1984, Santiapillai and Suprahman 1986, Easa 1989), African oryx (Ruckstuhl and Neuhaus 2009), rhinoceros (Owen-Smith 1988, Kandel and Jhala 2008) have been studied in their natural habitat. Activity patterns for ungulates belonging to the group of wild cattle have been studied for African buffalo (Stark 1986, Prins 1996, Sinclair 1977, Ryan and Jordaan 2005), Bison (McHugh 1958 and 1972, Shult 1972, Korockina 1972, Vajner 1980, Brink Van Den 1980, Cabon-Raczynska *et al*. 1983, Reinhardt 1985, Rutley and Hudson 2001), Banteng (Halder 1976, Pudyatmoko 2005), Anoa (Mustari 1996) and gaur (Schaller 1967, Moorthy 1989, Prabhakar 1992, Vairavel 1998, Sankar *et al*. 2001, Gad 2011).

In the present study the diurnal activity patterns, activity budgets of different age and sex classes of the reintroduced gaur population and social interactions between the individuals among the gaur population were studied from March 2012 to February 2014.

3.2: METHODOLOGY

For the collection of data on behavioural patterns of gaur the scan sampling technique (Altman 1974) was used. Of the entire reintroduced gaur population (n=50) a total of 27 individuals were radio collared and hence different gaur herds were tracked using radio telemetry. When a gaur herd was sighted, instantaneous scan samples were recorded at five minutes intervals and the activities of all animals visible at that time were recorded. The observation time was of five minutes followed by an interval of five minutes which amounted to six scans per hour. In each scan the age and sex class of the animal, activity, plant species and plant part

eaten if feeding were recorded. Observations lasted till sunlight favoured visibility or the animals left the location and went out of sight. This type of sampling has also been termed as “time sampling” (Hutt and Hutt 1974), “point sampling” (Dunbar 1976) and “on the dot sampling” (Slater 1978). In a month the activity data on gaur was collected from 0600 hrs in the morning to 1800 hrs in the evening. The observations were made from vehicle (open top four wheel drive vehicle) and on foot.

For the classification of gaur into different age and sex classes a modified Schaller’s (1967) gaur classification was followed (The adult cow was used as a comparative measure for the classification of individuals into different age classes). Seven different age and sex classes of gaur have been recognized for this study:

1. Adult cow – a full grown adult cow stands at shoulder up to 1.5 m on an average, dewlap and the dorsal ridge are less prominent.
2. Black bull – bull with black pelage and larger in size than adult cow, prominent dewlap and dorsal ridge.
3. Brown bull – bull which is almost the size and colour of adult cow.
4. Sub adult (Sub adult cow/ Sub adult bull) – smaller, less bulky than adult cow and ¾ the size of adult cow.
5. Yearling – about 2/3 the size of adult cow.
6. Calf – quarter the size of adult cow.

To collect the behavioural data, 13 distinct activities were defined which were as follows:

1. Feeding – the animals feed on various type of plant material (trees, shrubs, ground layer).

2. Standing – the animals just stand without doing any other activity.
3. Moving – the animals move from one place to another.
4. Resting – the animals generally sit in shade (many a times ruminate) and might also sleep by resting their head on the ground.
5. Autogrooming – the animals lick themselves; scratch their head on a tree trunk or with their foot.
6. Allogrooming – the animals lick other individuals which are near to them.
7. Drinking – the animals drink water.
8. Aggressive behaviour – the animals engage in activities like head to head fights, chasing, head butting or threatening.
9. Sexual behaviour – the males (adult bulls) engage in activities like rutting, flehmen, tending and mounting the females.
10. Defecating/Urinating – the animal defecate/urinates.
11. Vocalization – the animals vocalize (including alarm calls, rutting calls and threatening vocalisations).
12. Salt licking – the animals lick soil at a natural salt lick or lick the cubes of artificial salt licks provided by the forest department.
13. Alert behaviour – the animals raise their head up and look in a particular direction generally with their ears raised.

Social interactions among gaur include activities like allogrooming, vocalisations, sexual behaviour and various types of aggressive behaviours. These activities tend to be underrepresented in a dataset collected through scan sampling and hence *ad-libitum* sampling was used to record the occurrence of the social interactions among the gaur population.

3.3: DATA ANALYSIS

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

$$P_i = (n_i / N) \text{ X } 100$$

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 seven different age and sex classes of gaur for all the seasons. The data for all the age and sex classes was pooled together to calculate the percent time spent in different activities by gaur in general. The annual and seasonal activity patterns and activity budgets were calculated for all the age and sex classes of gaur and for gaur in general. For the analysis of annual activity budgets and activity patterns the data for the entire study period (six seasons) was pooled together. For the analysis of activity pattern the entire day (0600-1800 hrs) was divided in six time frames of two hours each *viz*. 0600-0800, 0800-1000, 1000-1200, 1200-1400, 1400-1600 and 1600-1800 hrs. As rain and temperature has an effect on activity (Joshua 1992), the entire year was divided into three seasons *viz*. summer (March-June), monsoon (July-October) and winter (November-February).

The statistical package SPSS was used for data analysis (Norusis 1993). The Kolmogorov-Smirnov test was used to test the data for normality (Siegel 1956) and since the data was found to be non-normal, the non parametric Kruskal-Wallis test was used to analyse the data. Percent time spent on activities like feeding, moving,

resting and alert behaviour by each age and sex class of gaur was tested for significant seasonal difference. Also the time spent in these activities in each season and annually was tested for significant difference across the different age and sex classes of gaur. Percentage frequency occurrence and event rates were calculated for the social interactions and other behaviours like drinking, leadership and vocalisations. Since the distribution of all the age and sex classes of gaur in the population was highly 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 of gaur) gave a better idea of the frequency of a behaviour for each age and sex class of gaur.

3.4: RESULTS

The details of the scan records obtained for each age and sex class of gaur are given in table 3.1. The season-wise hours of observation and scan records for each age and sex class of gaur are given in Appendix I.

Table 3.1: Scan records obtained for different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Age and sex class of gaur	Scan records			
	Summer	Monsoon	Winter	Total
Adult cow	2678	2096	1750	6524
Sub-adult cow	1237	1752	995	3984
Yearling	637	260	533	1430
Calf	1031	817	724	2572
Sub-adult bull	626	512	196	1334
Brown bull	297	189	207	693
Black bull	426	184	183	793
Gaur	**6932**	**5810**	**4588**	**17330**

The scan records were highest for adult cow (n=6524) and were lowest for brown bull (n=693) as the percentage of adult cow in the gaur population was highest (37%) and that of brown bull (8.2%) was very low during the study period. The total observation hours were more in summer (127.3 hrs) compared to monsoon (116.6 hrs) and winter (107 hrs) because of greater visibility in the forest due to leaf shedding and less understory growth.

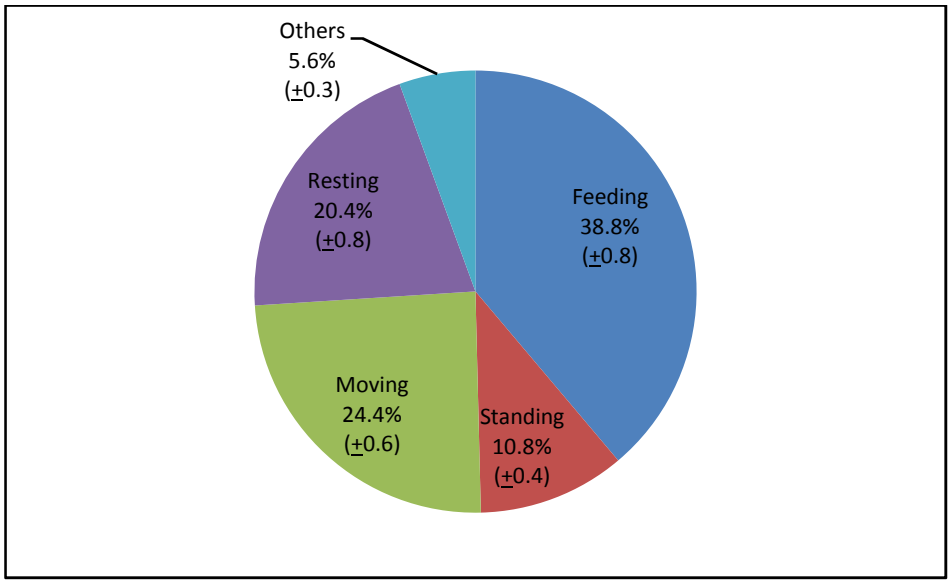
3.4.1: Activity budget

Gaur

A total of 17,330 scan records were obtained for gaur (taking all the age and sex classes of gaur together). Figure 3.1 shows the annual activity budget of gaur in Bandhavgarh. It was observed that feeding, moving and resting constituted the major activities of gaur throughout the year. The percentage time spent on feeding, moving and resting was 38.8%, 24.4% and 20.4% respectively. Standing accounted for 10.8% of the time and about 5.6% time was spent on other activities like alert behaviour, autogrooming, social interactions, drinking and salt licking. The seasonal activity budget of gaur is given in figures 3.2, 3.3 and 3.4 for summer, monsoon and winter respectively. In all seasons, feeding was the main activity of gaur. But the time spent in feeding varied considerably between seasons. The time spent in feeding was highest in summer (42.5%) compared to monsoon (34%) and winter (39.7%). The difference in the percentage time spent for feeding across the seasons was found to be significant (Kruskal Wallis: χ^2 =11.352, $p<0.05$). The time spent in standing was higher in winter (13.2%) compared to summer (9.2%) and monsoon (10%). The difference was found to be significant (K.W: χ^2 =7.302, $p<0.05$). Gaur spent about 28.3% of the time moving in winter compared to 19.4% in summer and

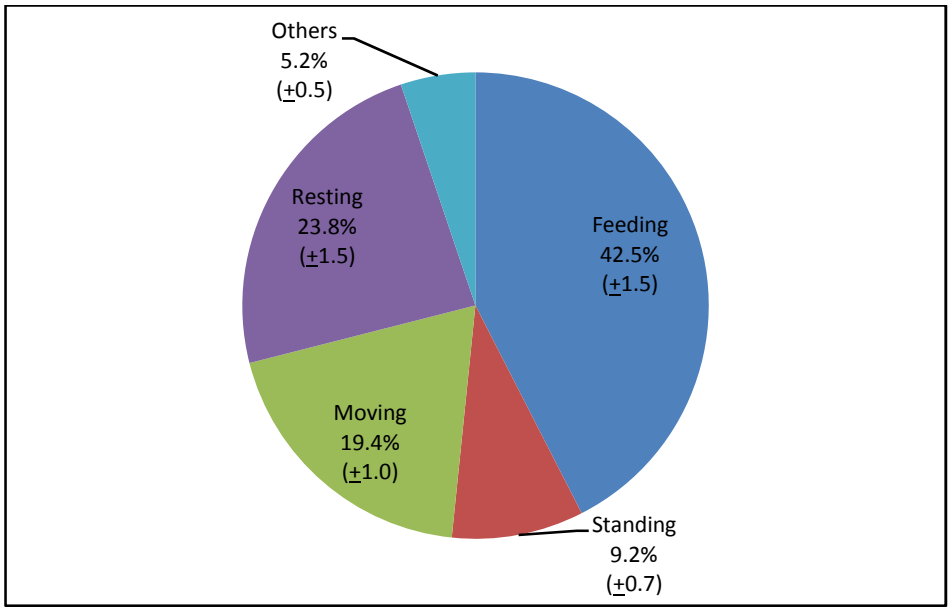
25.6% in monsoon. Time spent moving across the seasons showed significant difference (K.W: χ^2 =45.310, p<0.05). The time spent resting by gaur in winter (14.7%) was significantly lower compared to summer (23.8%) and monsoon (22.9%) (K.W: χ^2 =38.277, p<0.05).

Figure 3.1: Annual activity budget of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by gaur in major activities annually)



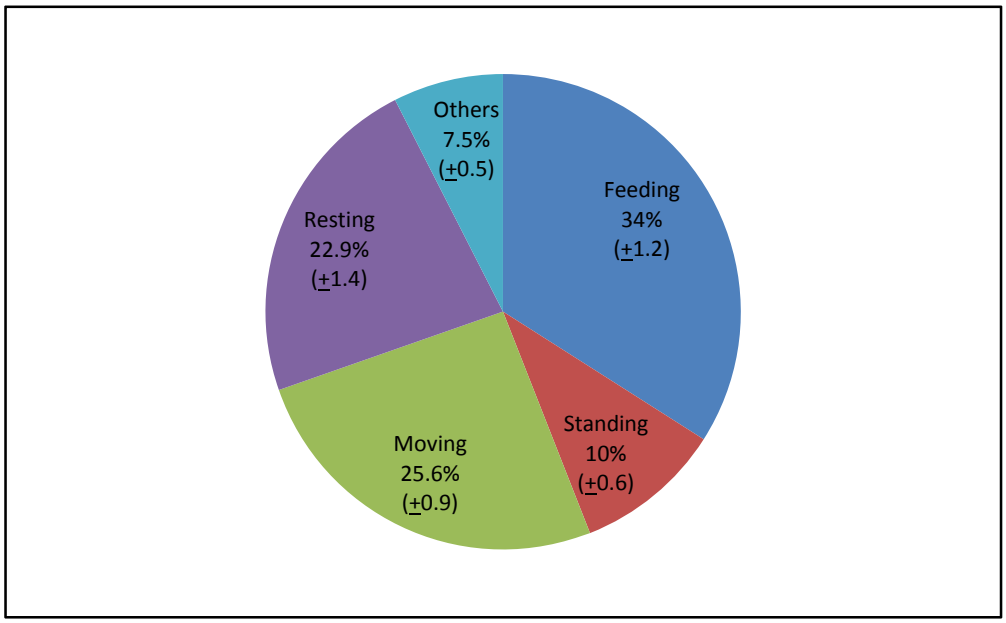
Number of scan records: 17330

Figure 3.2: Summer activity budget of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by gaur in major activities in summer)



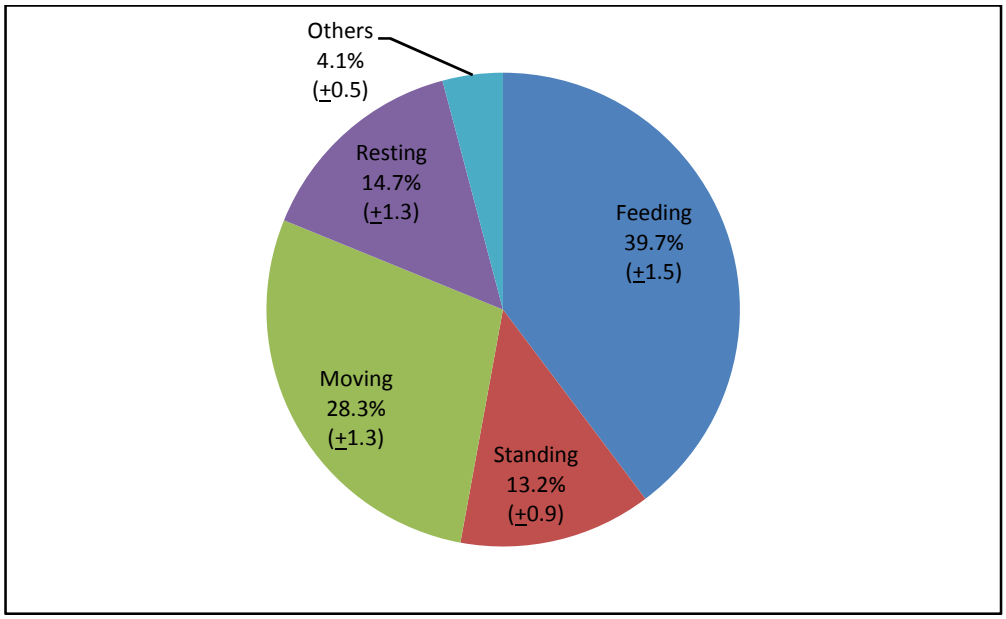
Number of scan records: 6932

Figure 3.3: Monsoon activity budget of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by gaur in major activities in monsoon)



Number of scan records: 5810

Figure 3.4: Winter activity budget of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by gaur in major activities in winter)



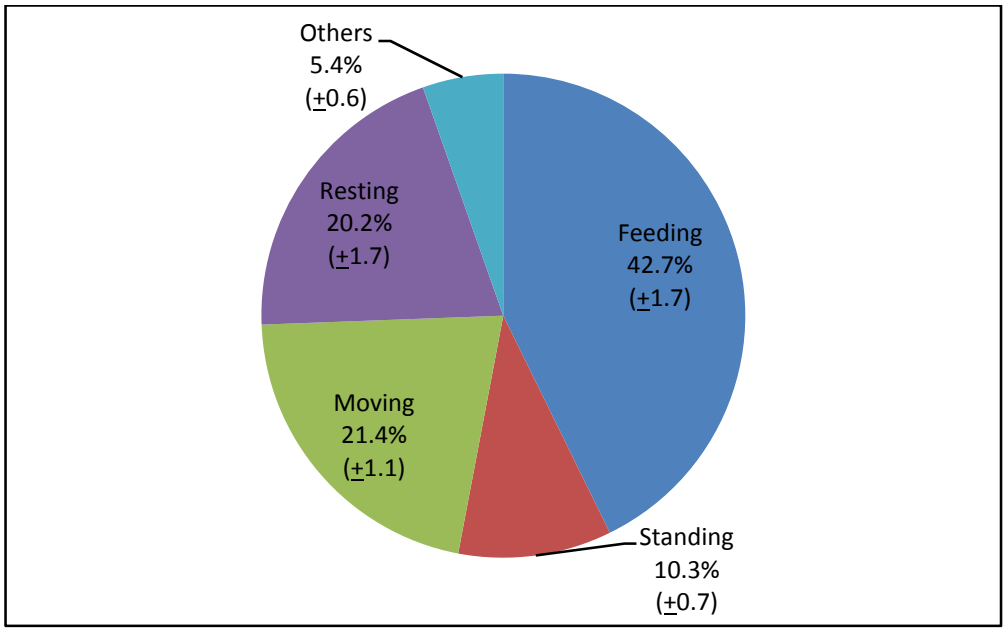
Number of scan records: 4588

Activity budget of different age and sex classes of gaur

Adult cow

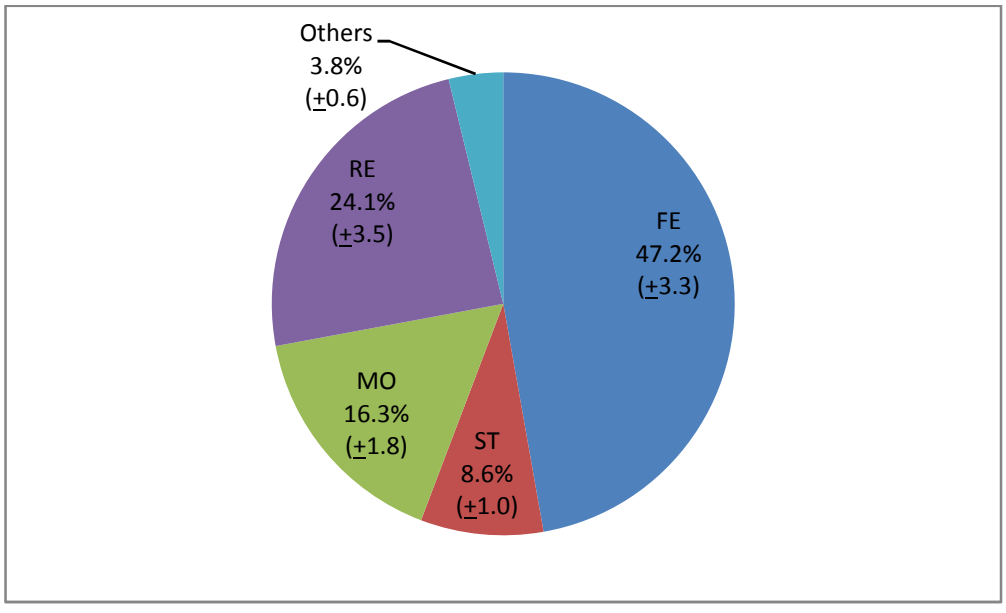
The annual activity budget of adult cow (fig. 3.5) showed that the time spent in feeding (42.7%) was highest followed by moving (21.4%), resting (20.2%) and standing (10.3%). The activity budget of adult cow for summer, monsoon and winter is given in figures 3.6, 3.7 and 3.8 respectively. The percentage time spent for feeding by adult cow was considerably higher in summer (47.2%) and winter (46.3%) as compared to monsoon (34.9%) (K.W: χ^2 =10.536, $p<0.05$). Time spent in moving was similar in monsoon (23.2%) and winter (23.9%) but was significantly lower in summer (16.3%) (K.W: χ^2 =10.883, $p<0.05$). The time spent in resting by adult cow was significantly lower in winter (13.7%) as compared to summer (24.1%) and monsoon (23.9%) (K.W: χ^2 =10.060, $p<0.05$).

Figure 3.5: Annual activity budget of gaur adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by adult cow in major activities annually)



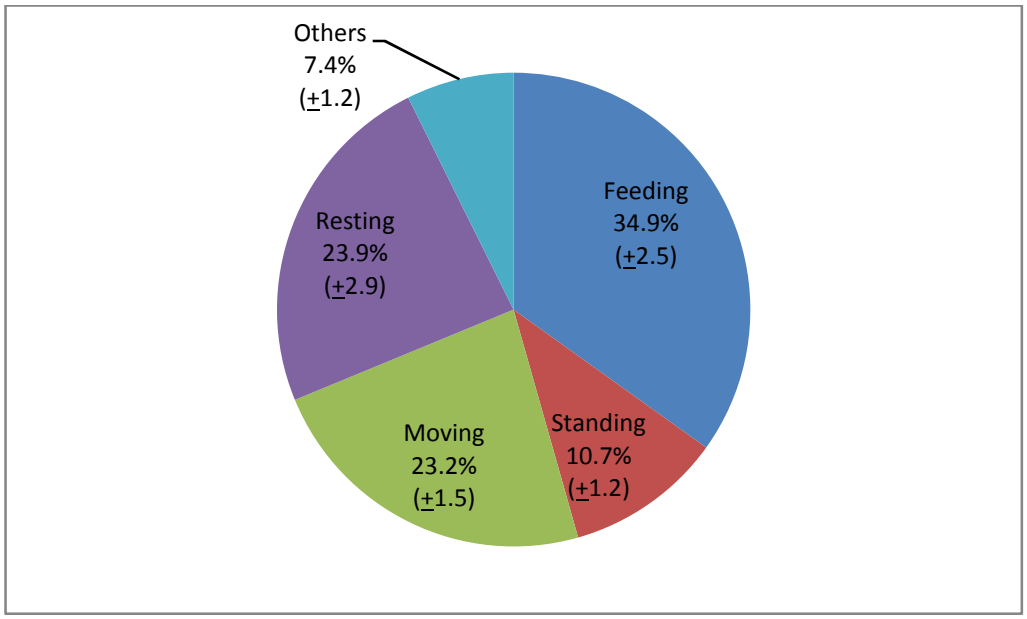
Number of scan records: 6524

Figure 3.6: Summer activity budget of gaur adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by adult cow in major activities in summer)



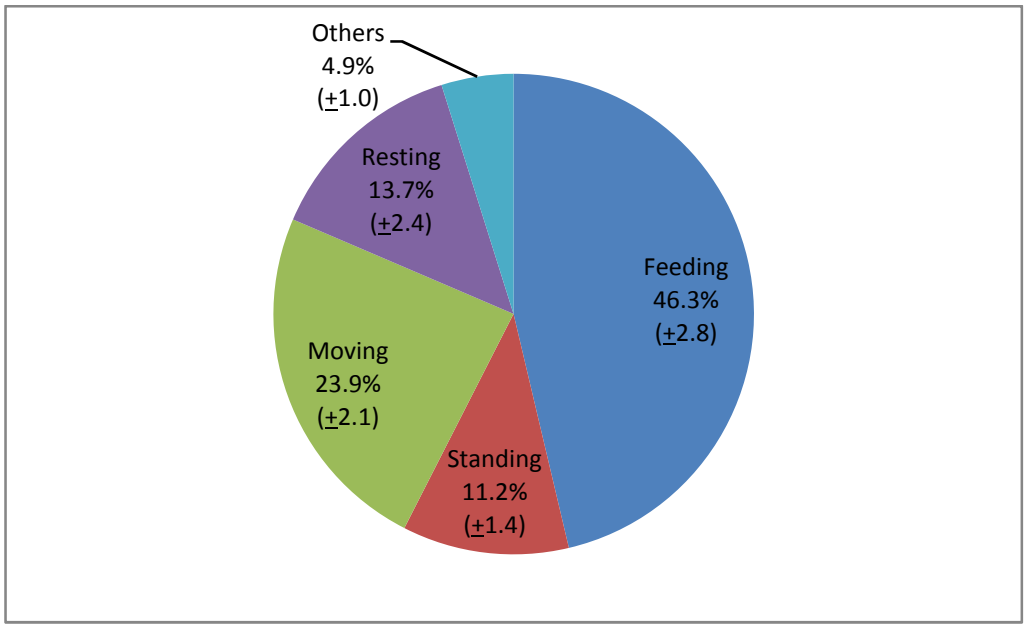
Number of scan records: 2678

Figure 3.7: Monsoon activity budget of gaur adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by adult cow in major activities in monsoon)



Number of scan records: 2096

Figure 3.8: Winter activity budget of gaur adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by adult cow in major activities in winter)

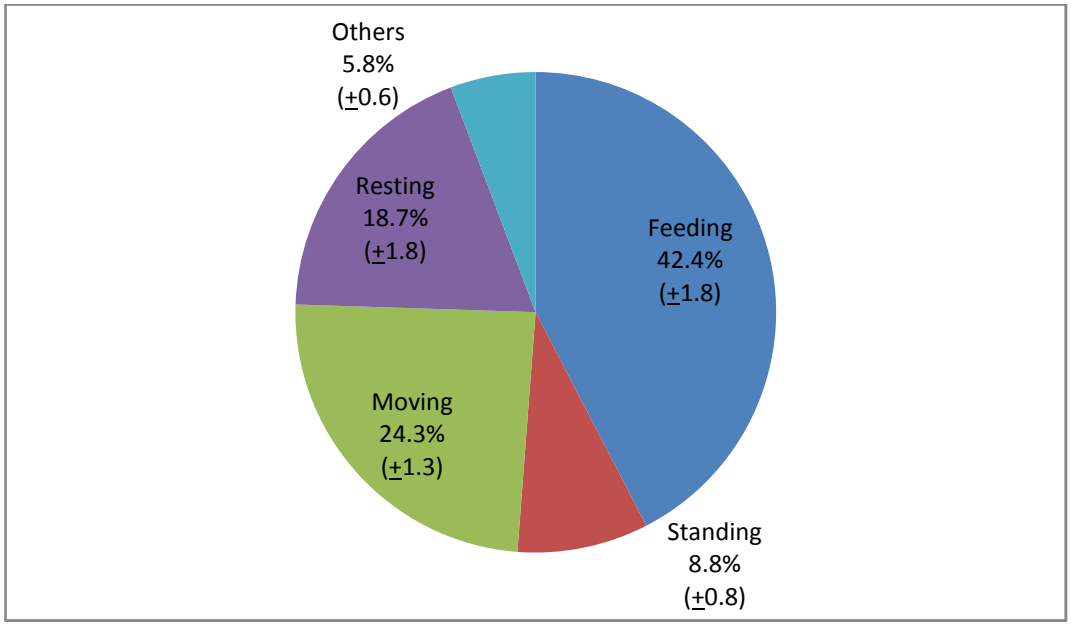


Number of scan records: 1750

Sub-adult cow

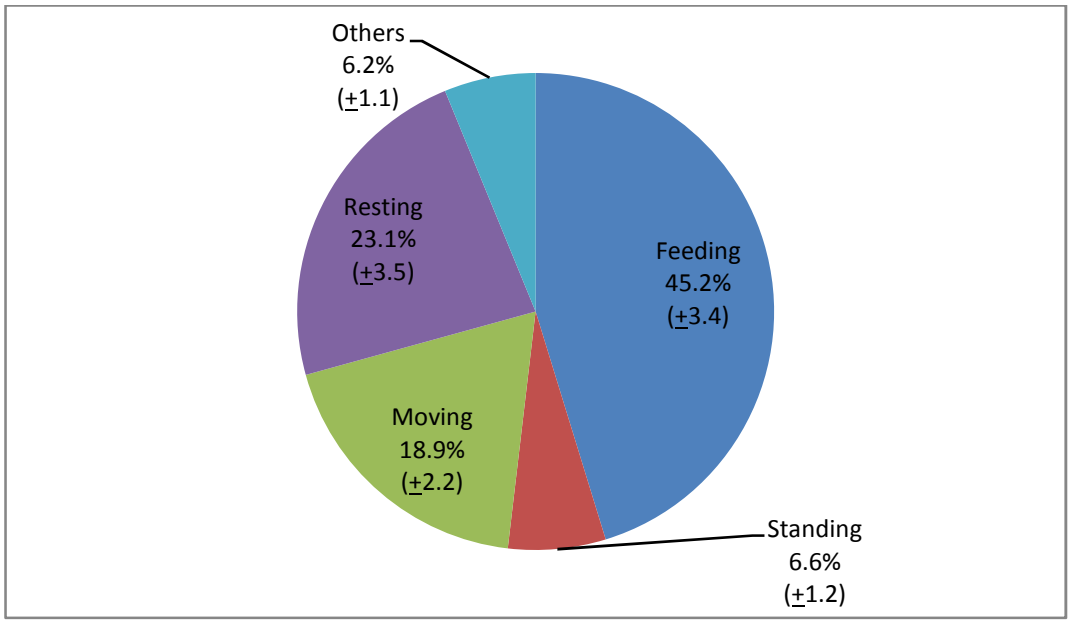
Annually the observed major activities for sub-adult cow were feeding (42.4%), followed by moving (24.3%) and resting (18.7%) (fig. 3.9). The time spent for feeding did not vary significantly across the seasons (figs. 3.10, 3.11, 3.12). Time spent moving was highest in winter (28.8%) compared to summer (18.9%) and monsoon (25%) and was found to differ significantly (K.W: χ^2 =10.246, $p<0.05$). Time spent in resting was significantly higher in summer (23.1%) as compared to monsoon (18.5%) and winter (14.8%) (K.W: χ^2 =5.669, $p<0.05$).

Figure 3.9: Annual activity budget of gaur sub-adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by sub-adult cow in major activities annually)



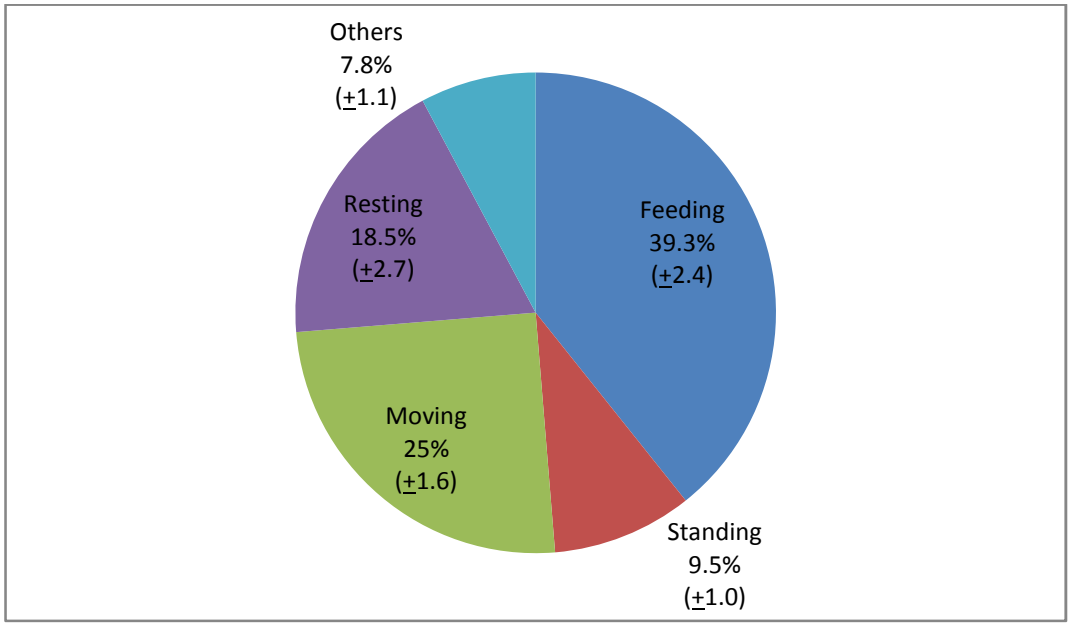
Number of scan records: 3984

Figure 3.10: Summer activity budget of gaur sub-adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by sub-adult cow in major activities in summer)



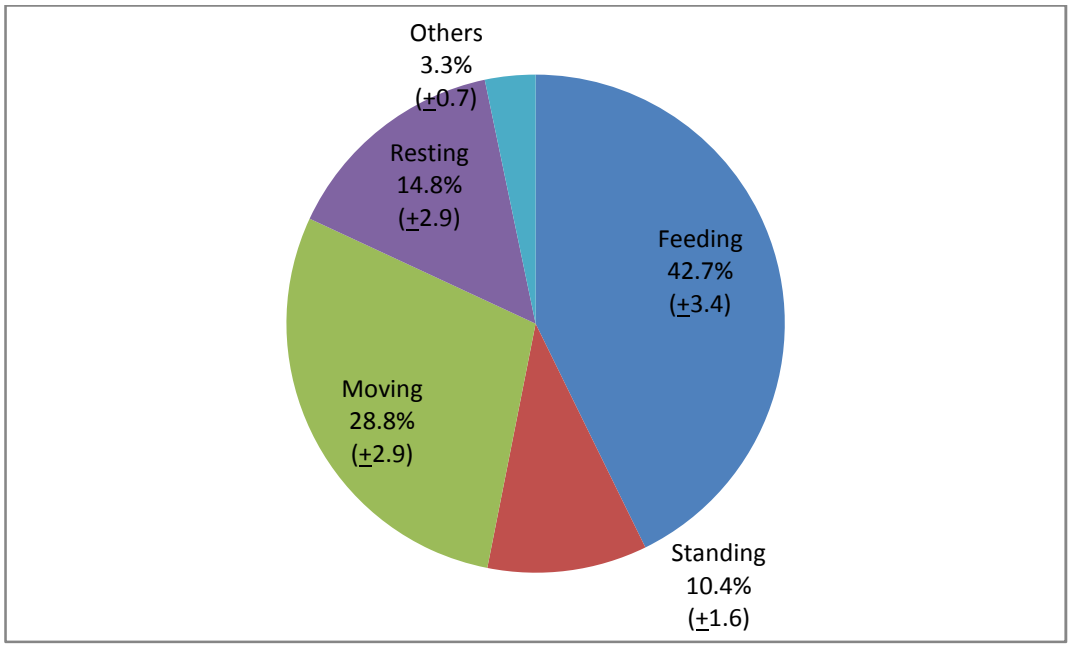
Number of scan records: 1237

Figure 3.11: Monsoon activity budget of gaur sub-adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by sub-adult cow in major activities in monsoon)



Number of scan records: 3752

Figure 3.12: Winter activity budget of gaur sub-adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by sub-adult cow in major activities in winter)

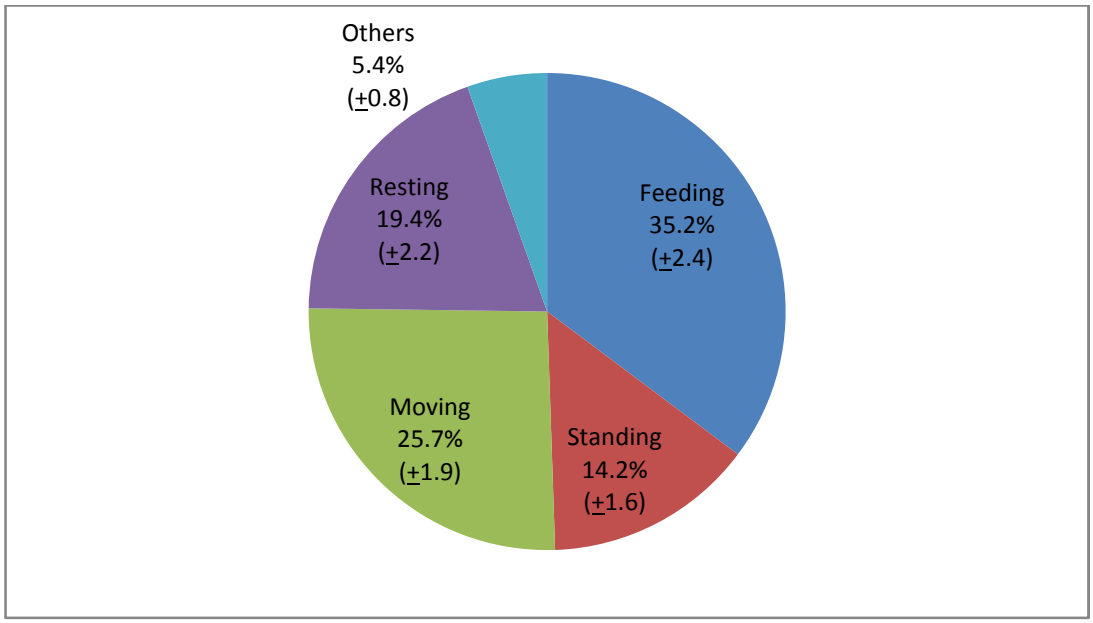


Number of scan records: 995

Yearling

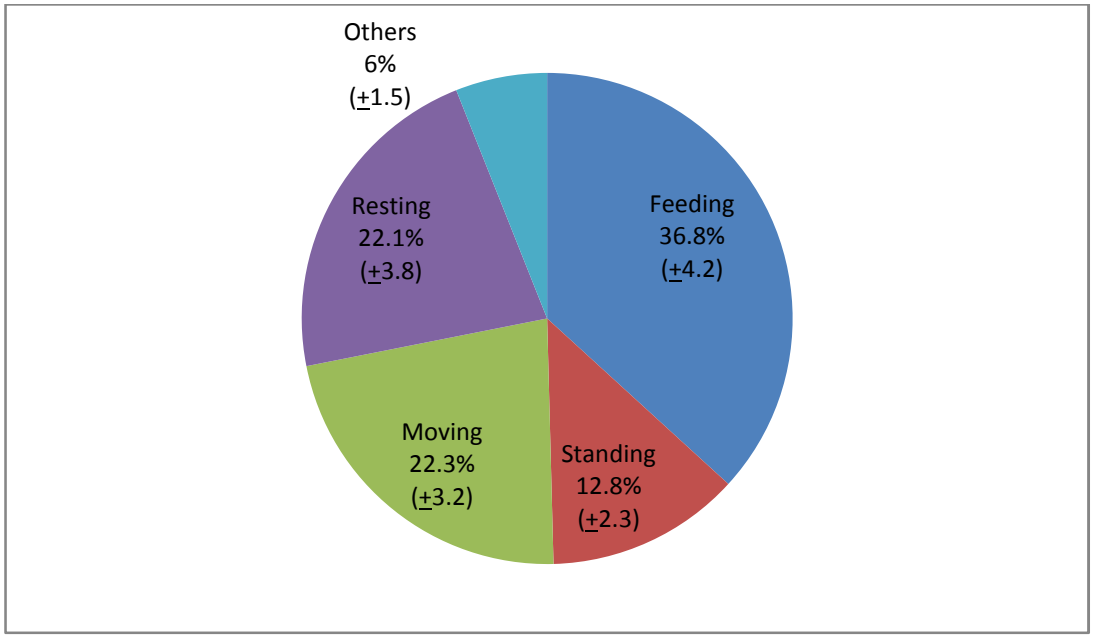
The annual activity budget of yearling (fig. 3.13) showed that the major portion of the time was spent in feeding (35.2%), moving (25.7%), resting (19.4%) and standing (14.2%). Time spent by yearling in feeding and resting across the seasons did not differ significantly (figs. 3.14, 3.15, 3.16). Yearling moved significantly more in monsoon (30.8%) compared to summer (22.3%) and winter (25.9%) (K.W: χ^2 =6.881, p<0.05).

Figure 3.13: Annual activity budget of yearling gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by yearling in major activities annually)



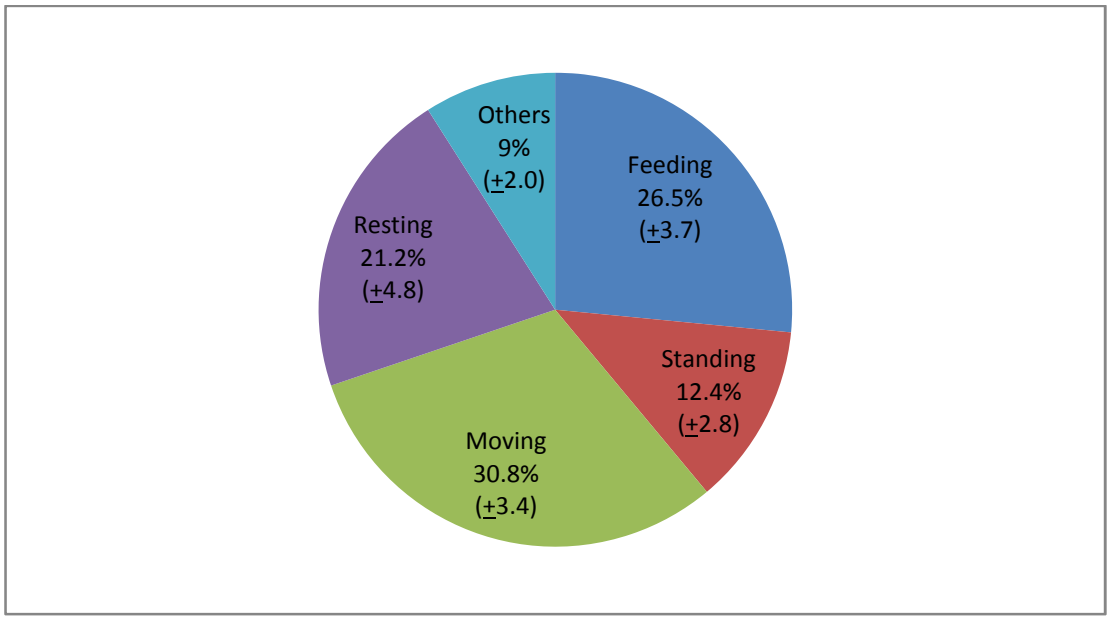
Number of scan records: 1430

Figure 3.14: Summer activity budget of yearling gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by yearling in major activities in summer)



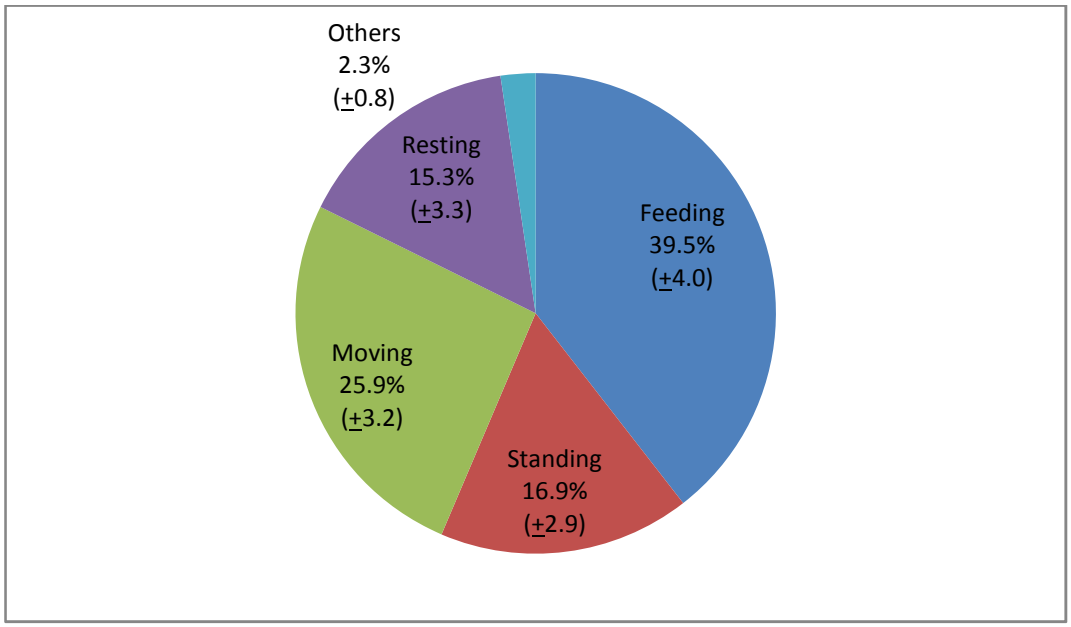
Number of scan records: 637

Figure 3.15: Monsoon activity budget of yearling gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by yearling in major activities in monsoon)



Number of scan records: 260

Figure 3.16: Winter activity budget of yearling gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by yearling in major activities in winter)

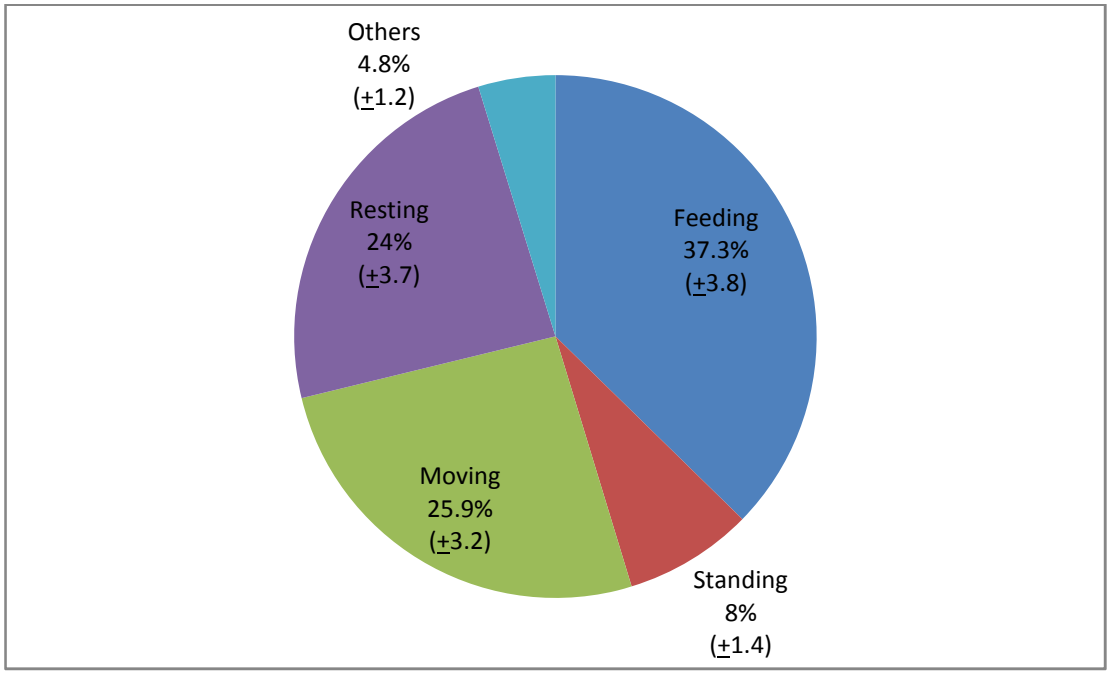


Number of scan records: 533

Brown Bull

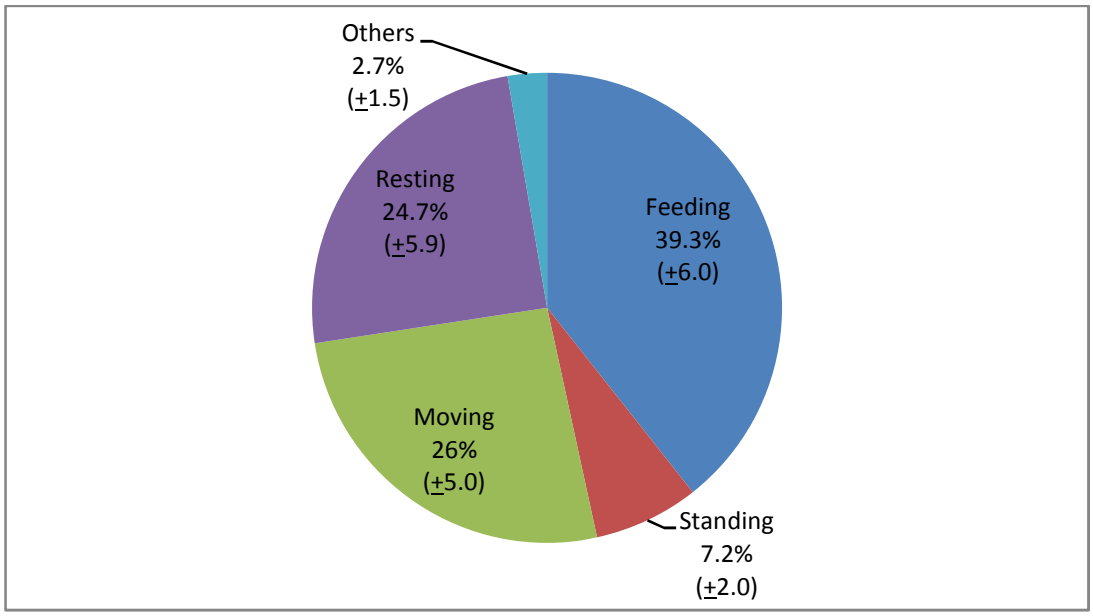
The annual activity budget of brown bull (fig.3.17) showed that feeding constituted 37.3% of the time annually followed by moving (25.9%) and resting (24%). The seasonal activity budgets of brown bull are given in figures 3.18, 3.19 and 3.20. Time spent for resting was significantly higher in monsoon (33.6%) as compared to summer (24.7%) and winter (14.2%) (K.W: χ^2 =7.163, $p<0.05$). The seasonal variations in the time spent in activities like feeding, standing and moving did not show any significant difference.

Figure 3.17: Annual activity budget of gaur brown bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by brown bull in major activities annually)



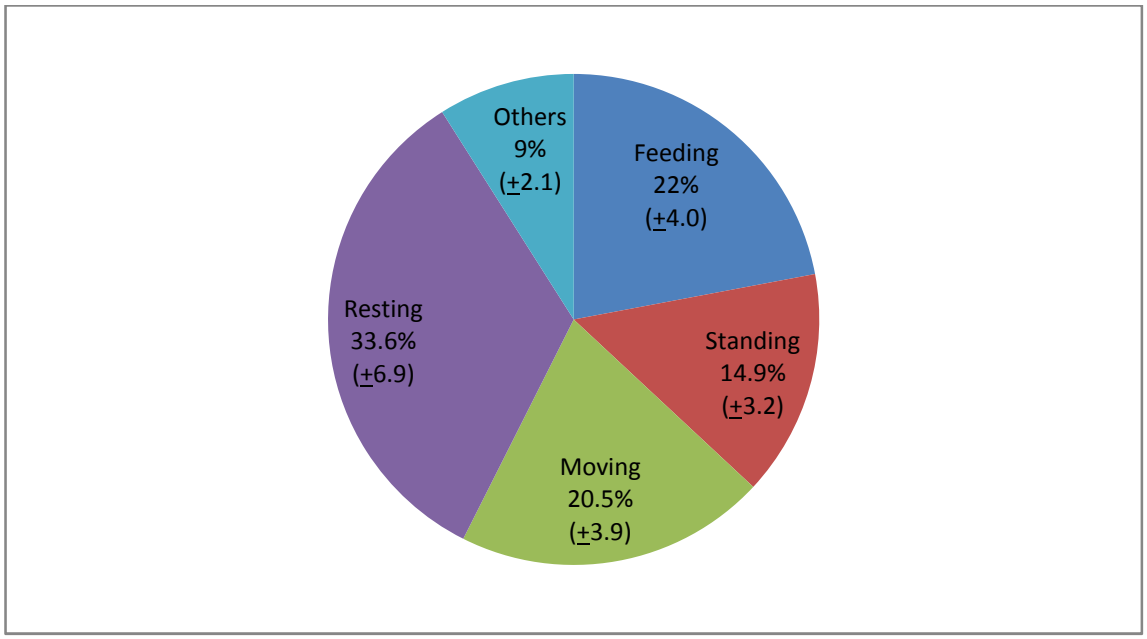
Number of scan records: 693

Figure 3.18: Summer activity budget of gaur brown bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by brown bull in major activities in summer)



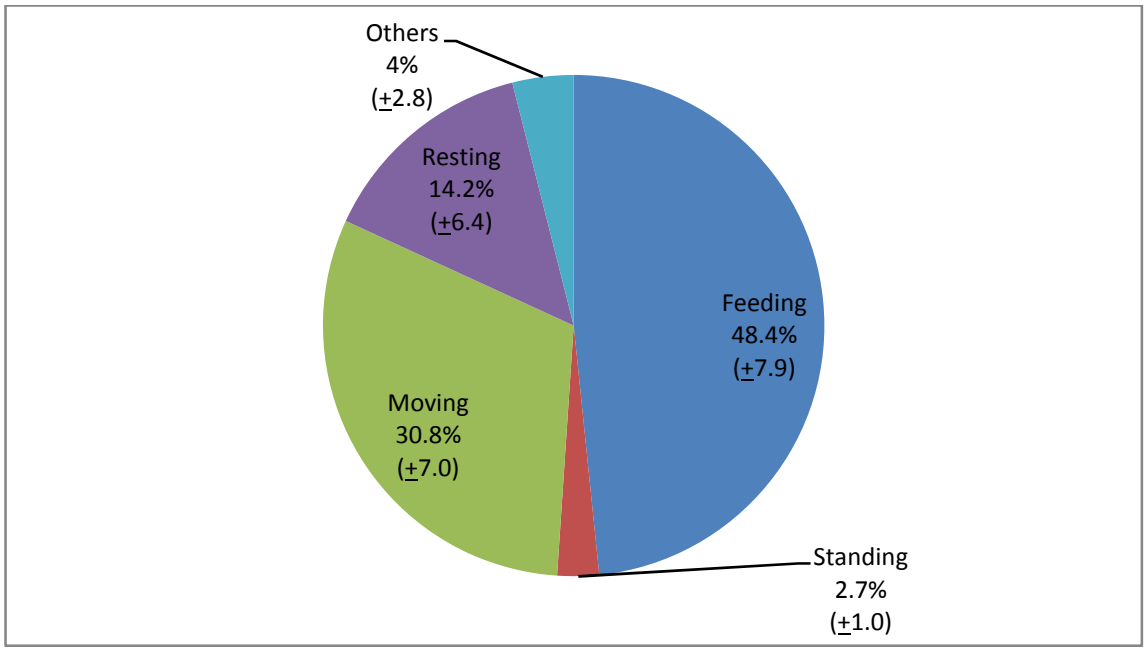
Number of scan records: 297

Figure 3.19: Monsoon activity budget of gaur brown bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by brown bull in major activities in monsoon)



Number of scan records: 189

Figure 3.20: Winter activity budget of gaur brown bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by brown bull in major activities in winter)

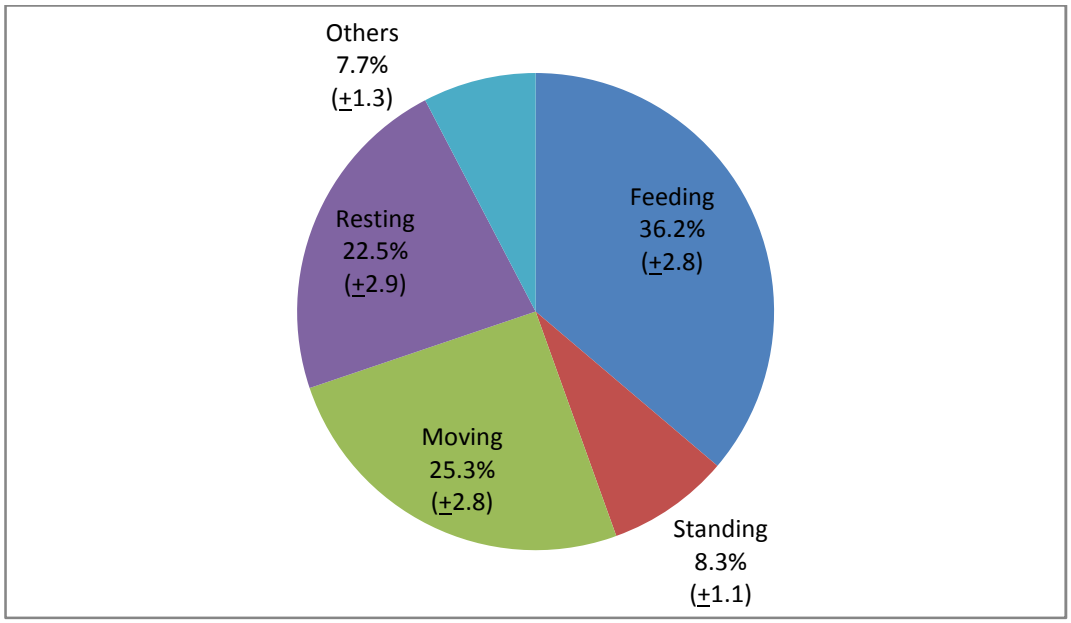


Number of scan records: 207

Black bull

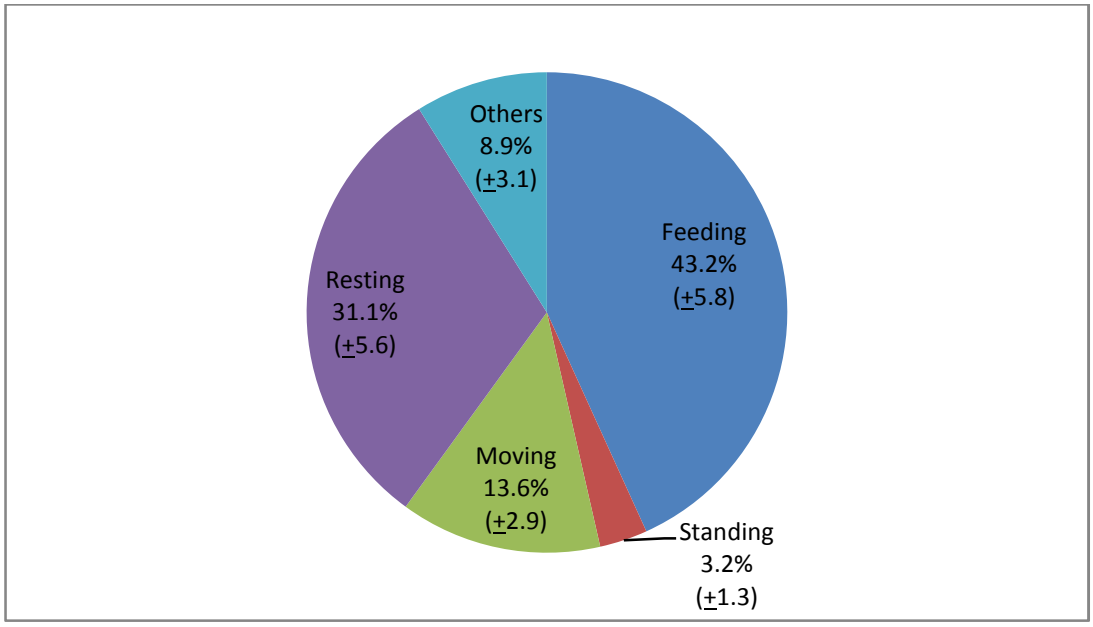
The annual activity budget of black bull showed that the time spent for feeding (36.2%) was higher compared to all other activities (fig.3.21). The seasonal activity budgets of black bull are given in figures 3.22, 3.23 and 3.24. The time spent for feeding was higher in summer (43.2%) compared to monsoon (29.5%) and winter (35.5%). The time spent standing by black bull was significantly lower in summer (3.2%) than in monsoon (9.3%) and winter (12.1%) (K.W: χ^2 =11.731, $p<0.05$). Also significant difference was observed in the time spent in moving across the seasons (K.W: χ^2 =16.896, $p<0.05$). No significant difference was observed in the time spent in feeding and resting across the seasons.

Figure 3.21: Annual activity budget of gaur black bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by black bull in major activities annually)



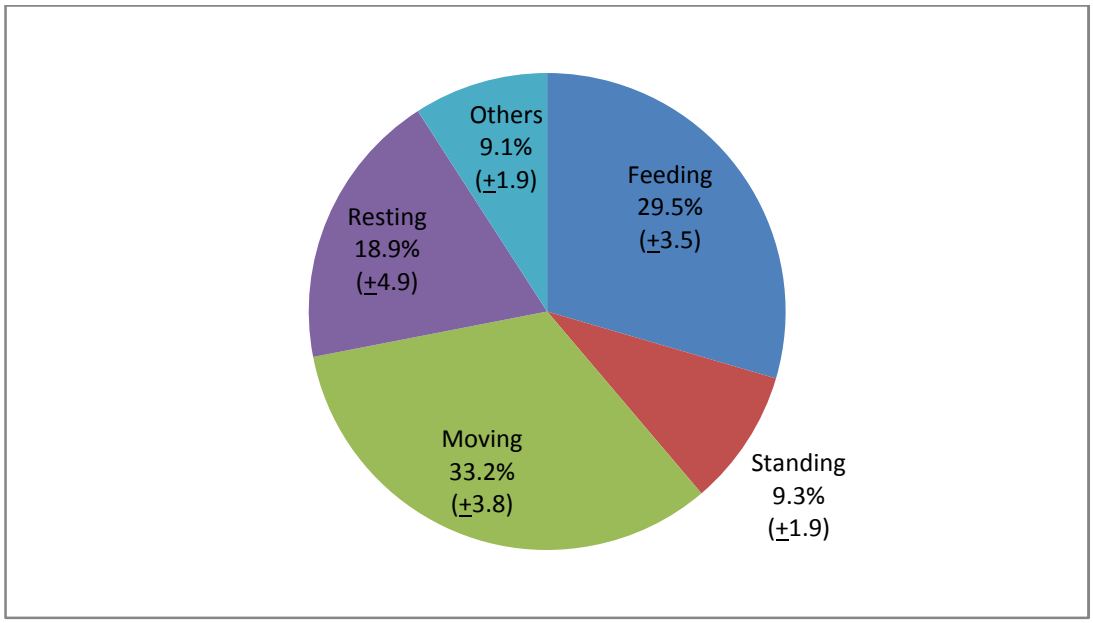
Number of scan records: 793

Figure 3.22: Summer activity budget of gaur black bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by black bull in major activities in summer)



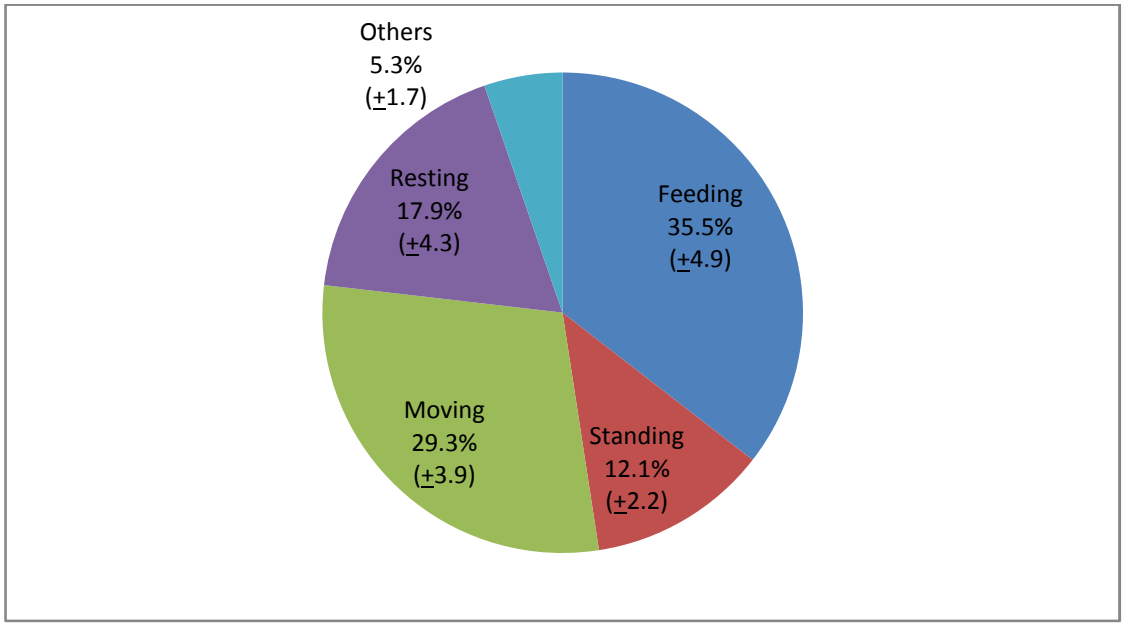
Number of scan records: 426

Figure 3.23: Monsoon activity budget of gaur black bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by black bull in major activities in monsoon)



Number of scan records: 184

Figure 3.24: Winter activity budget of gaur black bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by black bull in major activities in winter)

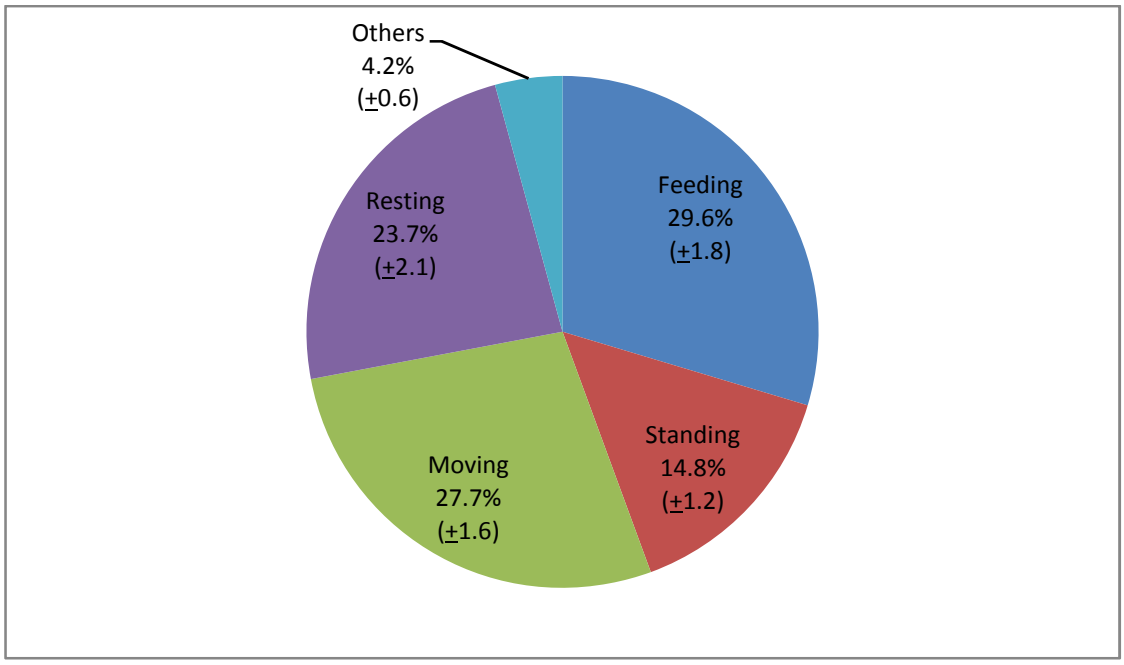


Number of scan records: 183

Calf

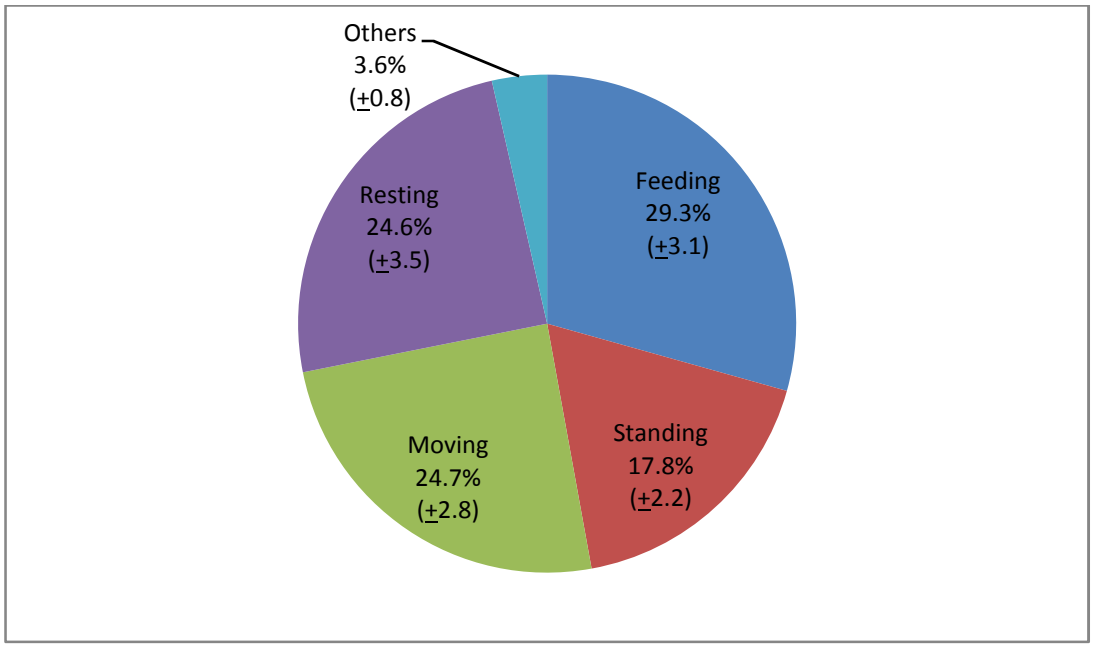
The annual activity budget of calf (fig. 3.25) showed that feeding (29.6%) and moving (27.7%) were the major activities followed by resting (23.7%). Time spent in standing was almost similar in summer (17.8%) and winter (18.6%) but was significantly lower in monsoon (7.8%) (K.W: χ^2 =21.467, $p<0.05$). Also the time spent in resting was significantly lower in winter (17.8%) as compared to summer (24.6%) and monsoon (28.7%) (K.W: χ^2 =8.3, $p<0.05$). The seasonal differences in time spent in feeding and moving were not found significant (figs. 3.26, 3.27 and 3.28).

Figure 3.25: Annual activity budget of gaur calf in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by calf in major activities annually)



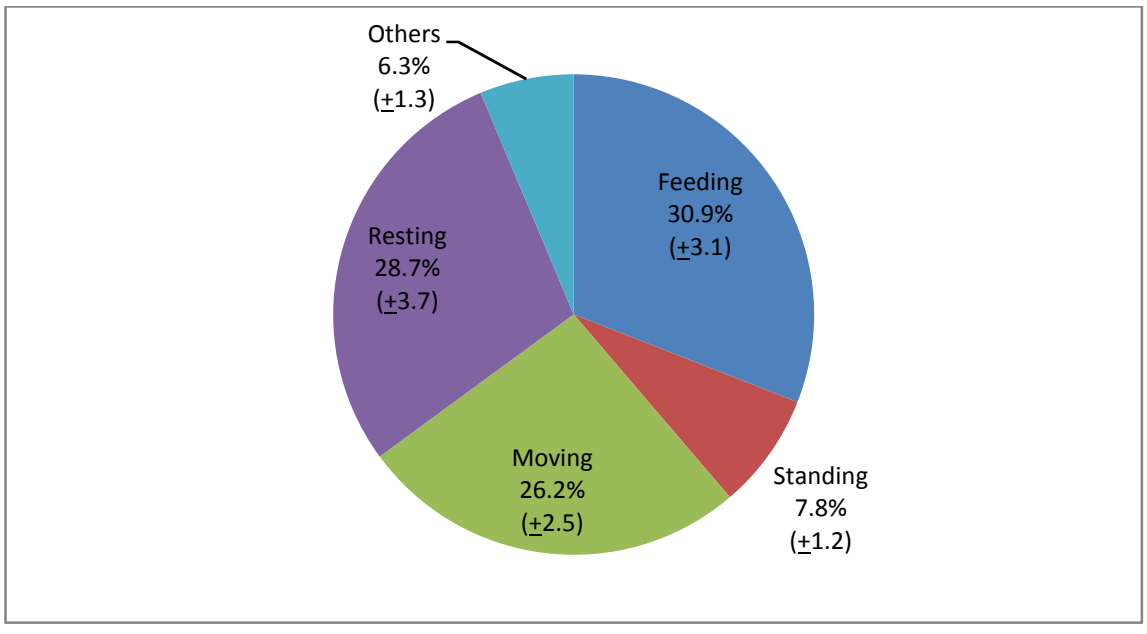
Number of scan records: 2572

Figure 3.26: Summer activity budget of gaur calf in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by calf in major activities in summer)



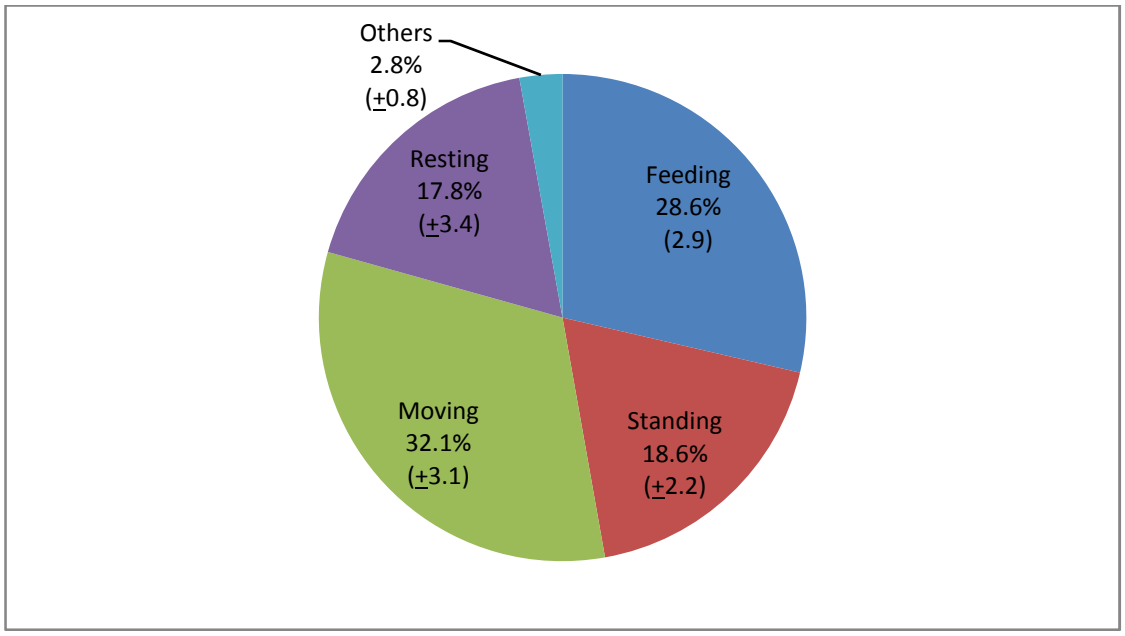
Number of scan records: 1031

Figure 3.27: Monsoon activity budget of gaur calf in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by calf in major activities in monsoon)



Number of scan records: 817

Figure 3.28: Winter activity budget of gaur calf in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by calf in major activities in winter)

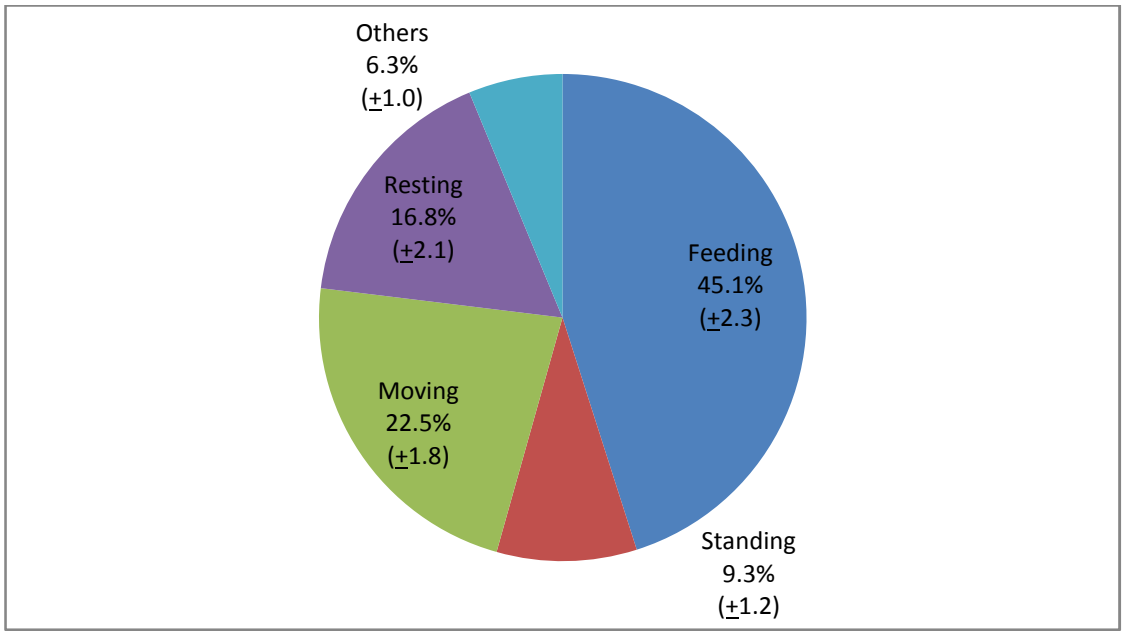


Number of scan records: 724

Sub-adult bull

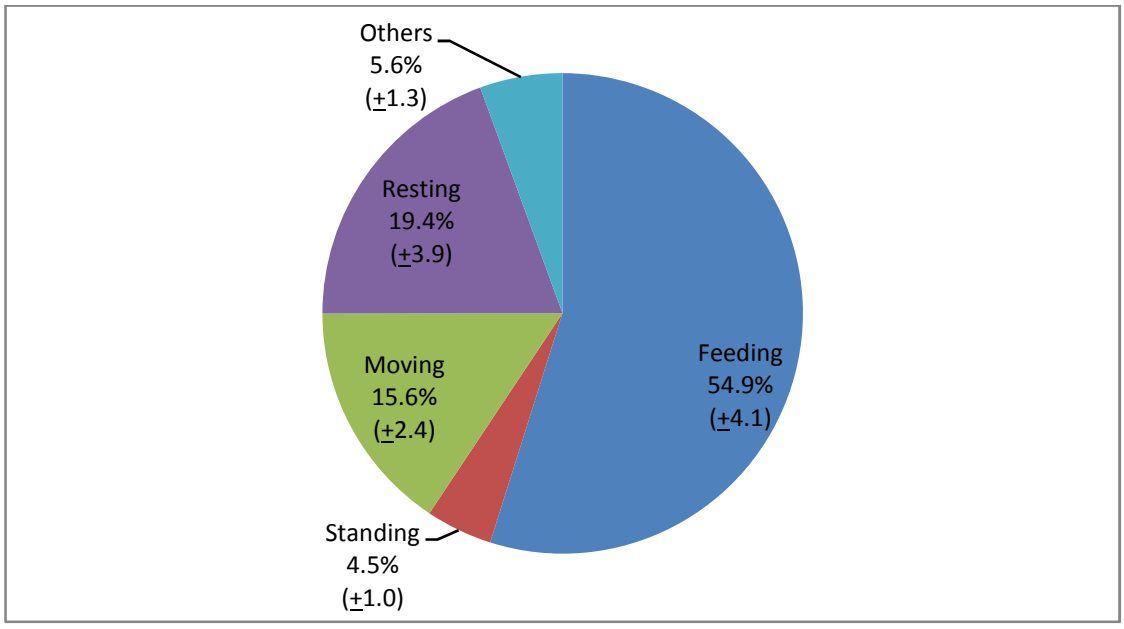
Annually the time spent for feeding (45.1%) by sub-adult bull was much higher than all the other activities (fig. 3.29). The seasonal activity budgets for sub-adult bull are given in figures 3.30, 3.31 and 3.32. The time spent for feeding was higher in summer (54.9%) as compared to monsoon (41.2%) and winter (36.3%). The difference in time spent for feeding across the seasons was found to be significant (K.W: χ^2 =11.55, $p<0.05$). The time spent moving was significantly higher in winter (32.4%) compared to that in summer (15.6%) and monsoon (22.7%) (K.W: χ^2 =10.201, $p<0.05$). Time spent resting was almost similar in summer (19.4%) and monsoon (20.6%) but was significantly lower in winter (7.7%) (K.W: χ^2 =9.734, $p<0.05$).

Figure 3.29: Annual activity budget of gaur sub-adult bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by sub-adult bull in major activities annually)



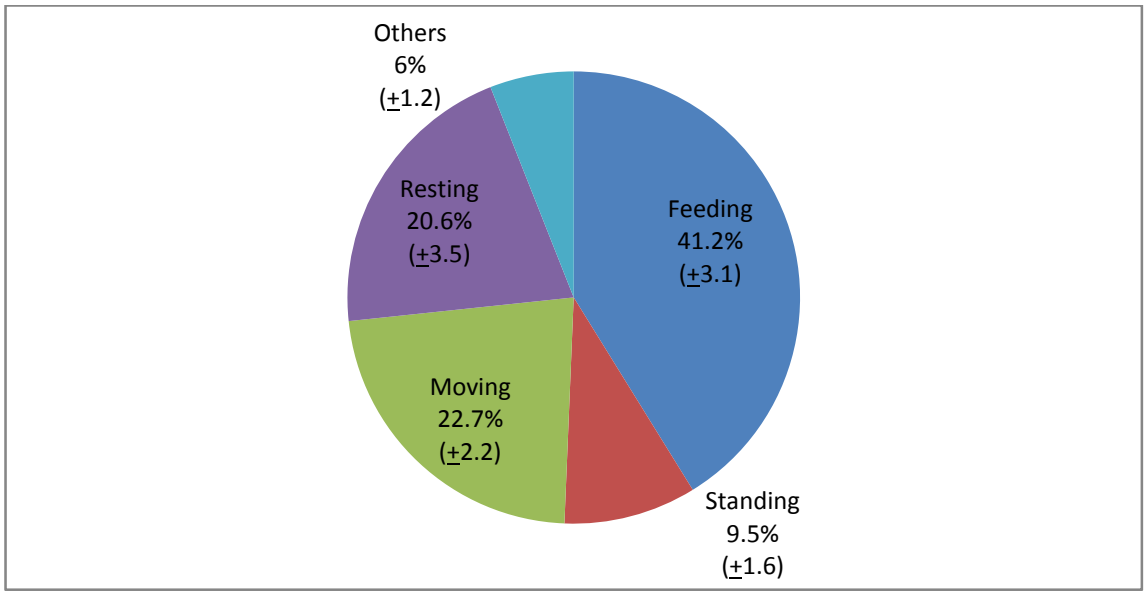
Number of scan records: 1334

Figure 3.30: Summer activity budget of gaur sub-adult bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by sub-adult bull in major activities in summer)



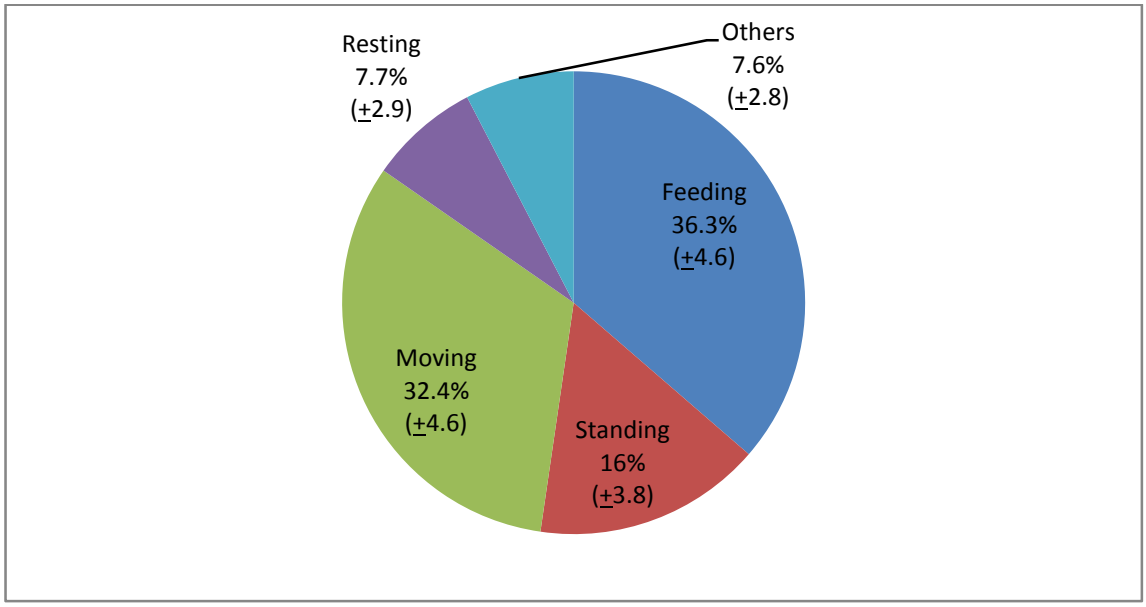
Number of scan records: 626

Figure 3.31: Monsoon activity budget of gaur sub-adult bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by sub-adult bull in major activities in monsoon)



Number of scan records: 512

Figure 3.32: Winter activity budget of gaur sub-adult bull in Bandhavgarh Tiger Reserve (March 2012-February 2014). (Percent time spent by sub-adult bull in major activities in winter)



Number of scan records: 196

Time spent in major activities by different age and sex classes of gaur

The percentage time spent annually in major activities like feeding, moving and resting by different age and sex classes of gaur is given in figures 3.33, 3.34 and 3.35 respectively. Time spent feeding annually was found to differ significantly among the different age and sex classes of gaur (K.W: χ^2 =44.425, $p<0.05$). Annually the time spent feeding was highest for sub-adult bull (45.1%) and was lowest for calf (29.6%). No significant difference was observed in the time spent moving and resting among the different age and sex classes of gaur. Annually the time spent moving and resting was observed to be highest for calf (27.7%) and brown bull (24%) respectively.

Figure 3.33: Percentage time spent feeding annually by different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

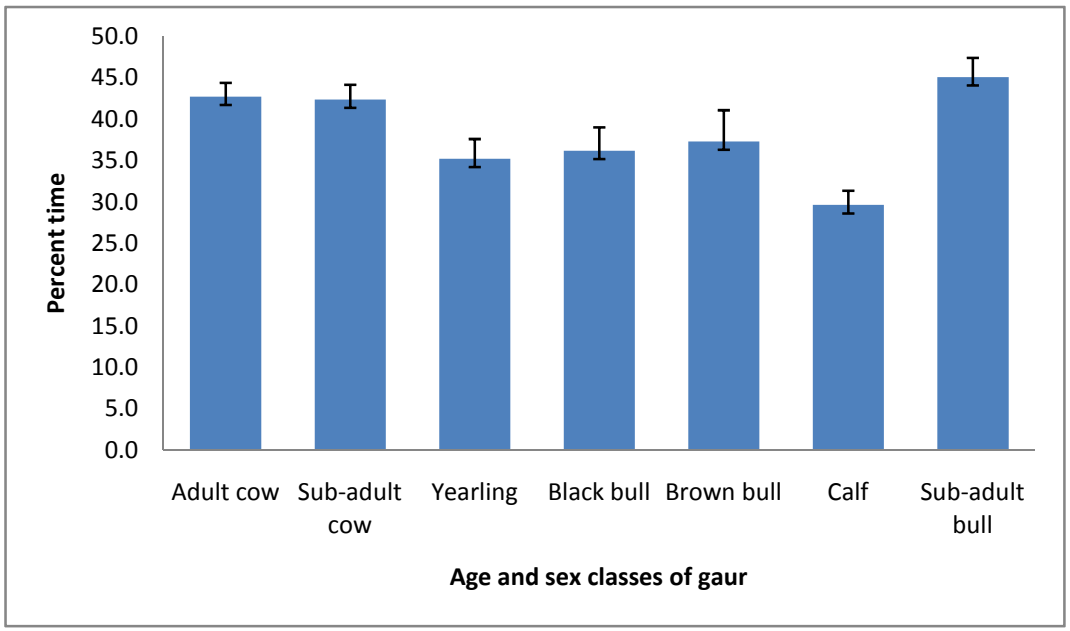


Figure 3.34: Percentage time spent moving annually by different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

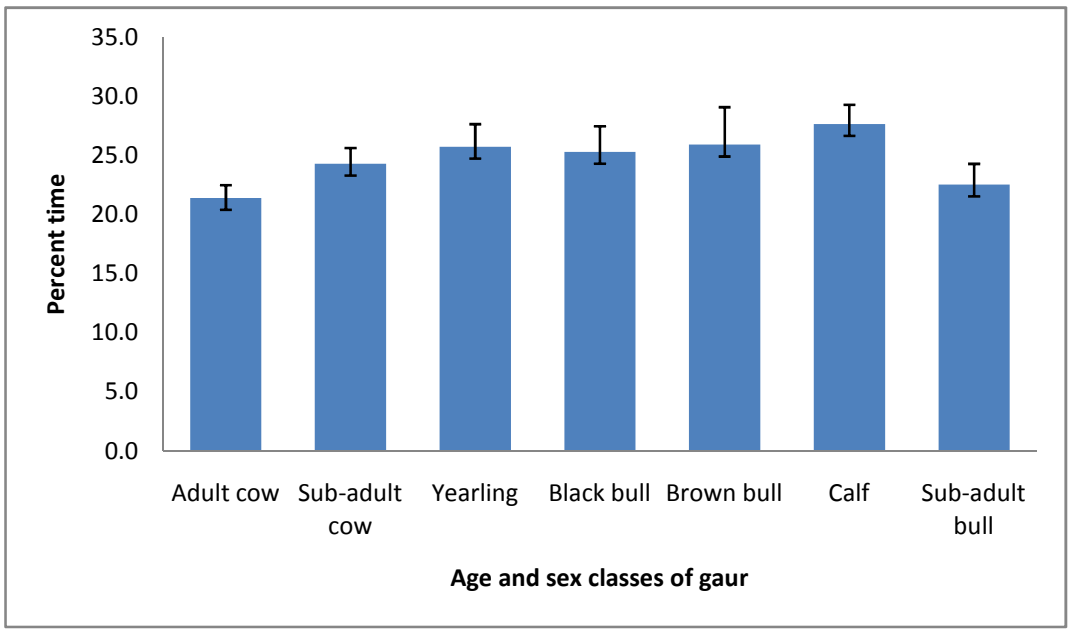
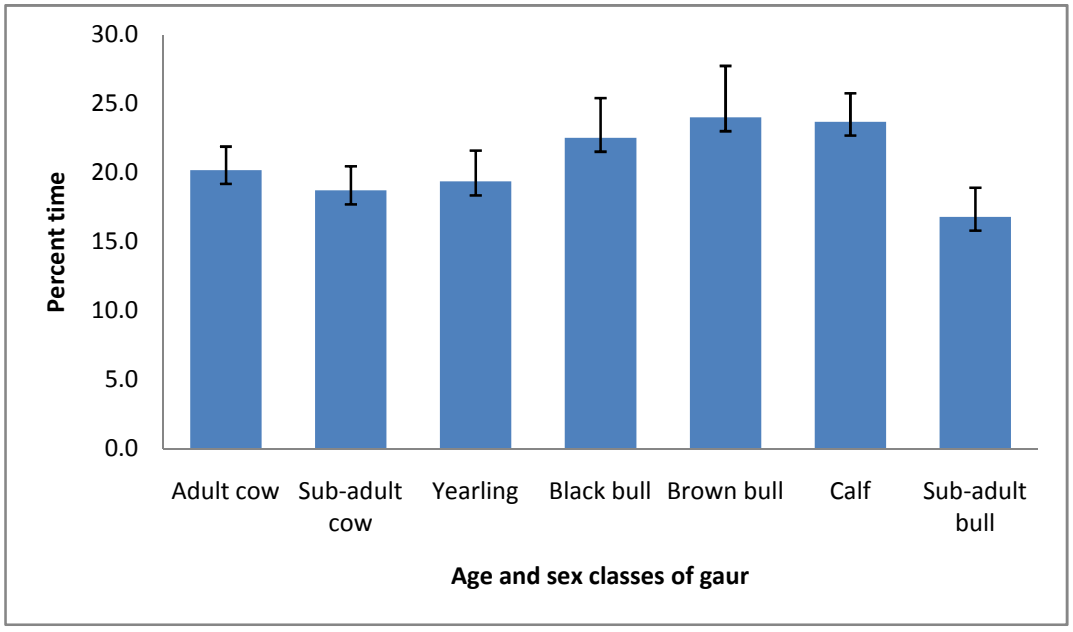


Figure 3.35: Percentage time spent resting annually by different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The results of the Kruskal-Wallis test used for testing the percentage time spent in major activities by different age and sex classes of gaur for significant difference in each of the three seasons is given in table 3.2.

Table 3.2: Results of Kruskal-Wallis test on time spent in major activities by different age and sex classes of gaur in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Activity	Summer		Monsoon		Winter	
	χ^2 value	*P*	χ^2 value	*P*	χ^2 value	*P*
Feeding	27.472	**0.000**	23.878	**0.001**	18.268	**0.006**
Moving	12.259	0.056	8.916	0.178	4.002	0.676
Resting	4.426	0.619	9.204	0.162	5.147	0.525

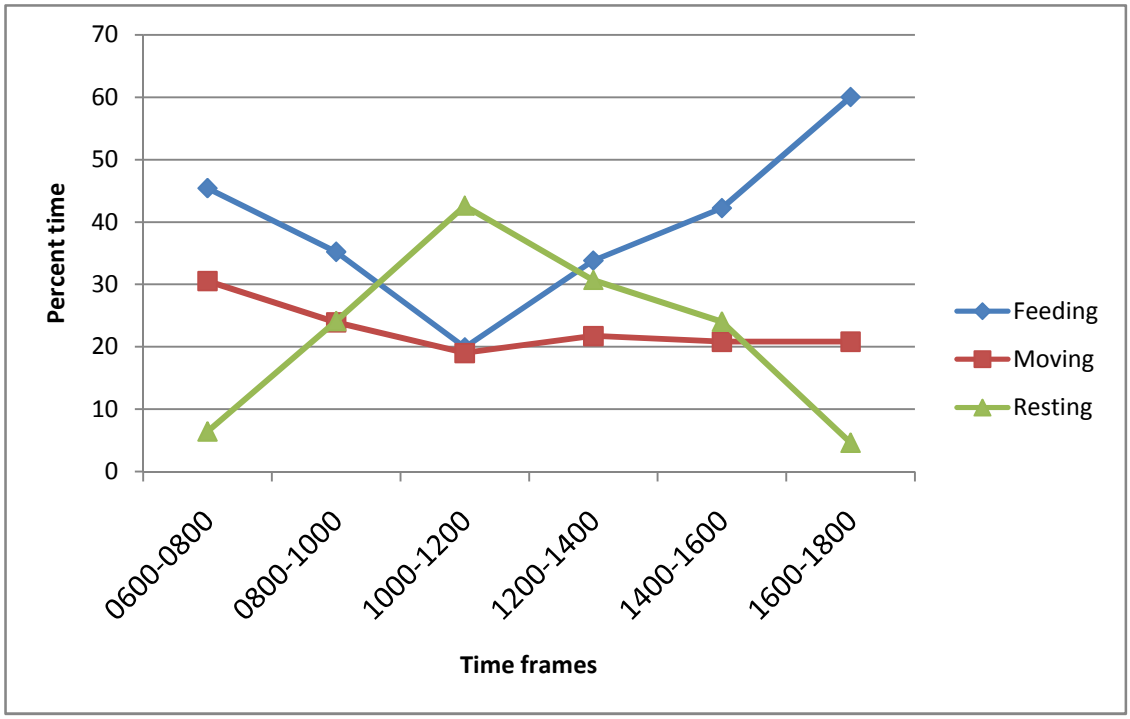
Of the three major activities of gaur (feeding, moving and resting), the time spent in feeding was observed to differ significantly among the different age and sex classes of gaur in all the seasons (summer: $\chi^2 = 27.472$, $p<0.05$; monsoon: $\chi^2 = 23.878$, $p<0.05$; winter: $\chi^2 = 18.268$, $p<0.05$). The time spent in moving and resting did not show any significant difference among the different age and sex classes of gaur in any of the seasons (table 3.2).

3.4.2 Major activity patterns of gaur in Bandhavgarh Tiger Reserve

The diurnal annual activity pattern of gaur (pooled data for all the age and sex classes) for the major activities like feeding, moving and resting is given in figure 3.36. The feeding activity peaked in the early morning hours (0600-0800 hrs) and in the late afternoon and evening hours (1600-1800 hrs). Time spent feeding by gaur was observed to be lowest in the time frame of 1000-1200 hrs after which it steadily

increased. Time spent moving was highest in the 0600-0800 hrs time frame after which it declined till 1200 hrs and then did not show much variation till 1800 hrs. Resting activity peaked in the 1000-1200 hrs time frame whereas the time spent resting was minimal during the early morning and evening time frames.

Figure 3.36: Annual major activity patterns of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The activity pattern for major activities of gaur in summer, monsoon and winter respectively is given in figures 3.37, 3.38 and 3.39. In all the seasons the time spent for feeding by gaur peaked in the time frames of 0600-0800 hrs and 1600-1800 hrs. Time spent moving by gaur in summer and monsoon showed a similar pattern wherein it was highest for the time frame of 0600-0800 hrs after which it steadily declined in the mid-day hours and then increased again. In winter, the time spent

moving was higher in the mid-day hours as compared to the early morning and late evening hours. In all the seasons the time spent resting by gaur was highest in the mid-day hours whereas it was very low in the early morning and late evening time frames. In winter the time spent resting in the mid-day hours by gaur was much lower than that observed in summer and monsoon.

Figure 3.37: Major activity patterns of gaur during summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

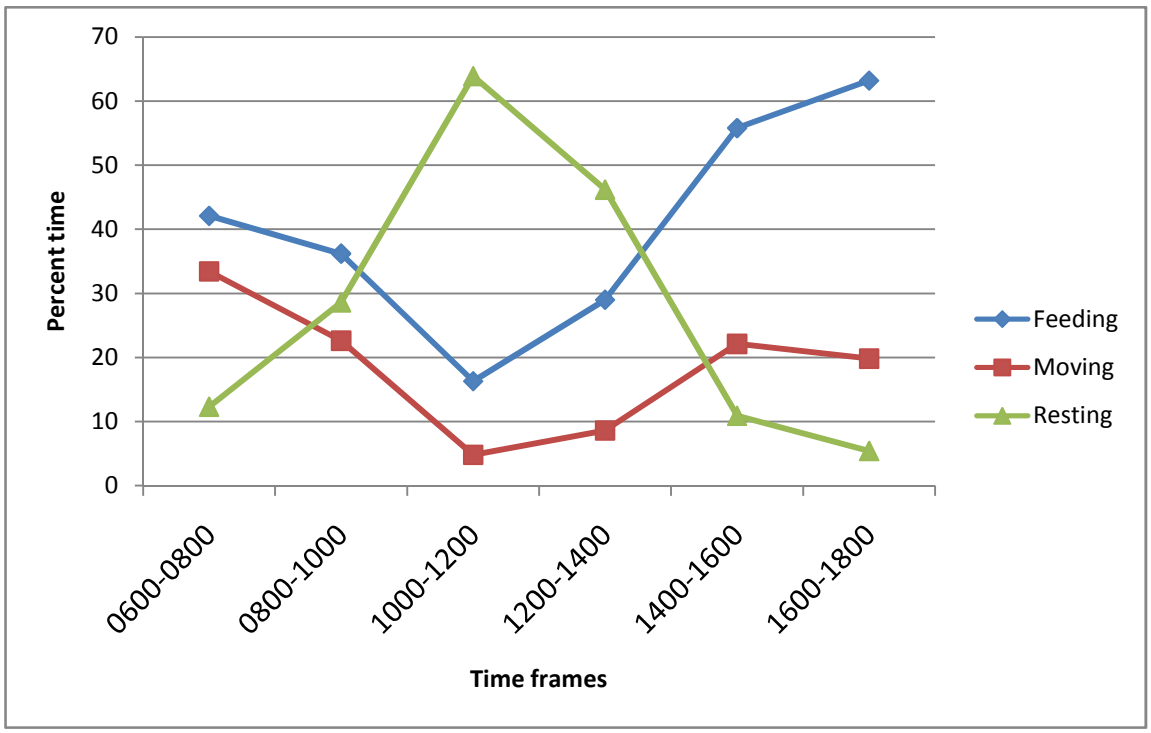


Figure 3.38: Major activity patterns of gaur during monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

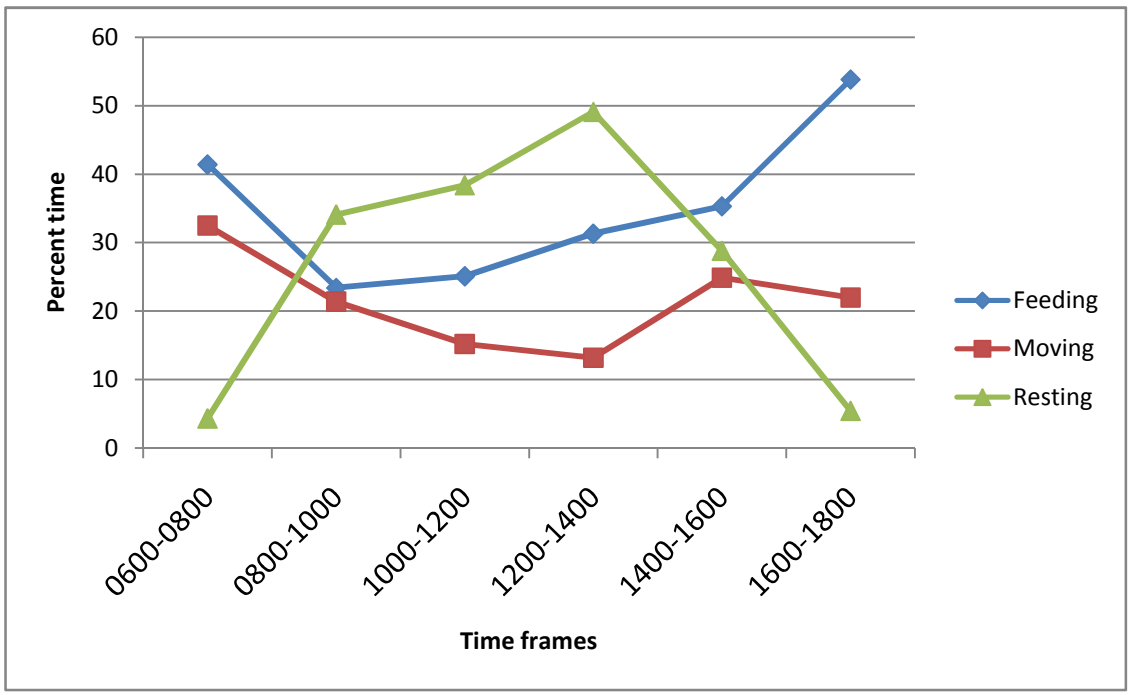
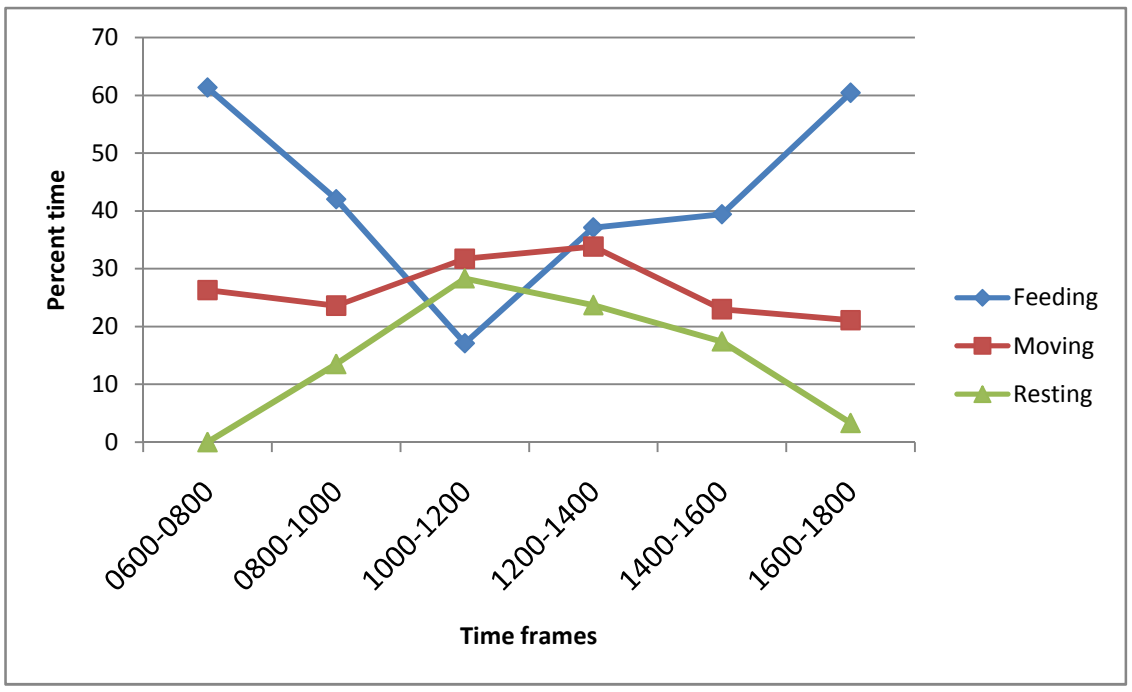


Figure 3.39: Major activity patterns of gaur during winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).

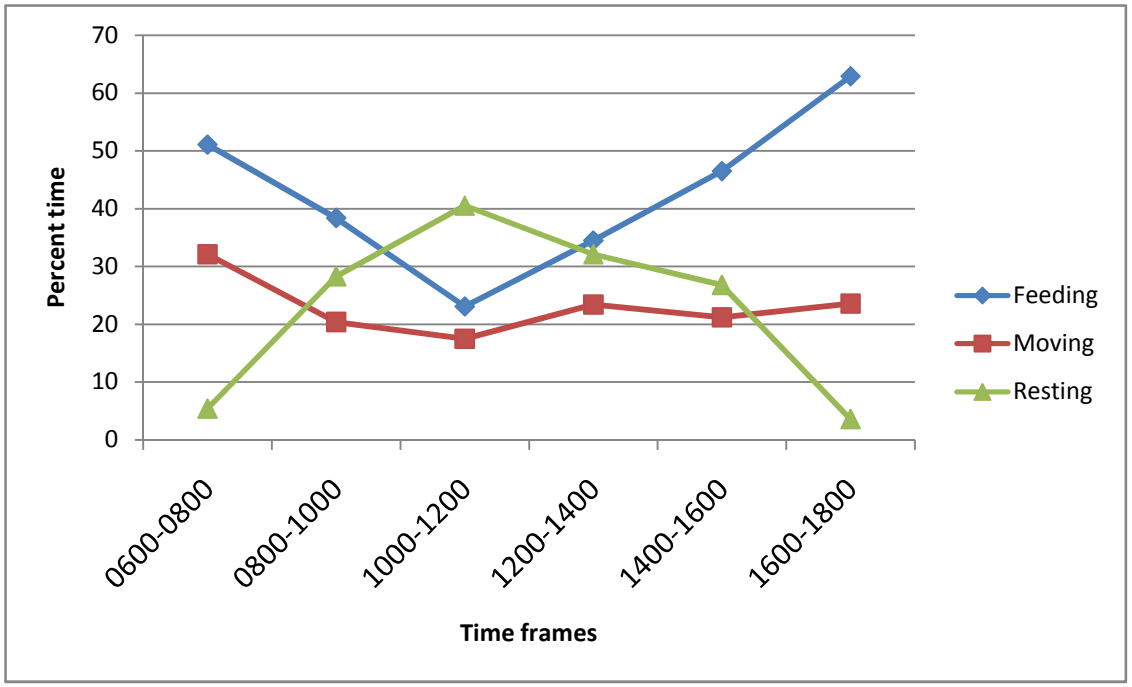


Activity patterns of different age and sex classes of gaur

Adult cow

The annual activity pattern of adult cow (fig. 3.40) showed that the time spent feeding was highest in the time frame of 1600-1800 hrs followed by 0600-0800 hrs. Time spent for resting peaked in the time frame of 1000-1200 hrs whereas time spent in moving was highest in the early morning hours (0600-0800 hrs) after which it decreased in the 0800-1000 hrs time frame and did not show much variation thereafter.

Figure 3.40: Annual activity patterns of major activities of gaur adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The seasonal activity patterns of adult cow (figs. 3.41, 3.42 and 3.43) showed that the time spent for feeding was highest in the time frame of 1600-1800 hrs for

summer and monsoon whereas for winter it was almost similar in the early morning (0600-0800 hrs) and evening time frame (1600-1800 hrs). Time spent moving in summer and monsoon showed changes which were similar to the feeding pattern wherein the time spent moving was high in the early morning hours after which it declined in the mid-day hours and then showed an increase again in the late afternoon and evening hours. Time spent resting peaked in the time frame of 1000-1400 hrs in all the seasons but the time spent resting in this time frame was considerably lower in winter as compared to summer and monsoon.

Figure 3.41: Major activity patterns of gaur adult cow during summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

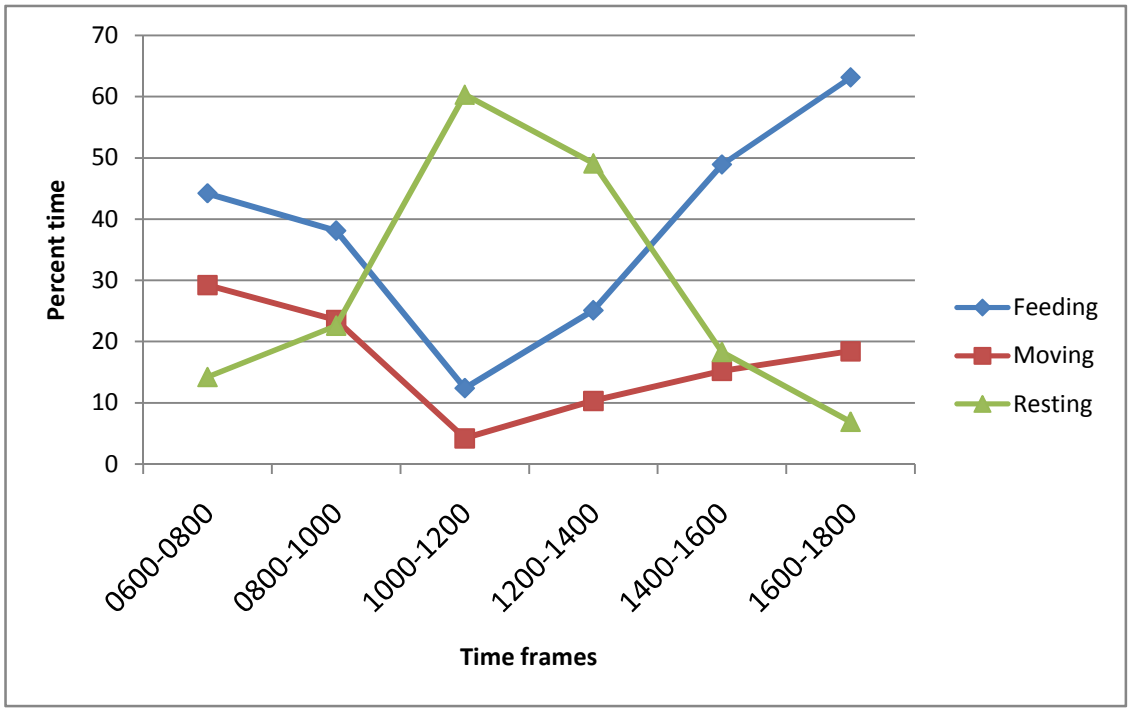


Figure 3.42: Major activity patterns of gaur adult cow during monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

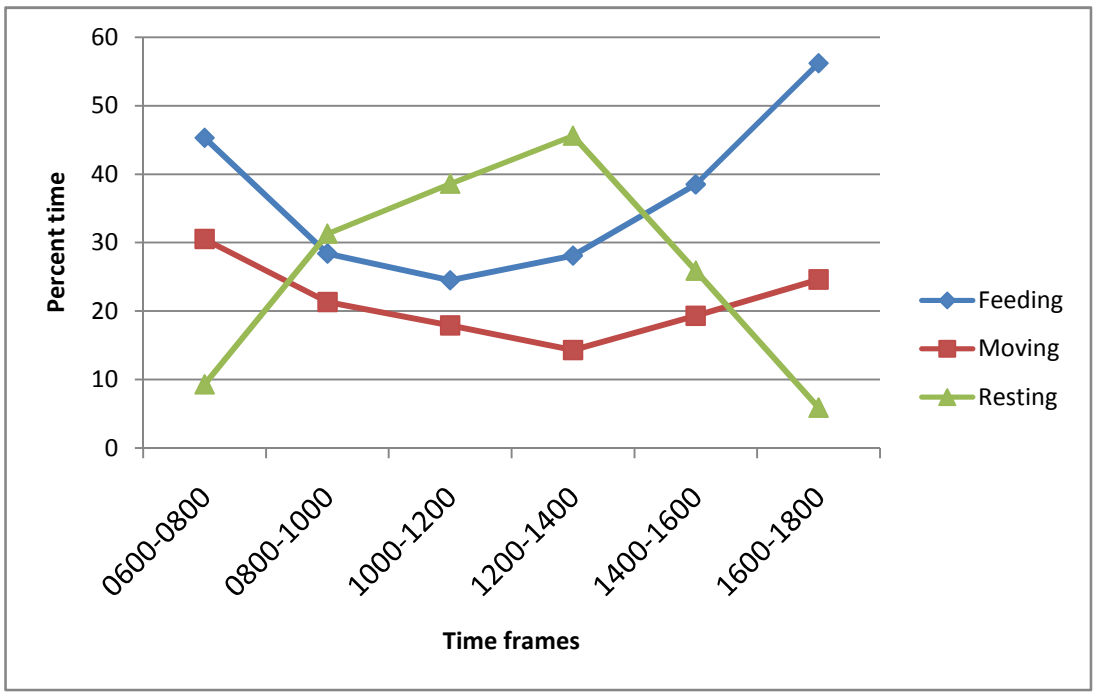
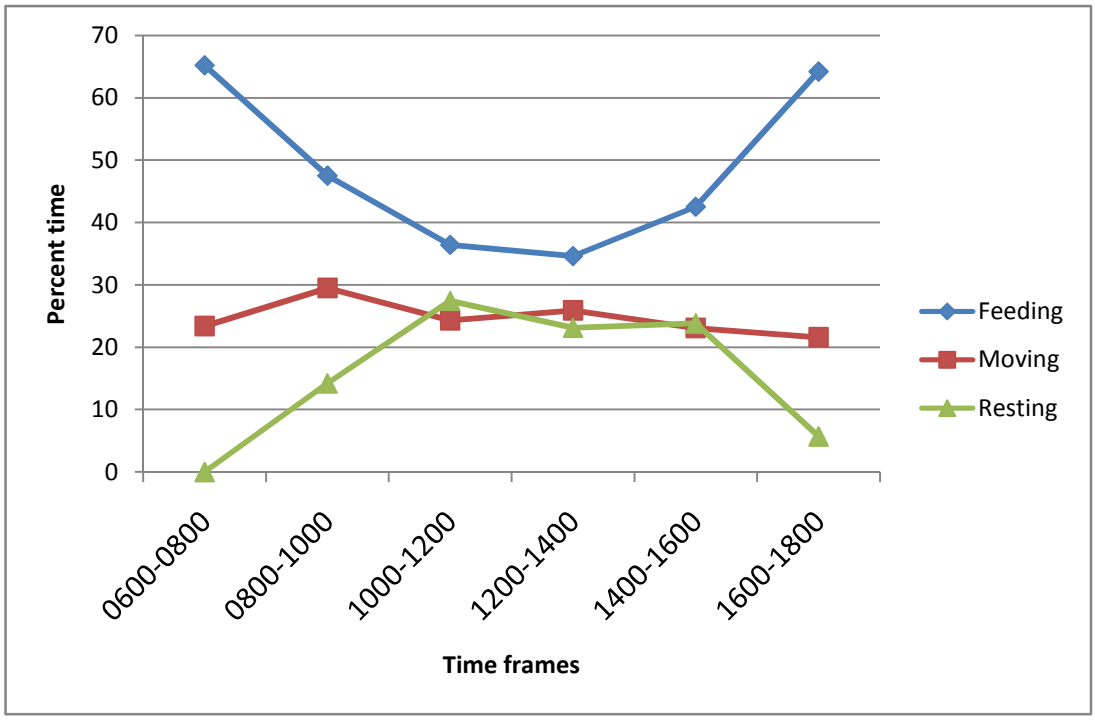


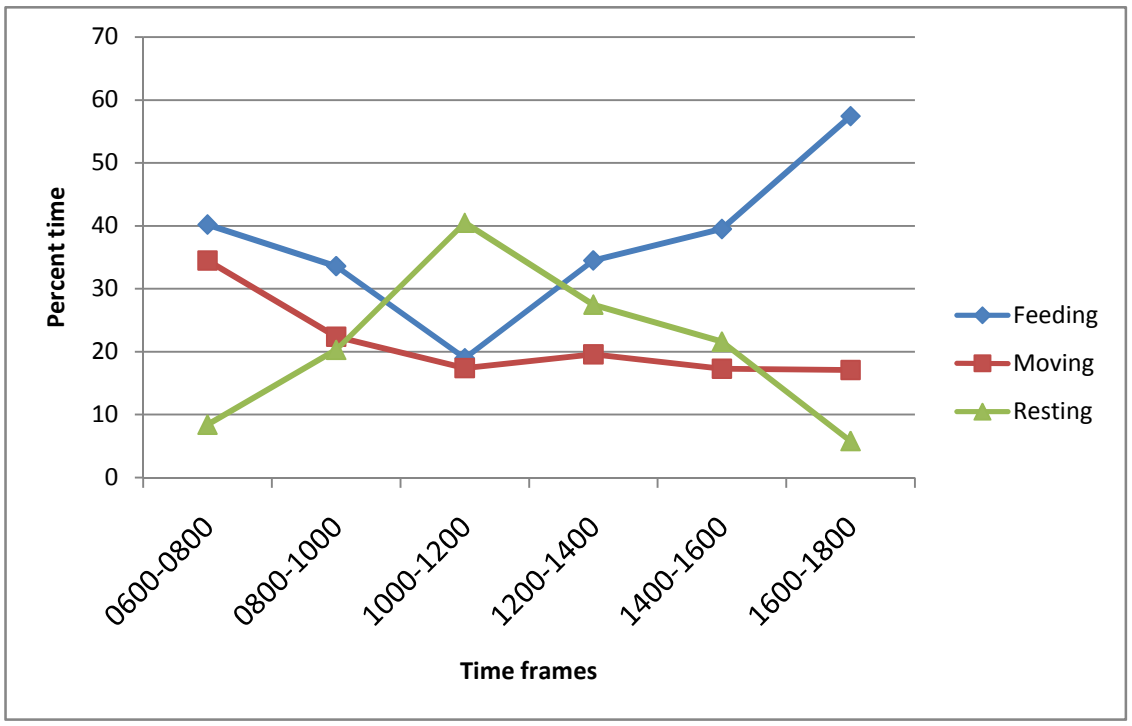
Figure 3.43: Major activity patterns of gaur adult cow during winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Sub-adult cow

Annually, the time spent feeding by sub-adult cow was found to be highest in evening hours (1600-1800 hrs) and lowest during the 1000-1200 hrs time frame (fig. 3.44). Time spent moving showed a steadily declining pattern from 0600 hrs to 1800 hrs. Resting occurred mainly during the mid-day hours.

Figure 3.44: Annual activity patterns of major activities of gaur sub-adult cow in Bandhavgarh Tiger Reserve (March 2012-February 2014).



In all the seasons, the feeding pattern of sub-adult cow showed two prominent peaks, one in the early morning time frame and the other in the evening time frame respectively (figs. 3.45, 3.46 and 3.47). In winter the time spent moving was considerably high from 1000-1800 hrs as compared to summer and monsoon. Time

spent resting by sub-adult cow was highest during the time frame of 1000-1400 hrs in all the seasons.

Figure 3.45: Major activity patterns of gaur sub-adult cow during summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

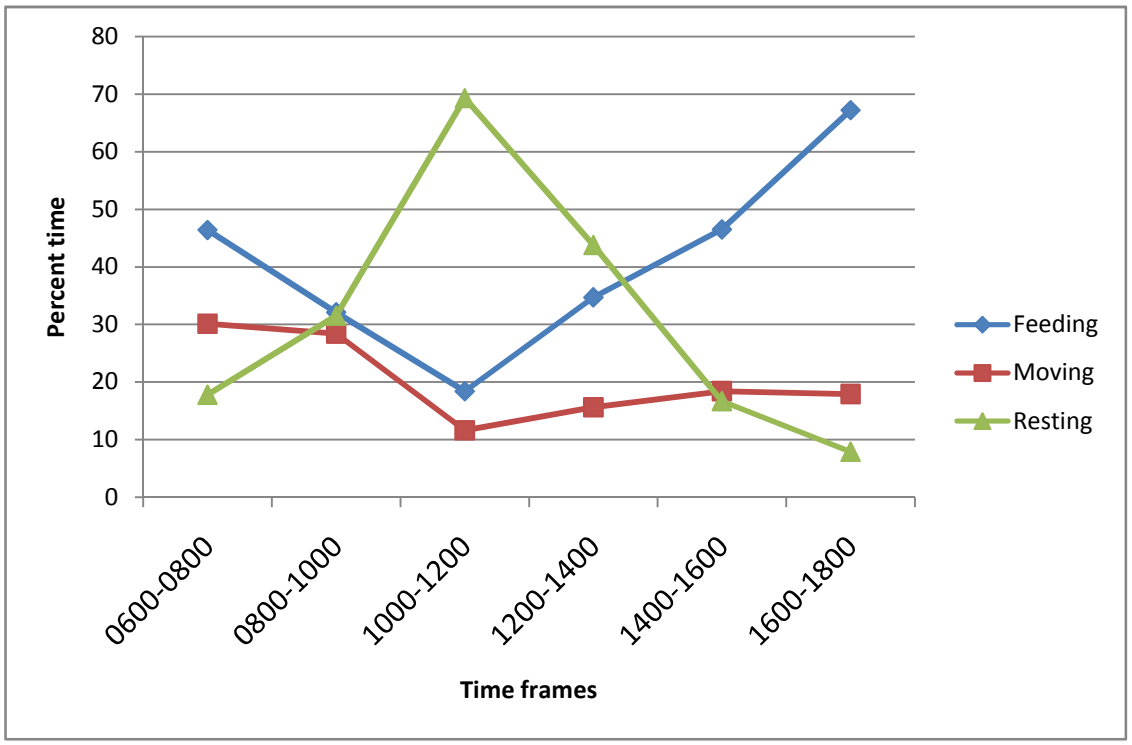


Figure 3.46: Major activity patterns of gaur sub-adult cow during monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

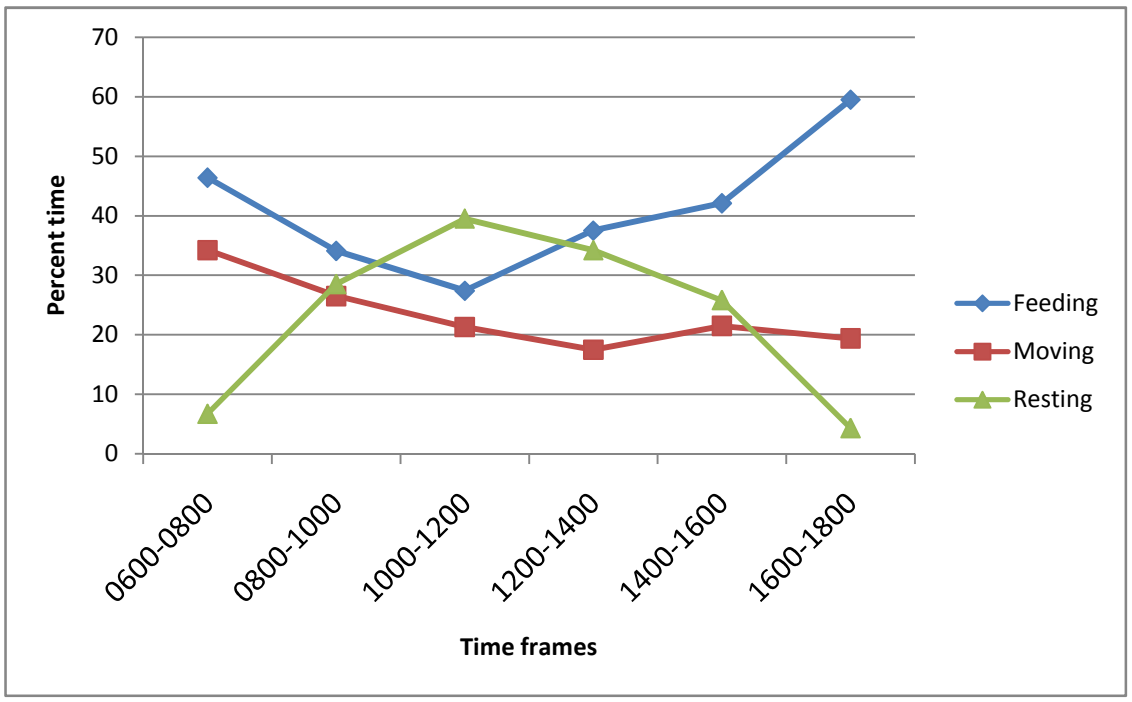
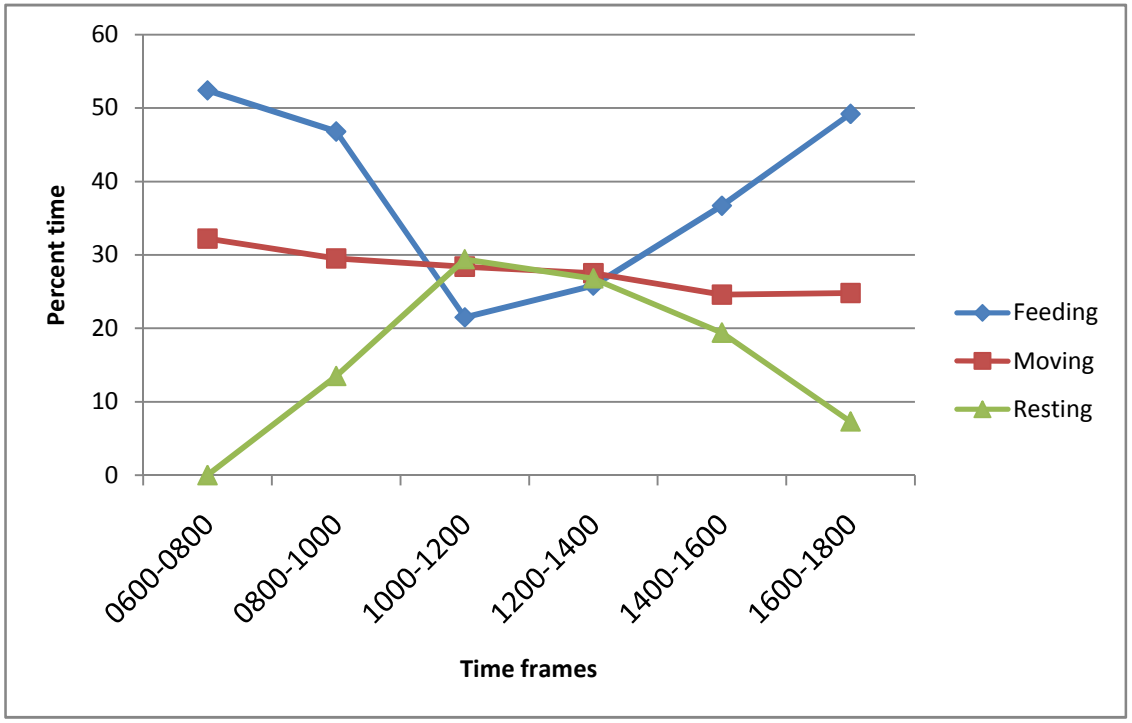


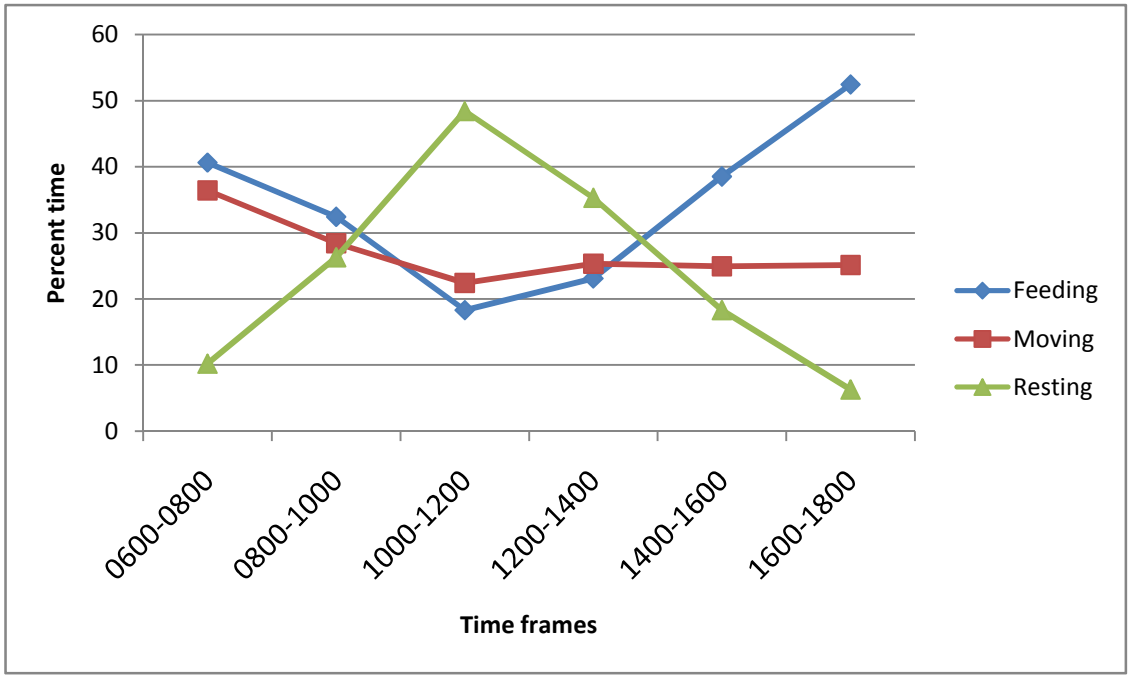
Figure 3.47: Major activity patterns of gaur sub-adult cow during winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Yearling

The annual activity pattern of yearling is given in figure 3.48. The time spent for feeding and moving was almost similar during 0600-1400 hrs. The time spent feeding was highest in the time frame of 1600-1800 hrs. Resting showed a clear peak in the 1000-1200 hrs time frame.

Figure 3.48: Annual activity patterns of major activities of yearling gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The seasonal activity patterns of yearling are given in figures 3.49, 3.50 and 3.51. The time spent for feeding and moving by yearling was observed to be similar from 0600-1800 hrs in monsoon whereas in summer it was similar from 0600-1400 hrs after which the time spent for feeding increased sharply. In winter the time spent moving was highest in the 1200-1400 hrs time frame. The time spent for resting by yearling was highest in the time frame of 1000-1400 hrs in all the seasons.

Figure 3.49: Major activity patterns of yearling gaur during summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

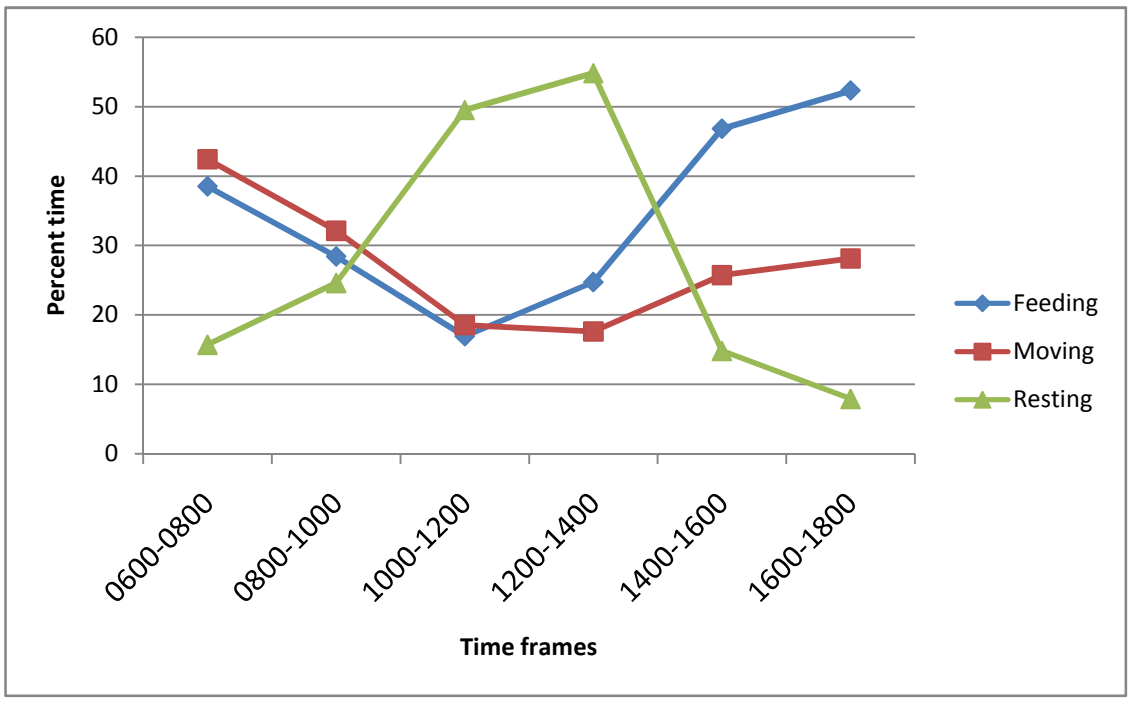


Figure 3.50: Major activity patterns of yearling gaur during monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

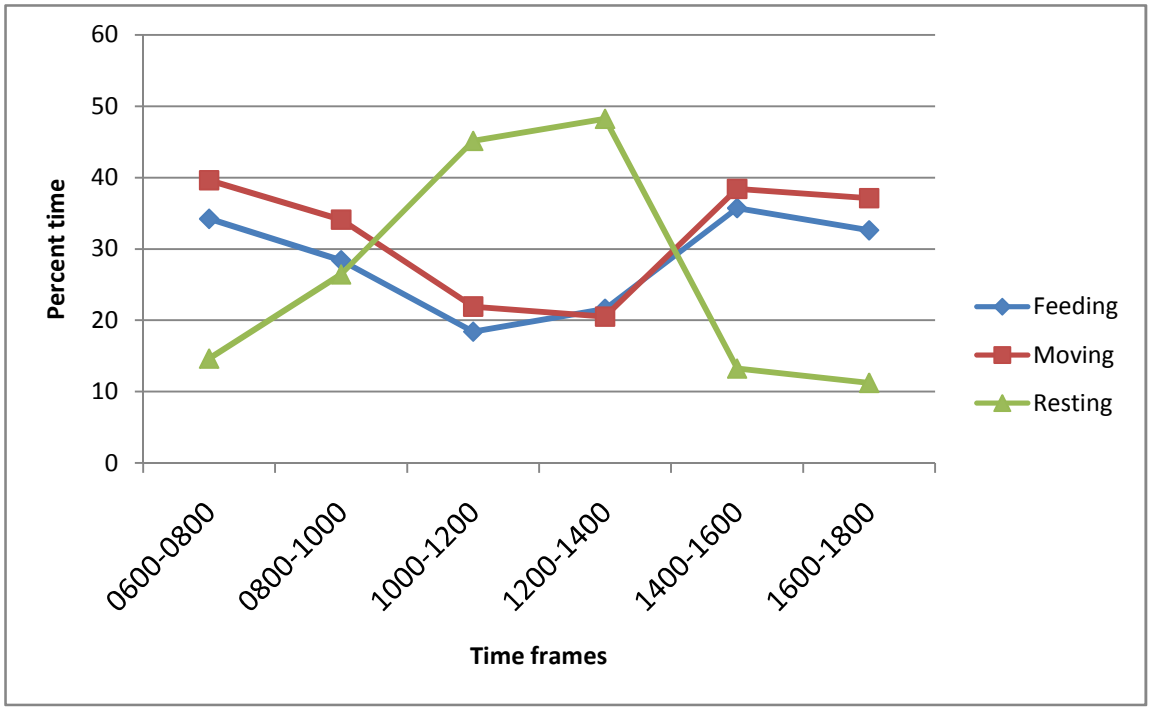
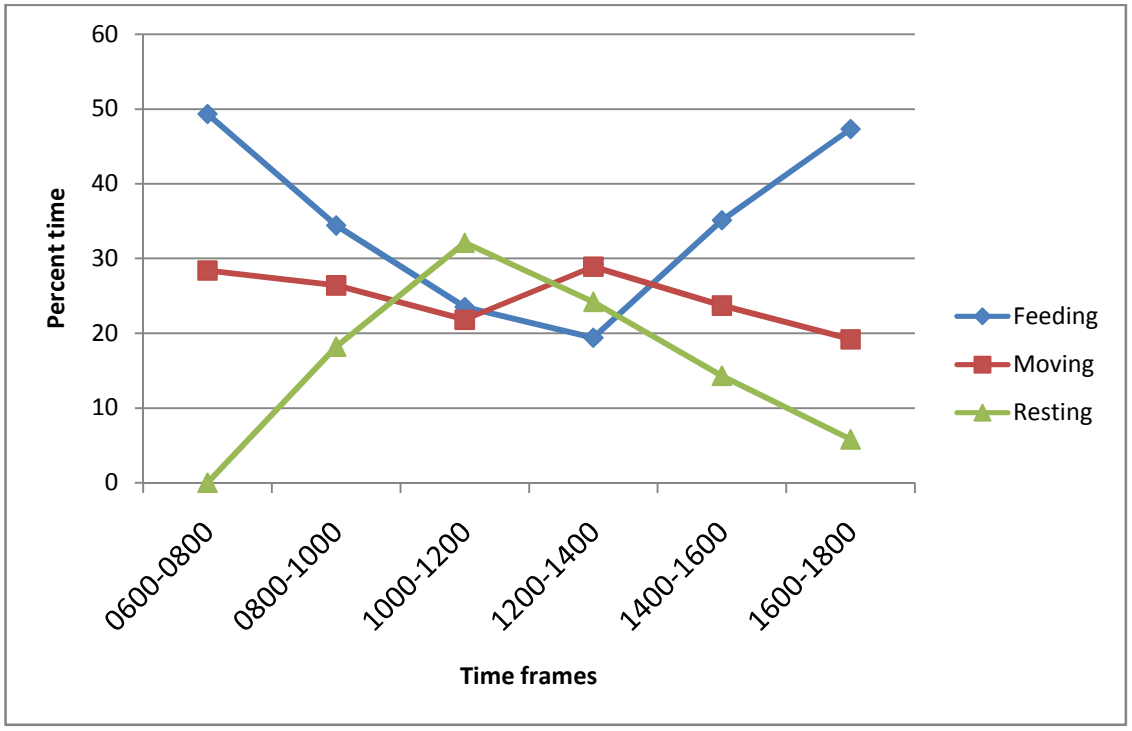


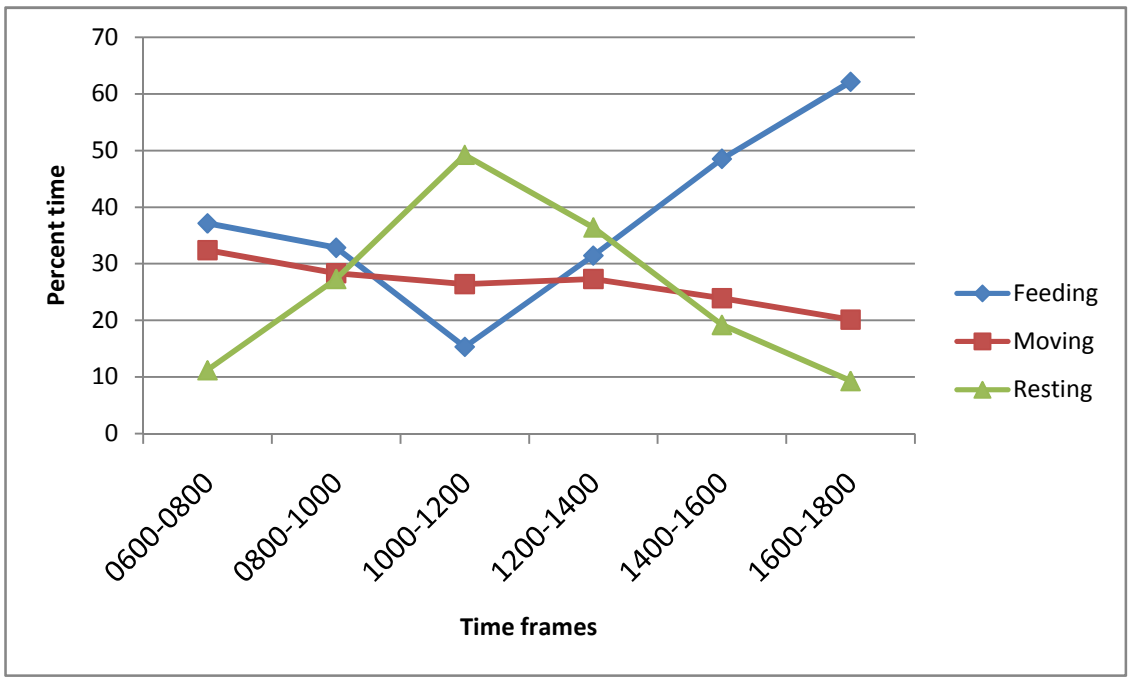
Figure 3.51: Major activity patterns of yearling gaur during winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Brown bull

Annually, the time spent feeding by brown bull was highest in the time frame of 1600-1800 hrs and lowest in the 1000-1200 hrs time frame. The time spent moving by brown bull was highest in the time frame of 0600-0800 hrs after which it showed a declining trend till 1800 hrs. Time spent resting was highest in the 1000-1200 hrs time frame (fig. 3.52).

Figure 3.52: Annual activity patterns of major activities of gaur brown bull in Bandhavgarh Tiger Reserve (March 2012-February 2014).



In all the seasons the time spent feeding by brown bull was highest in the time frame of 1600-1800 hrs (figs. 3.53, 3.54 and 3.55). Time spent in moving during the mid-day hours (1200-1400 hrs) was considerably higher in winter as compared to summer and monsoon. The time spent resting during the mid-day hours was much lower in winter as compared to summer and monsoon.

Figure 3.53: Major activity patterns of gaur brown bull during summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

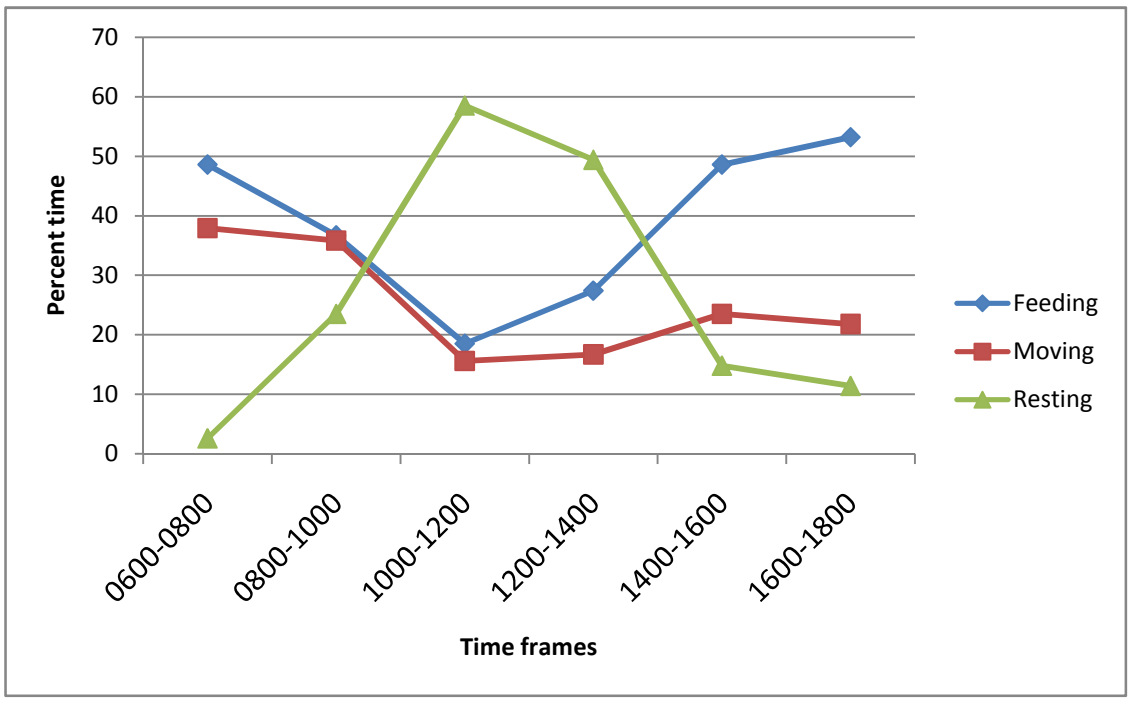


Figure 3.54: Major activity patterns of gaur brown bull during monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

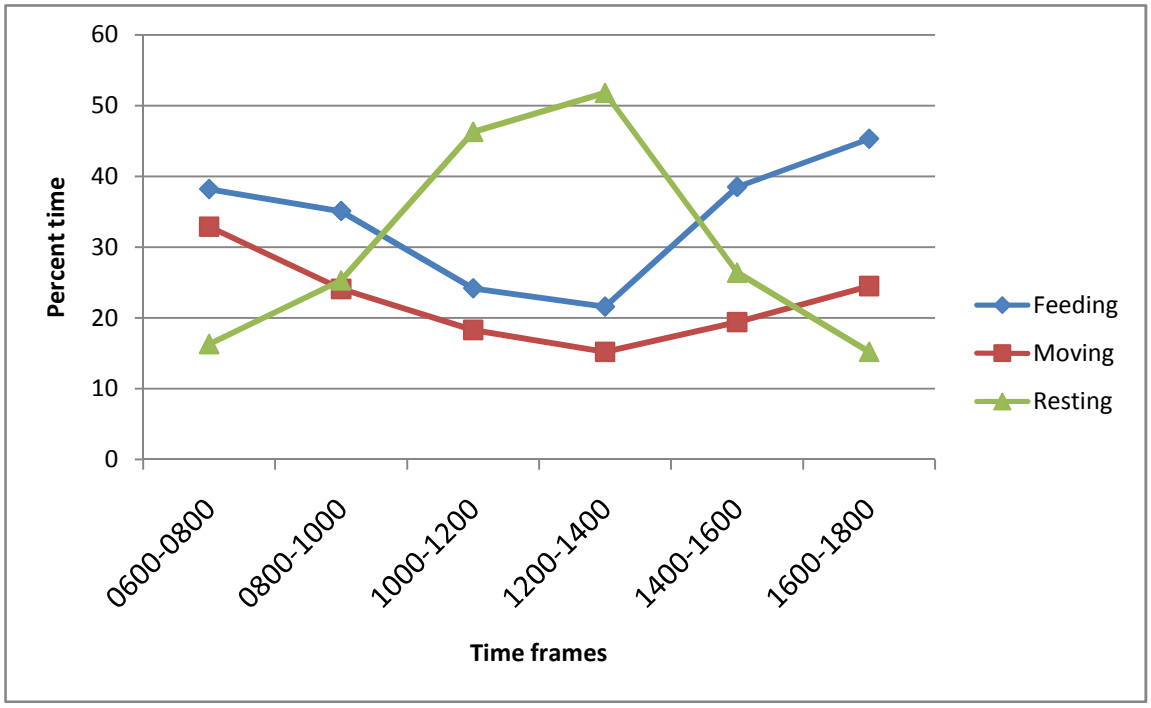
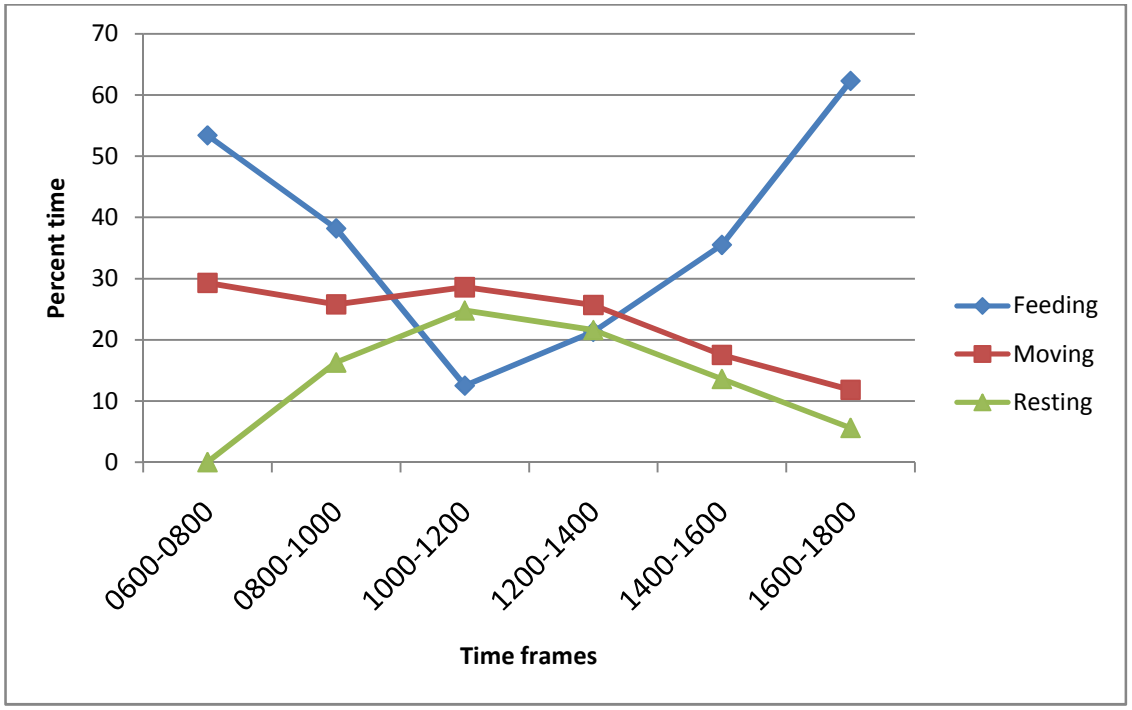


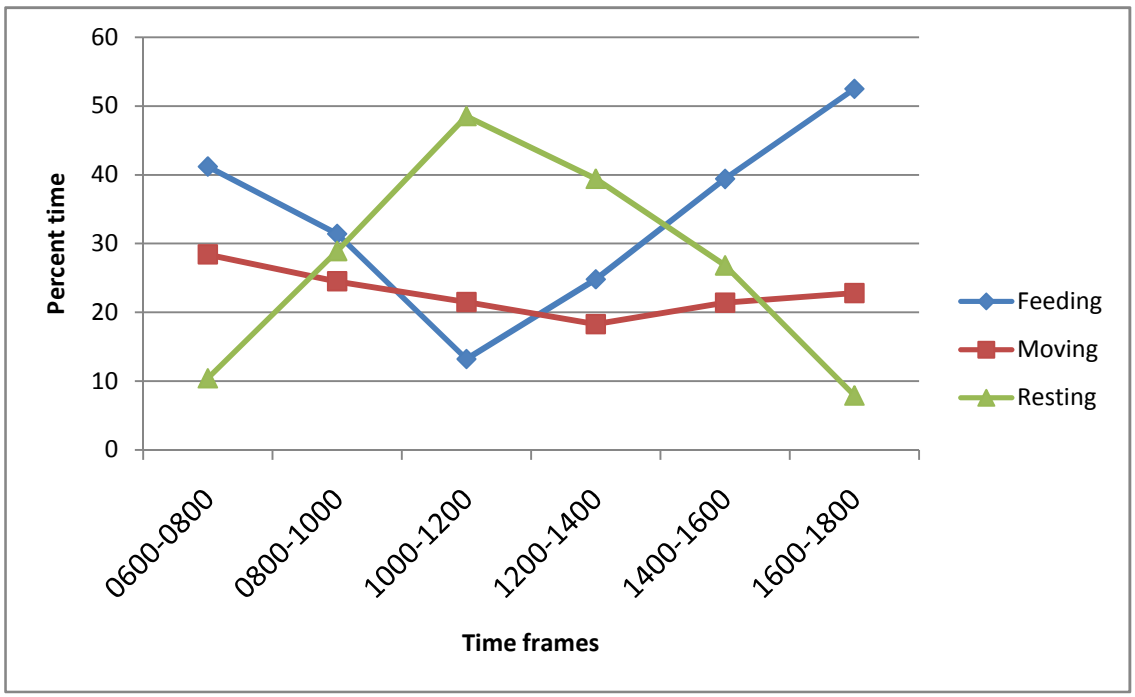
Figure 3.55: Major activity patterns of gaur brown bull during winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Black bull

Annually, the feeding pattern of black bull showed two peaks (fig. 3.56) i.e. one in the early morning hours (0600-0800) and the other in evening hours (1600-1800). Time spent moving was highest in the time frame of 0600-0800 hrs after which it declined till 1400 hrs and then increased again from 1400-1800 hrs. Time spent resting was highest in the time frame of 1000-1200 hrs.

Figure 3.56: Annual activity patterns of major activities of gaur black bull in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Seasonally, it was seen that the main feeding period of black bull was in the time frames of 0600-0800 and 1600-1800 hrs, but the time spent feeding in these two time frames in monsoon was considerably lower than that in summer and winter (figs. 3.57, 3.58 and 3.59). Time spent moving by black bull was observed to increase from 0600-1800 hrs in summer whereas in monsoon the time spent moving was highest in the early morning time frame after which it decresed in the mid-day hours and then showed an increase in the late afternoon and evening hours. In winter, the time spent moving by black bull was lowest in the 1000-1200 hrs time frame. The time spent resting by black bull was highest in the 1000-1200 hrs time frame in summer and winter whereas it was highest in the 1200-1400 hrs time frame in monsoon.

Figure 3.57: Major activity patterns of gaur black bull during summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

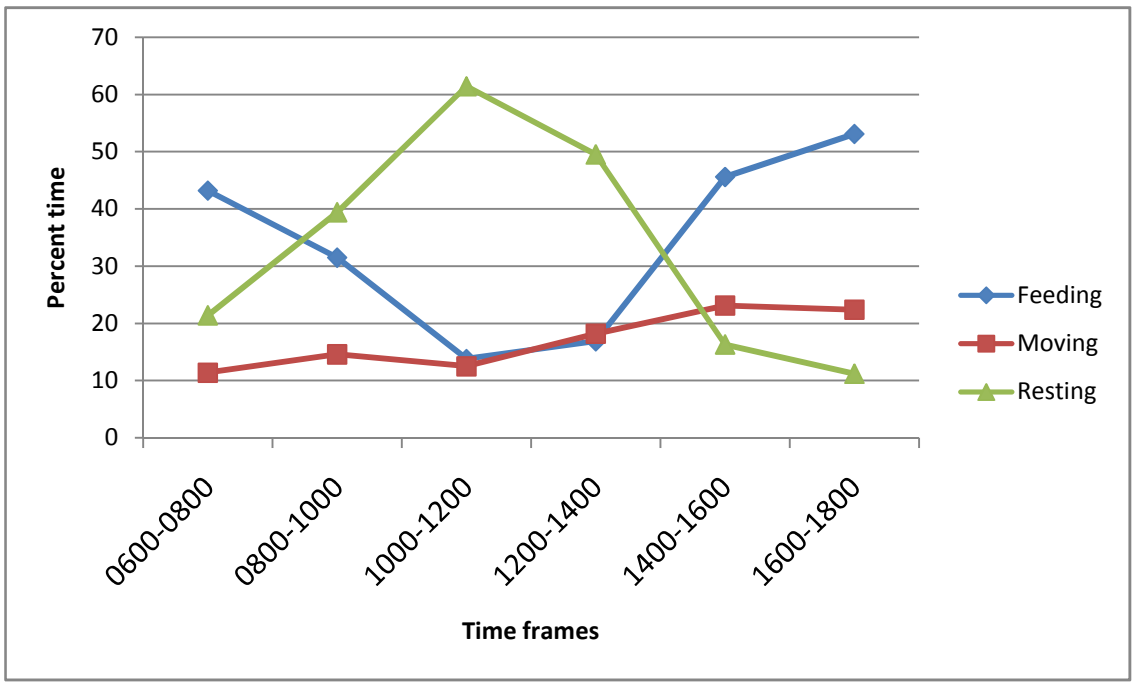


Figure 3.58: Major activity patterns of gaur black bull during monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

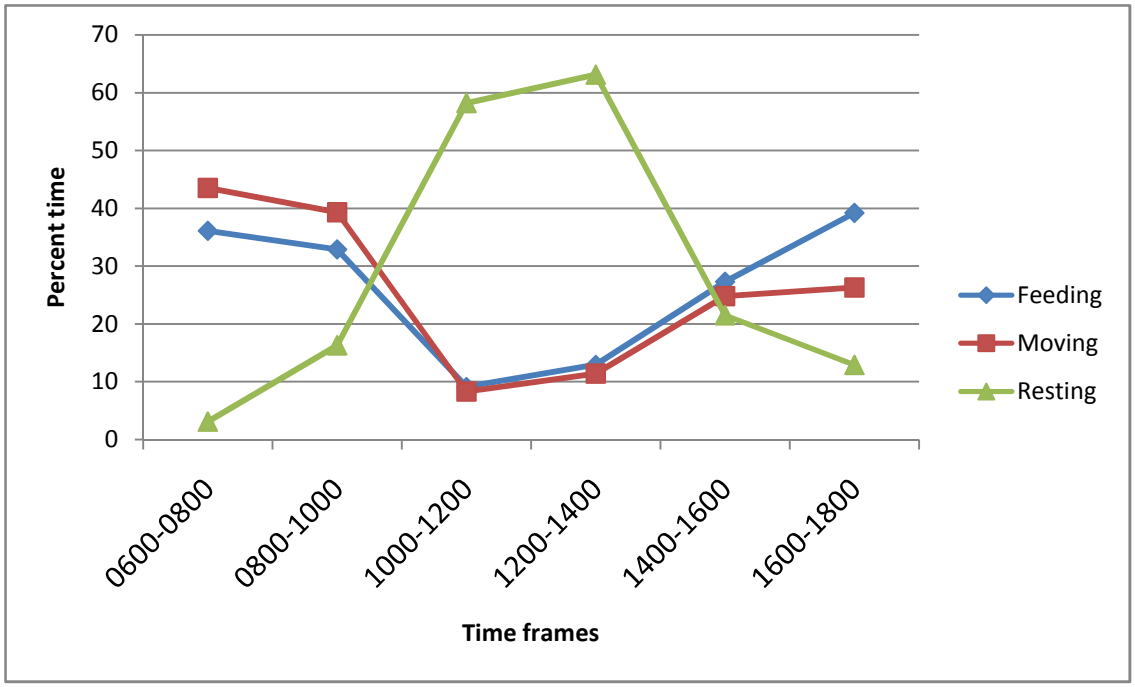
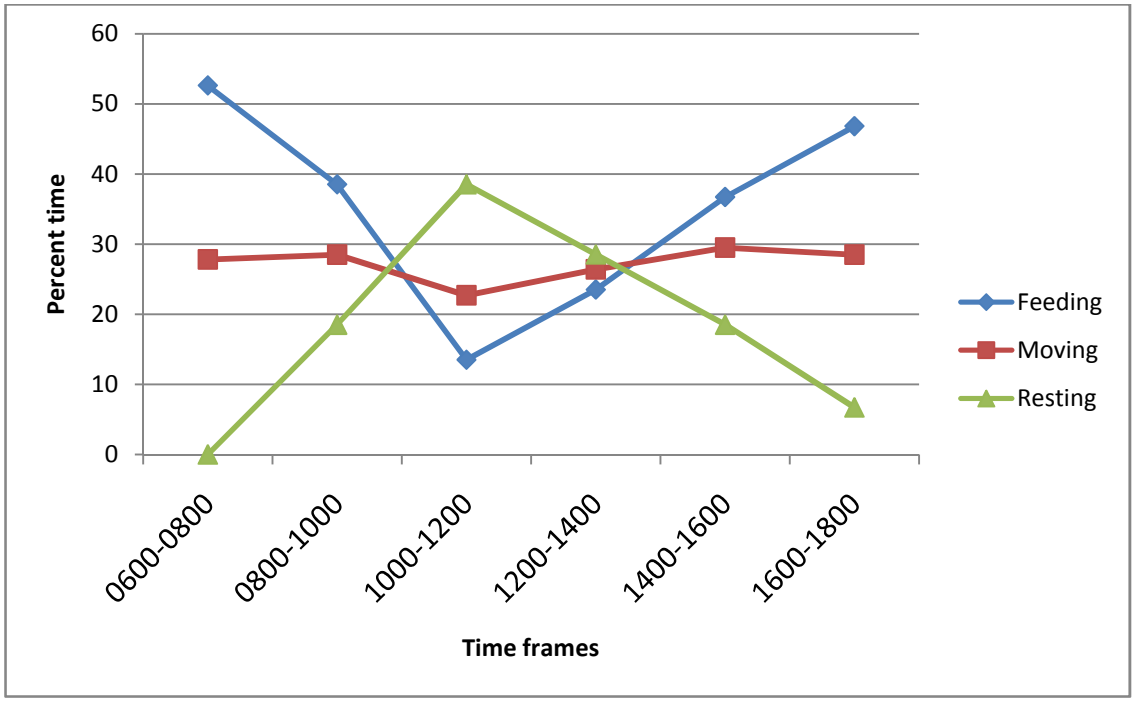


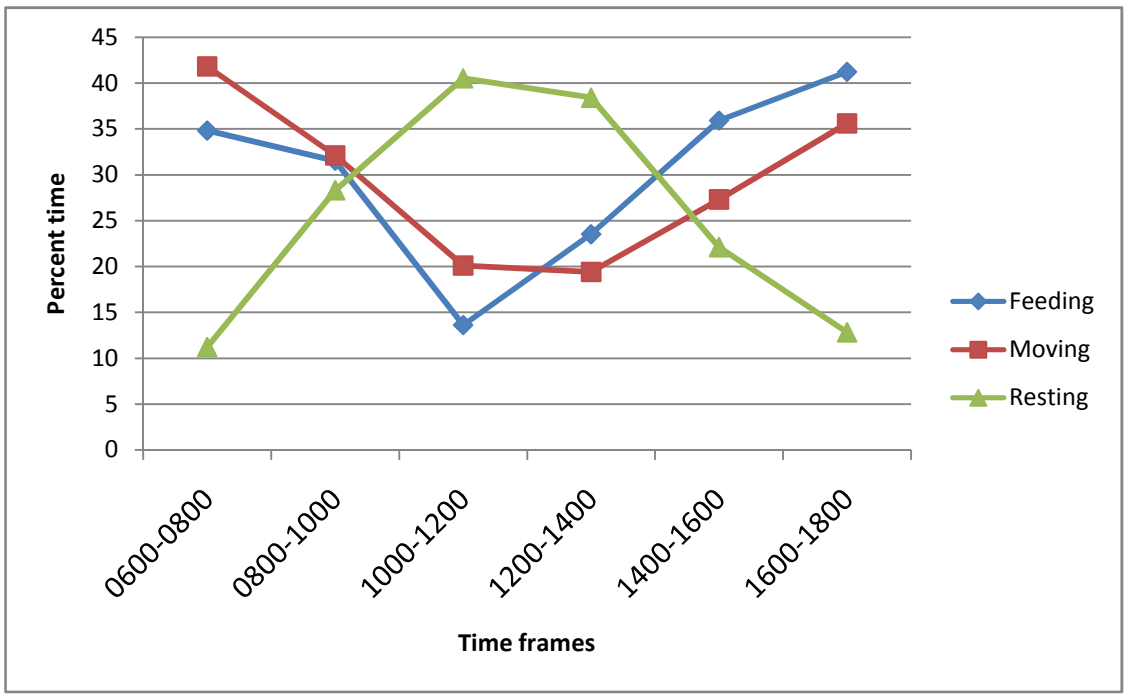
Figure 3.59: Major activity patterns of gaur black bull during winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Calf

The annual activity pattern of calf (fig. 3.60) showed that the time spent in feeding and moving was much similar across all the time frames. The time spent in feeding and moving was higher in the early morning and late afternoon and evening hours as compared to that in the mid-day hours. The time spent in resting by calf was higher in the time frames of 1000-1200 and 1200-1400 hrs as compared to the other time frames of the day.

Figure 3.60: Annual activity patterns of major activities of gaur calf in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The time spent feeding by calf was observed to be highest in the time frame of 1600-1800 hrs in all the seasons. The time spent in moving was highest in the time frame of 0600-0800 hrs in all the seasons but in winter, the time spent moving in the mid-day hours was considerably higher as compared to summer and monsoon (figs. 3.61, 3.62 and 3.63). In all the seasons the time spent resting was highest in the mid-day hours but in winter the time spent resting was much lower in the mid-day hours as compared to summer and monsoon.

Figure 3.61: Major activity patterns of gaur calf during summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

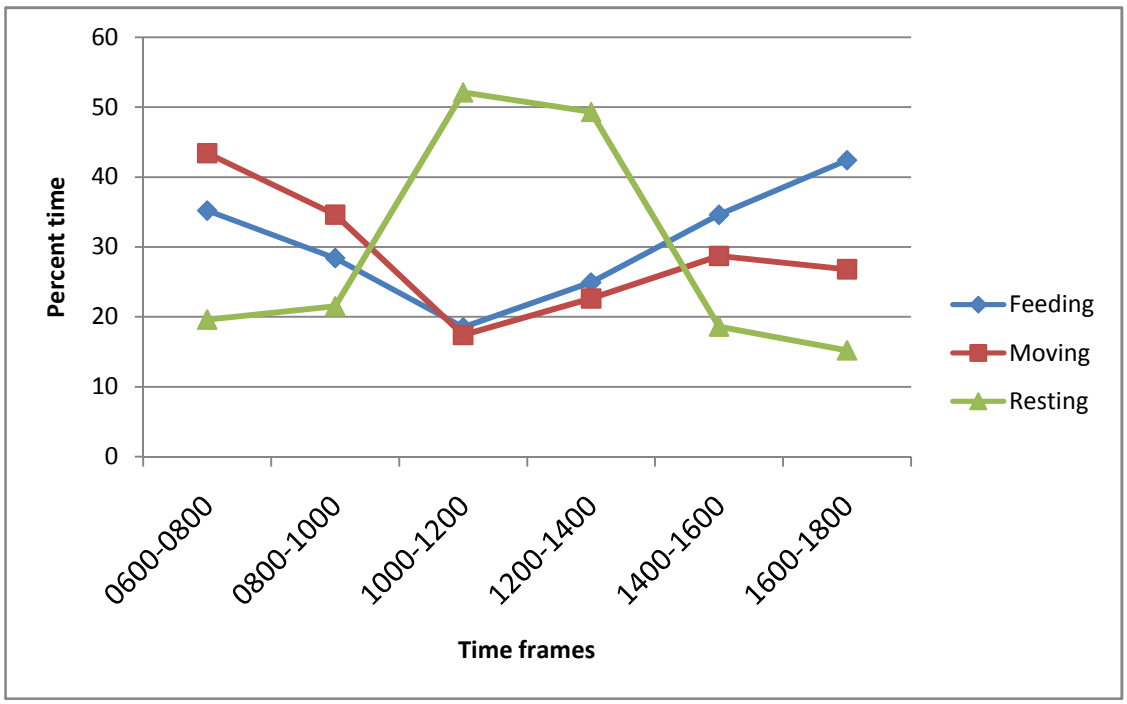


Figure 3.62: Major activity patterns of gaur calf during monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

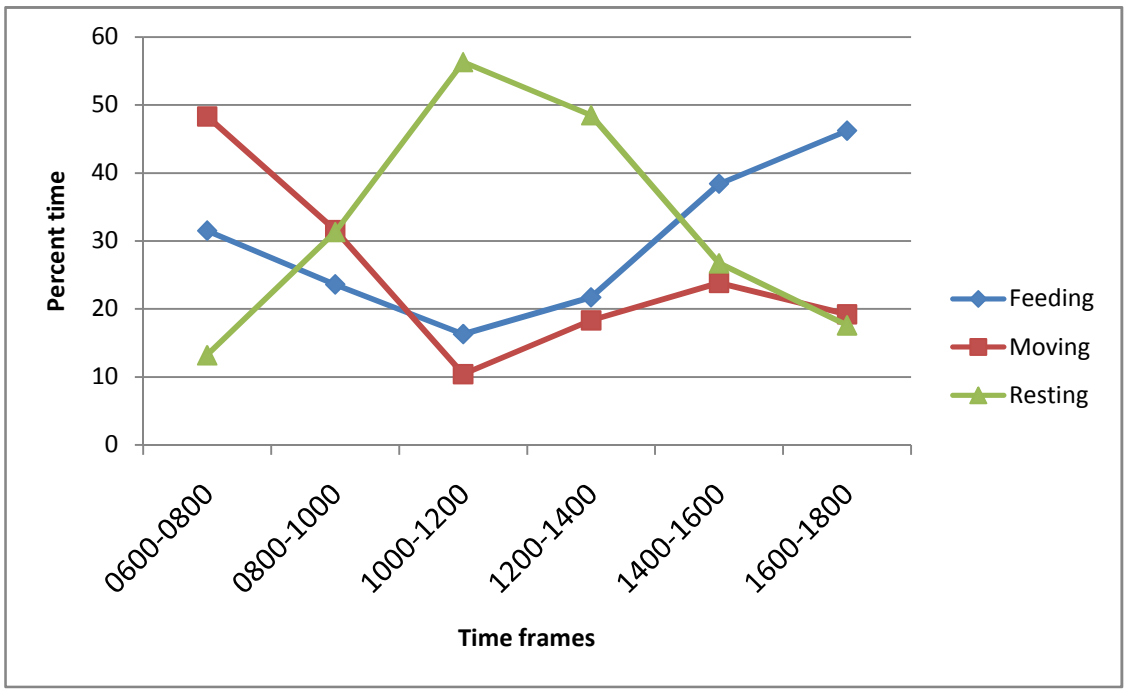
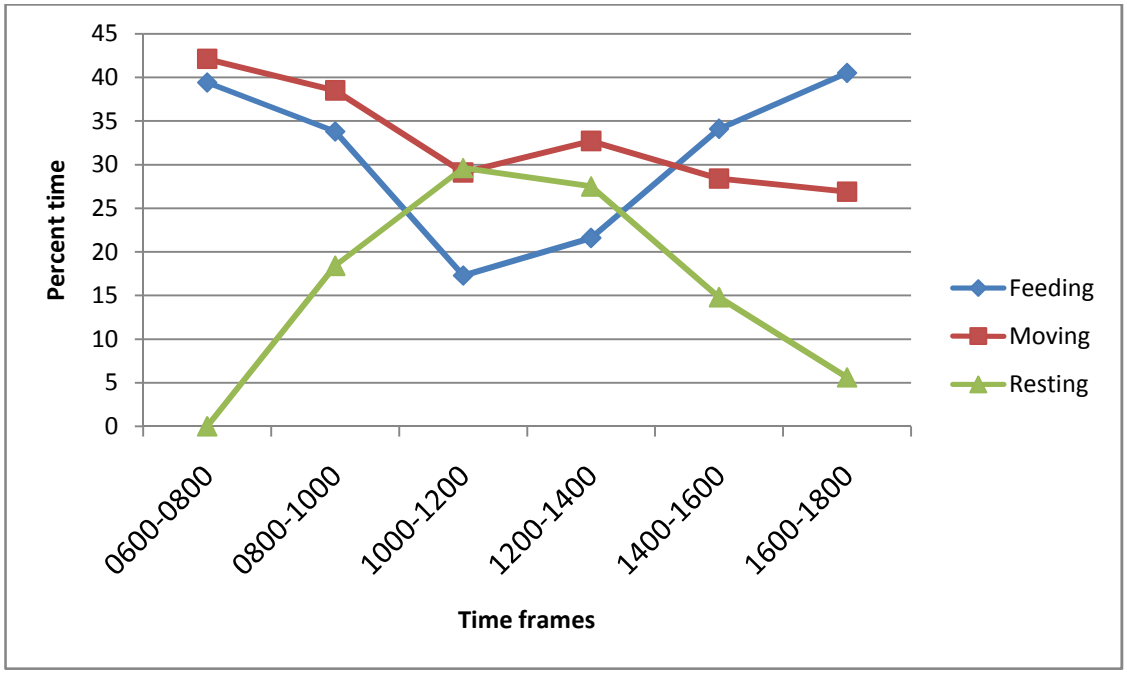


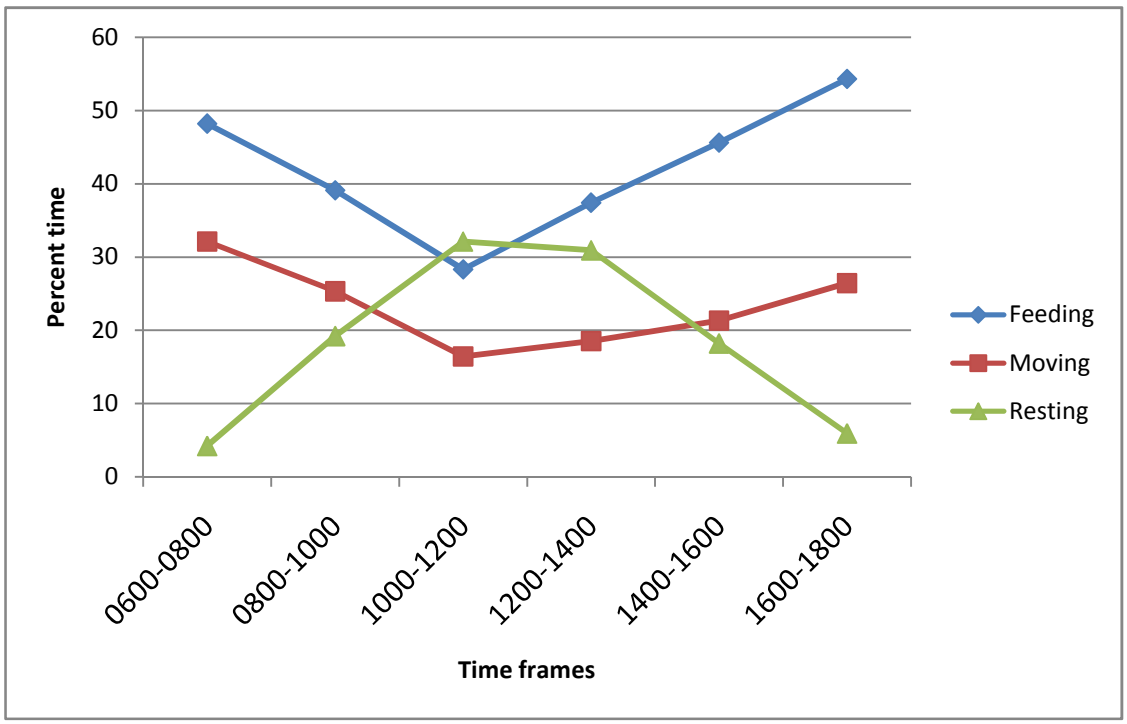
Figure 3.63: Major activity patterns of gaur calf during winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Sub-adult bull

It was observed that annually, feeding was the most prominent activity of sub-adult bull throughout the major part of the day (fig. 3.64). The time spent feeding was observed to be highest in the time frame of 1600-1800 hrs. Annually, the time spent moving also showed a similar pattern to the feeding activity wherein it was higher in the early morning and evening time frames as compared to that in the mid-day hours. The time spent resting by sub-adult bull was observed to peak from 1000-1400 hrs.

Figure 3.64: Annual activity patterns of major activities of gaur sub-adult bull in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The seasonal activity patterns of sub-adult bull are given in figures 3.65, 3.66 and 3.67. It was observed that the feeding activity peaked in the early morning (0600-0800 hrs) time frame in monsoon and winter whereas in summer it peaked in the evening (1600-1800 hrs) time frame. The time spent moving in the mid-day hours was observed to be considerably higher in winter as compared to summer and monsoon. In all the seasons, the time spent resting was observed to peak in the mid-day hours.

Figure 3.65: Major activity patterns of gaur sub-adult bull during summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

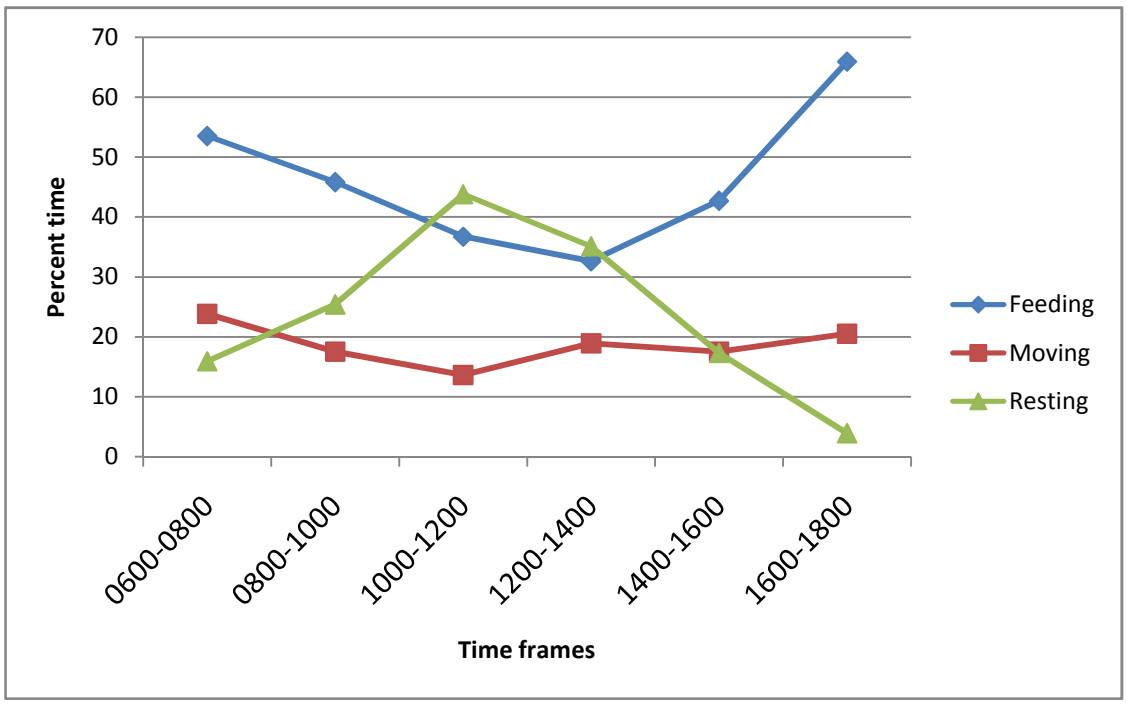


Figure 3.66: Major activity patterns of gaur sub-adult bull during monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

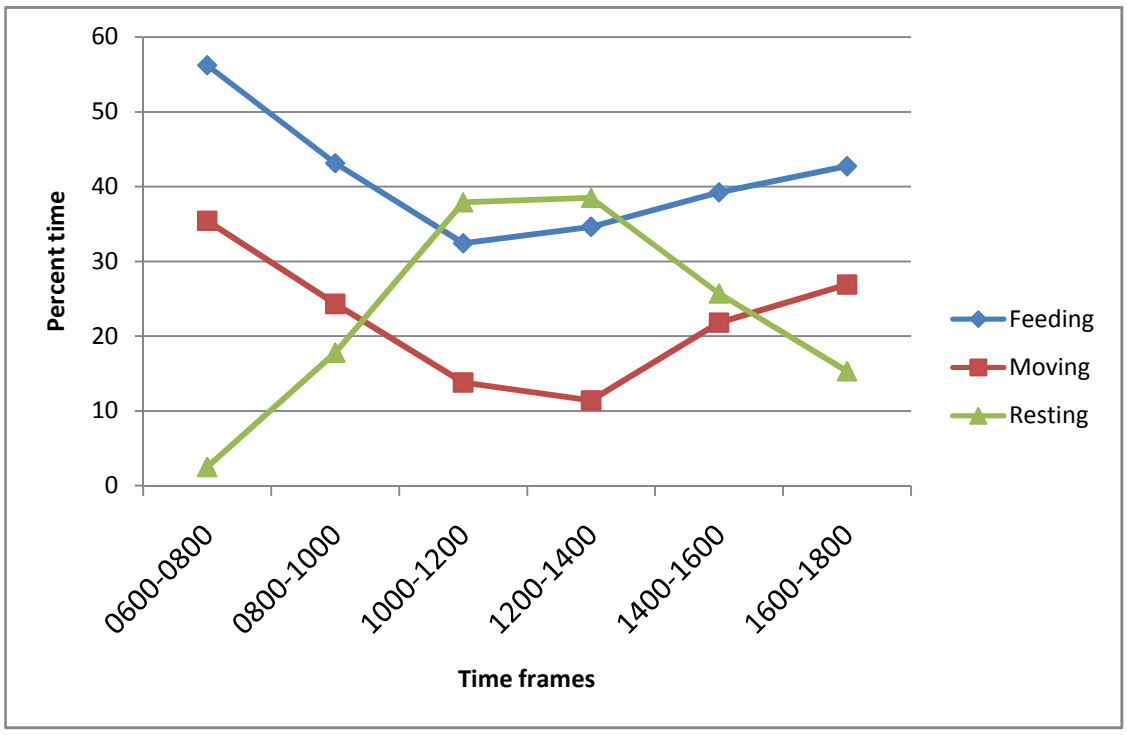
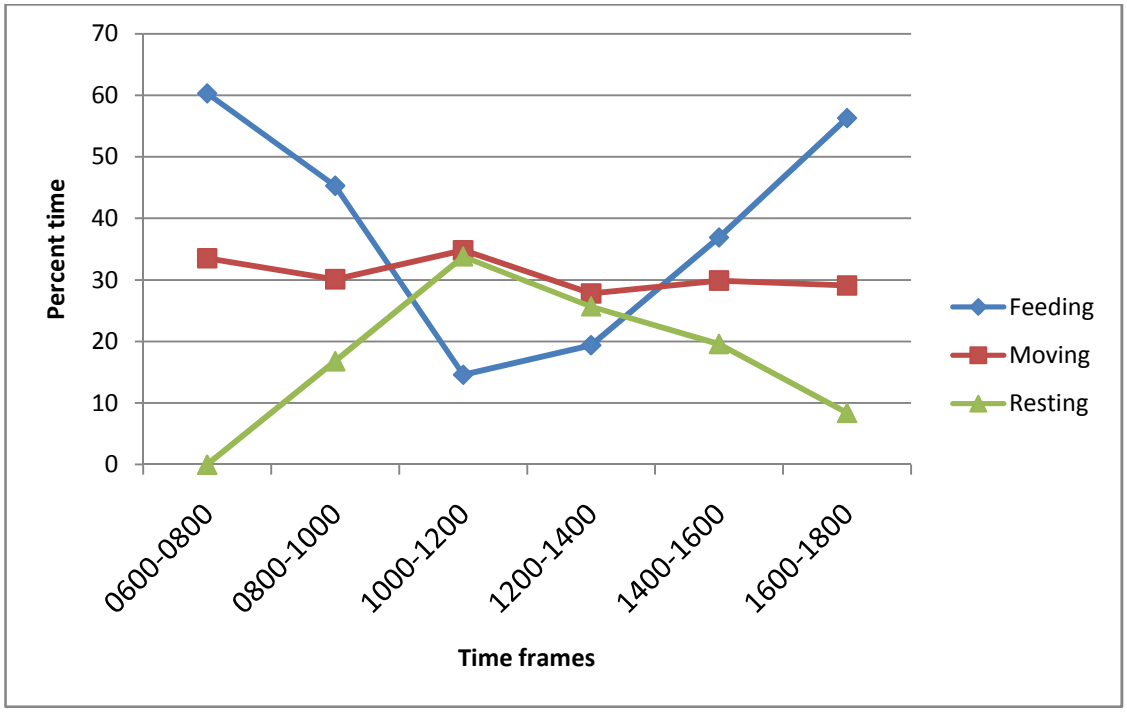


Figure 3.67: Major activity patterns of gaur sub-adult bull during winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



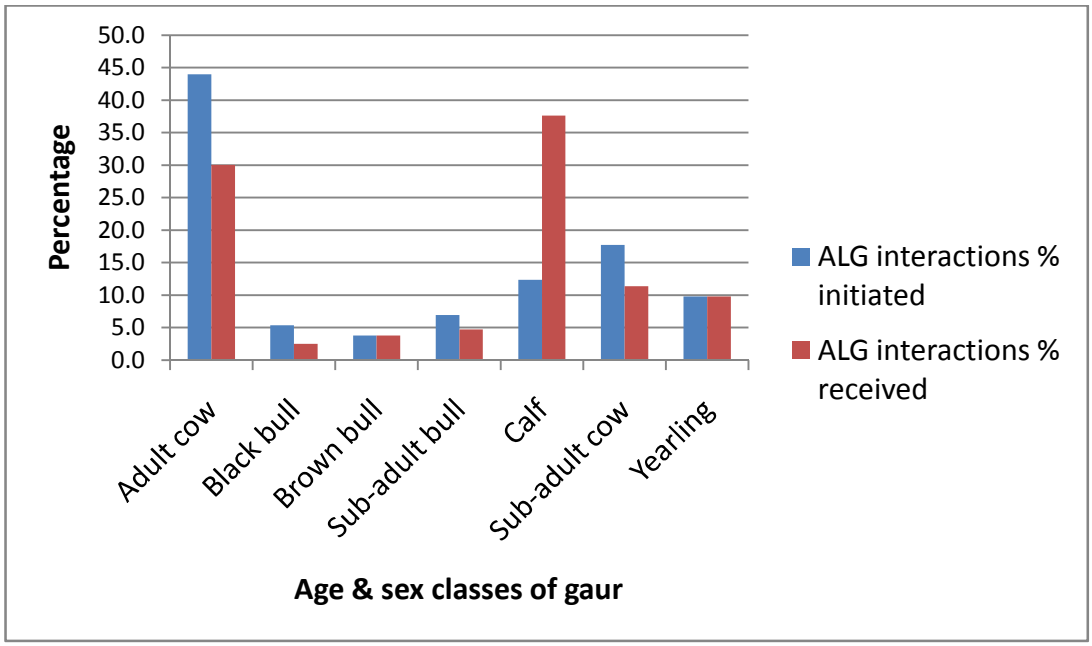
3.4.3 Social interactions

In the present study the social interactions among the members of a gaur herd were classified as allogrooming, dominance-subordination interactions and sexual behaviour.

Allogrooming

Allogrooming is the act when one individual licks another individual. This is a major social activity seen among all the age and sex classes of gaur. During the study period a total of 316 allogrooming interactions were recorded. The percentage of allogrooming interactions initiated and received by each age and sex class of gaur is given in figure 3.68.

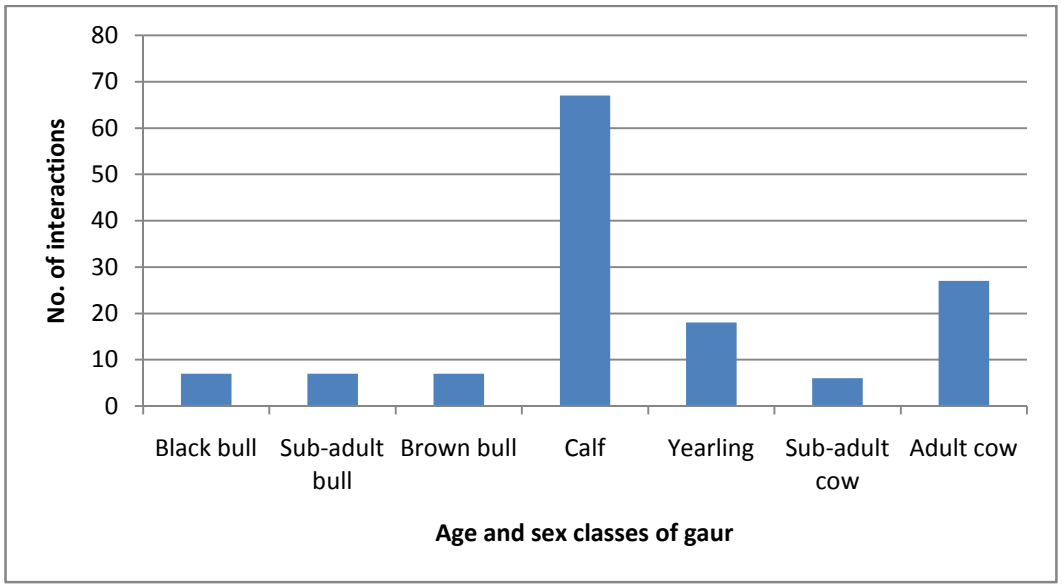
Figure 3.68: Percentage allogrooming interactions initiated and received by different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



(n=316)

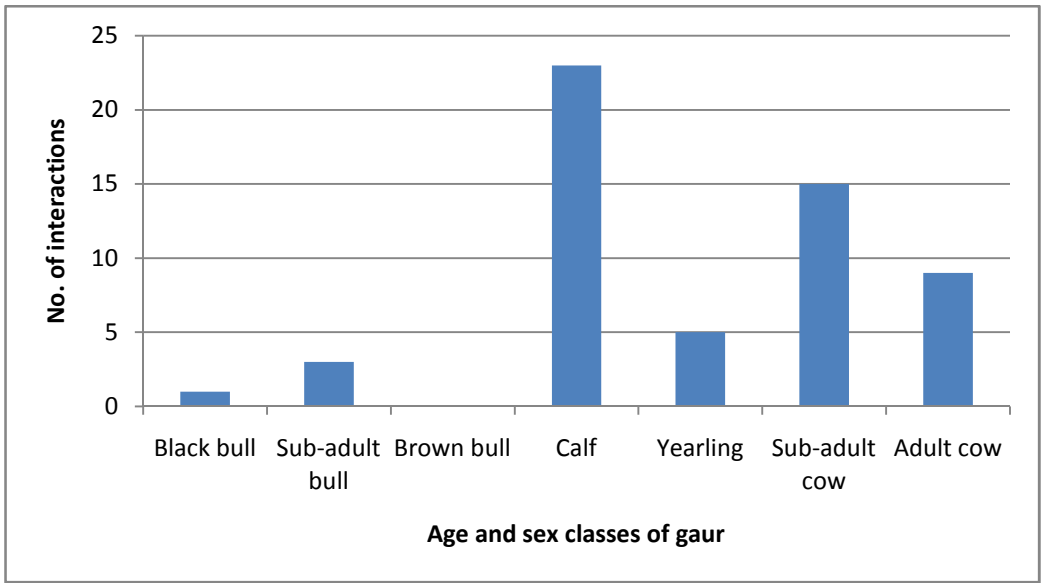
It was observed that adult cows initiated the highest percentage of allogrooming interactions (44%) followed by sub-adult cows (17.7%) whereas calves received the highest percentage of allogrooming interactions (37.7%) followed by adult cow (30.1%). The details about the number of allogrooming interactions shown by each age and sex class of gaur are given in figures 3.69 to 3.75.

Figure 3.69: Allogrooming interactions shown by adult cow towards different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



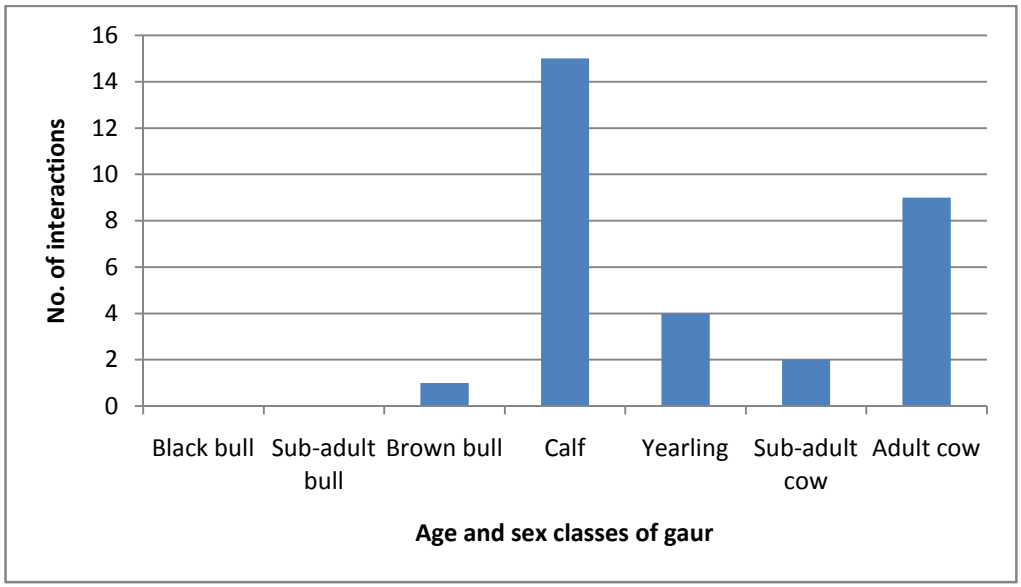
(n=139)

Figure 3.70: Allogrooming interactions shown by sub-adult cow towards different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



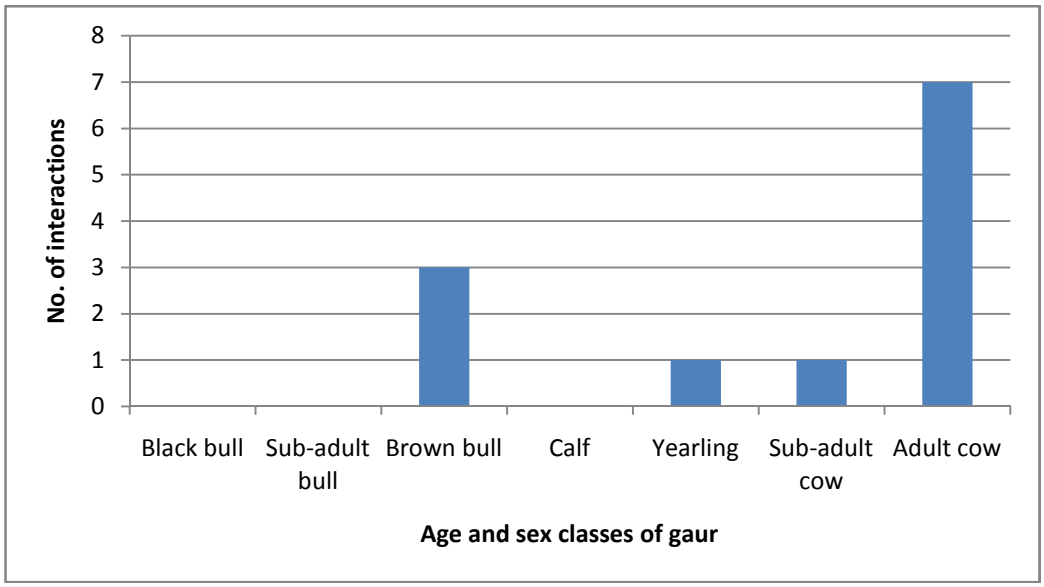
(n=56)

Figure 3.71: Allogrooming interactions shown by yearling towards different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



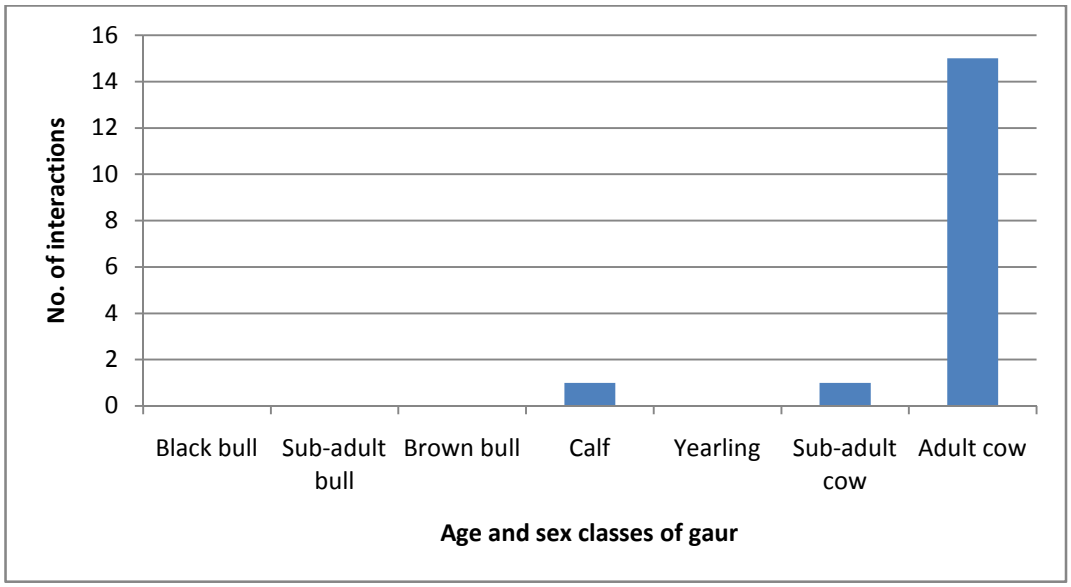
(n=31)

Figure 3.72: Allogrooming interactions shown by brown bull towards different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



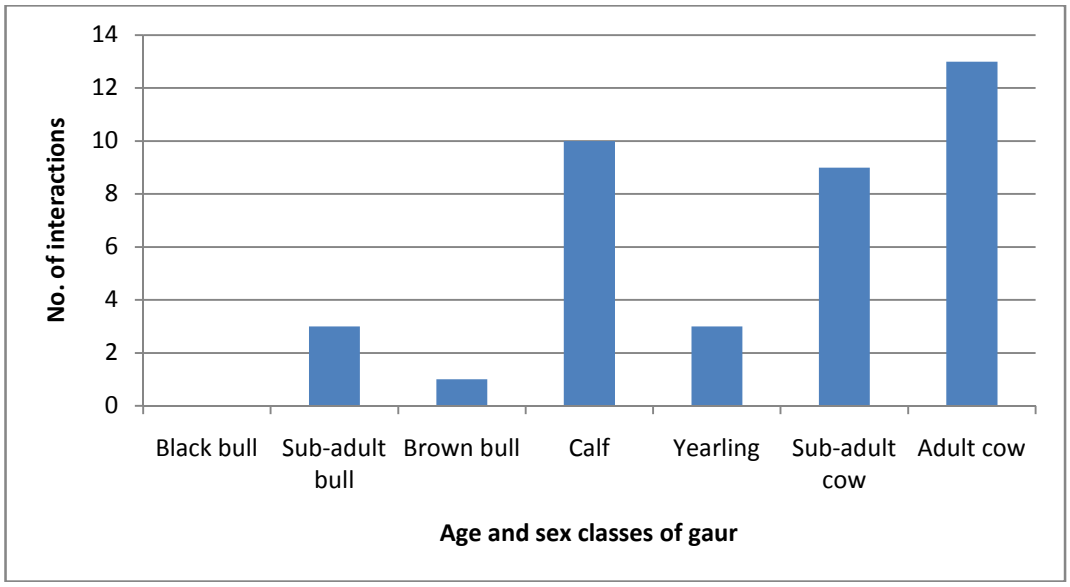
(n=12)

Figure 3.73: Allogrooming interactions shown by black bull towards different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



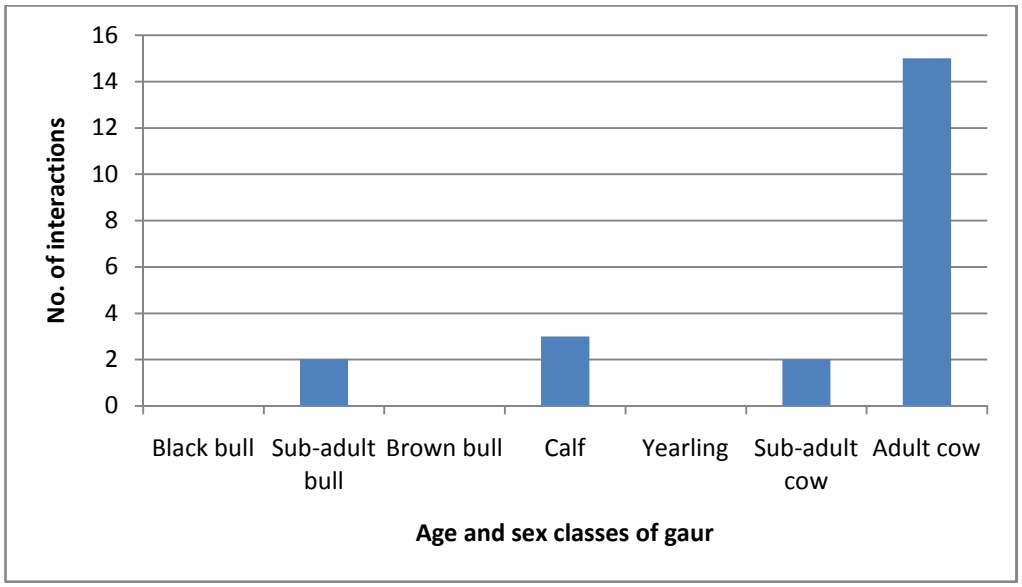
(n=17)

Figure 3.74: Allogrooming interactions shown by calf towards different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



(n=39)

Figure 3.75: Allogrooming interactions shown by sub-adult bull towards different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



(n=22)

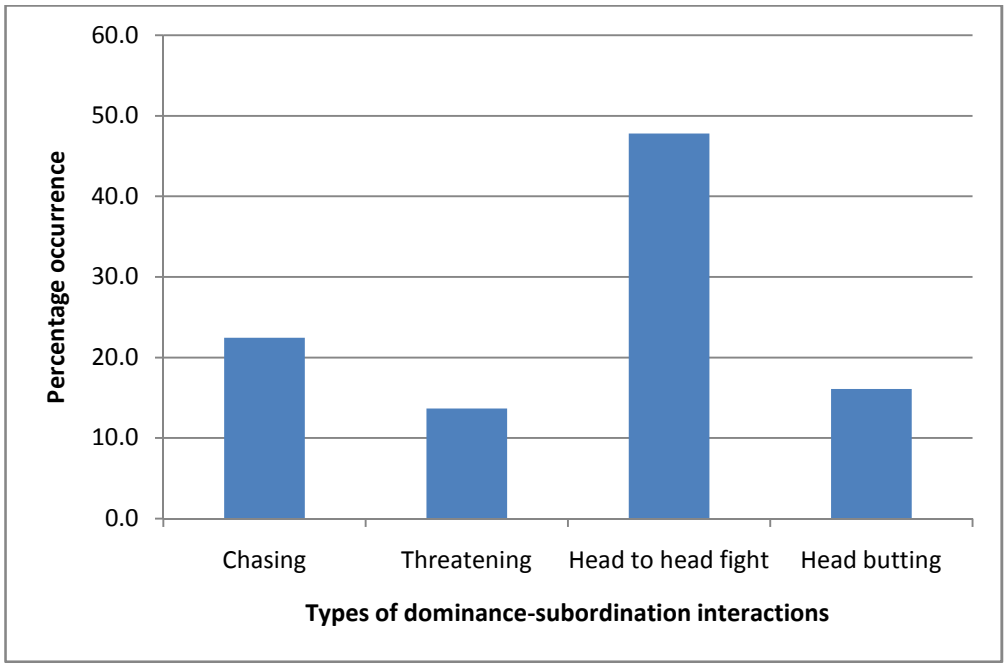
It was observed that the highest number of allogrooming interactions were recorded for adult cow (n=139) followed by subadult cow (n=56) whereas the allogrooming interactions recorded for brown bull were the lowest (n=12). Adult cows, sub-adult cows and yearlings allogroomed calves the most (n=67, 23 and 15 respectively). Calves and all the three age classes of bull *viz*. black bulls, brown bulls and sub-adult bulls showed the most allogrooming interactions towards adult cows (n=13, 15, 7 and 15 respectively).

Dominance-Subordination interactions

A hierarchical dominance exists in a group of gaur and rank indicating gestures (dominance-subordinate interactions) are used by gaur individuals to assert their hierarchical status in a group. Four types of dominance-subordination interactions were recorded among gaur during the study period in Bandhavgarh. These were

chasing, threatening, head-butting and head to head fighting. A total of 205 records have been made of these rank indicating gestures during the study period. Chasing comprises of a dominant animal running after a subordinate animal with its horns lowered for a short distance. Threatening behaviour comprised of a dominant animal walking over to a subordinate animal and the subsequent withdrawal of the subordinate animal from that spot where it had been standing or feeding. Sometimes it was observed that during a threatening behaviour, the dominant animal waved its horns towards the subordinate individual. Adult bulls (black and brown bulls) also used the lateral display as a means to establish their dominance over other bulls. In a lateral display the displaying bull stood parallel to another bull with its head lowered and back hunched as it displayed its profile to the other bull. Lateral displays were also recorded as a type of threatening behaviour. Head-butting comprises of one animal hitting another with its horns. This is usually followed by the withdrawal of the subordinate animal from the spot. Head to head fighting consists of two animals interlocking their horns and trying to push each other away till one of them breaks off and moves away. The percentage occurrence of different dominance-subordination interactions among the gaur population in the study period is given in figure 3.76.

Figure 3.76: Percentage occurrence of different dominance-subordination interactions among the gaur population in Bandhavgarh Tiger Reserve (March 2012-February 2014).



(n=205)

It was observed that among the dominance-subordination interactions, the occurrence of head to head fighting was the highest (47.8%) whereas that of the threatening behaviour was the lowest (13.7%). The details of different age and sex classes of gaur which engaged in different rank indicating gestures are given in tables 3.3 to 3.6.

Table 3.3: Age and sex classes of gaur involved in chasing behaviour in Bandhavgarh Tiger Reserve (March 2012-February 2014).

	Age and sex class that was chased							Total
	Black bull	**Sub-adult bull**	**Brown bull**	**Calf**	**Yearling**	**Sub-adult cow**	**Adult cow**	
Adult cow	0	2	0	3	3	20	6	**34**
Sub-adult cow	0	0	0	2	1	3	0	**6**
Black bull	0	0	1	0	0	1	0	**2**
Brown bull	0	0	0	2	0	0	1	**3**
Sub-adult bull	0	0	0	0	0	1	0	**1**

Table 3.4: Age and sex classes of gaur involved in threatening behaviour in Bandhavgarh Tiger Reserve (March 2012-February 2014).

	Age and sex class that was threatened							Total
	Black bull	**Sub-adult bull**	**Brown bull**	**Calf**	**Yearling**	**Sub-adult cow**	**Adult cow**	
Adult cow	0	1	0	2	3	10	2	**18**
Sub-adult cow	0	0	0	0	2	0	0	**2**
Black bull	3	1	2	0	0	1	1	**8**

Table 3.5: Age and sex classes of gaur involved in head to head fight in Bandhavgarh Tiger Reserve (March 2012-February 2014).

	Black bull	Sub-adult bull	Brown bull	Calf	Yearling	Sub-adult cow	Adult cow	Total
Adult cow	4	5	3	3	1	10	10	**36**
Sub-adult cow	1	9	2	13	4	6	10	**45**
Calf	0	0	0	4	3	13	3	**23**
Black bull	4	6	2	0	0	1	4	**17**
Brown bull	2	1	4	0	1	2	3	**13**
Sub-adult bull	6	2	1	0	0	9	5	**23**
Yearling	0	0	1	3	0	4	1	**9**

Table 3.6: Age and sex classes of gaur involved in head butting behaviour in Bandhavgarh Tiger Reserve (March 2012-February 2014).

	Age and sex class that was head butted							Total
	Black bull	Sub-adult bull	Brown bull	Calf	Yearling	Sub-adult cow	Adult cow	
Adult cow	1	0	1	1	1	14	2	**20**
Sub-adult cow	0	1	0	2	0	3	0	**6**
Black bull	0	1	0	1	0	0	1	**3**
Brown bull	0	0	1	0	0	0	0	**1**
Sub-adult bull	1	0	0	1	0	0	1	**3**

The most number of records for chasing, threatening and head butting were made for adult cow (34, 18 and 20 respectively) whereas that of head to head fighting were

found to be highest for sub-adult cow (n=45). Event rates (number of interactions per scan record) for each type of dominance-subordination interaction were calculated for each age and sex class of gaur so as to understand the frequency with which each age and sex class displayed those behaviours (figs. 3.77, 3.78, 3.79 and 3.80). It was observed that among all the age and sex classes of gaur, black bull showed the highest frequency for threatening, head to head fighting and head butting behaviours (0.01, 0.021 and 0.004 per scan record respectively) whereas the frequency of chasing behaviour was highest for adult cow (0.005 per scan record) followed by brown bull (0.004 per scan record).

Figure 3.77: Event rate of chasing behaviour for different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

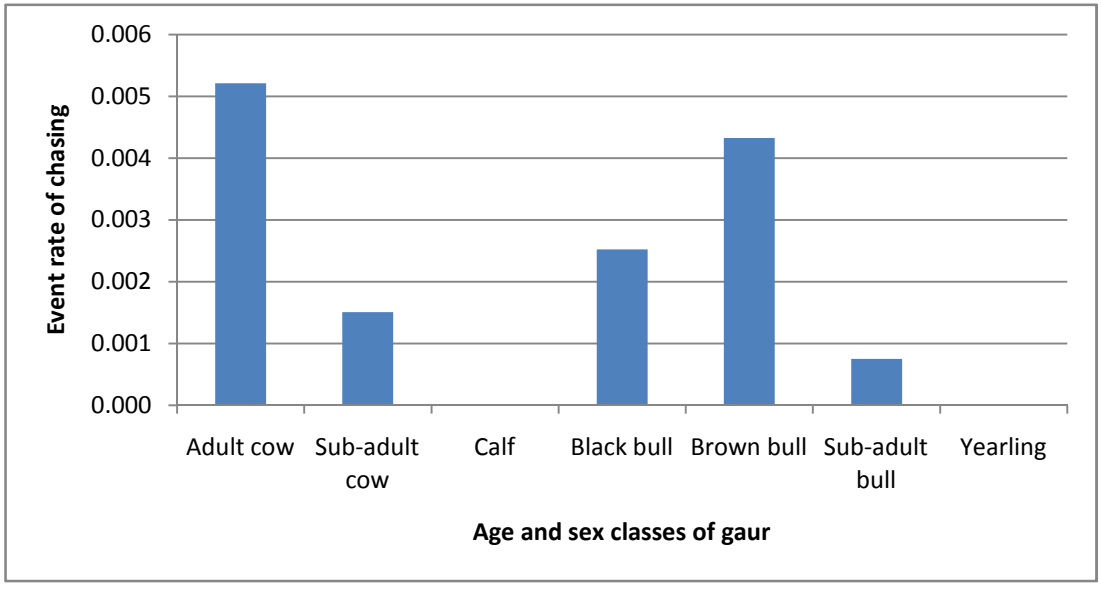


Figure 3.78: Event rate of threatening behaviour for different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

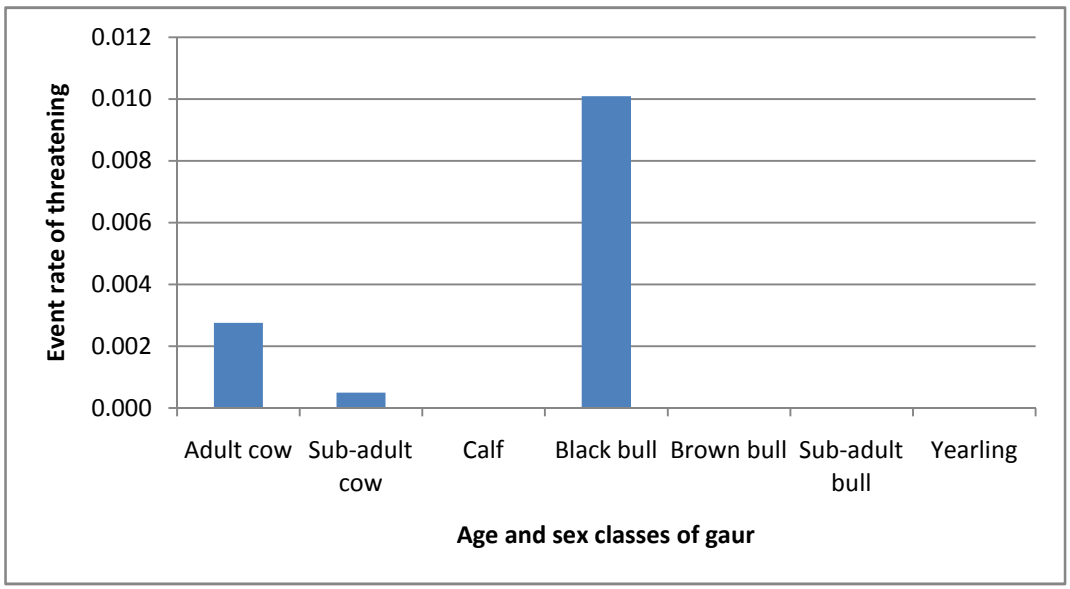


Figure 3.79: Event rate of head to head fights for different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

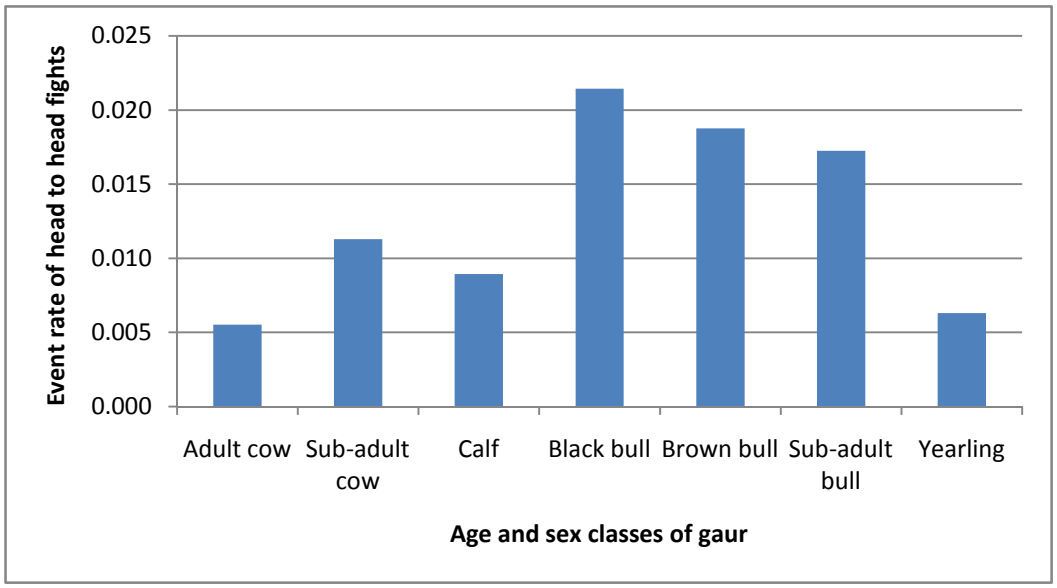
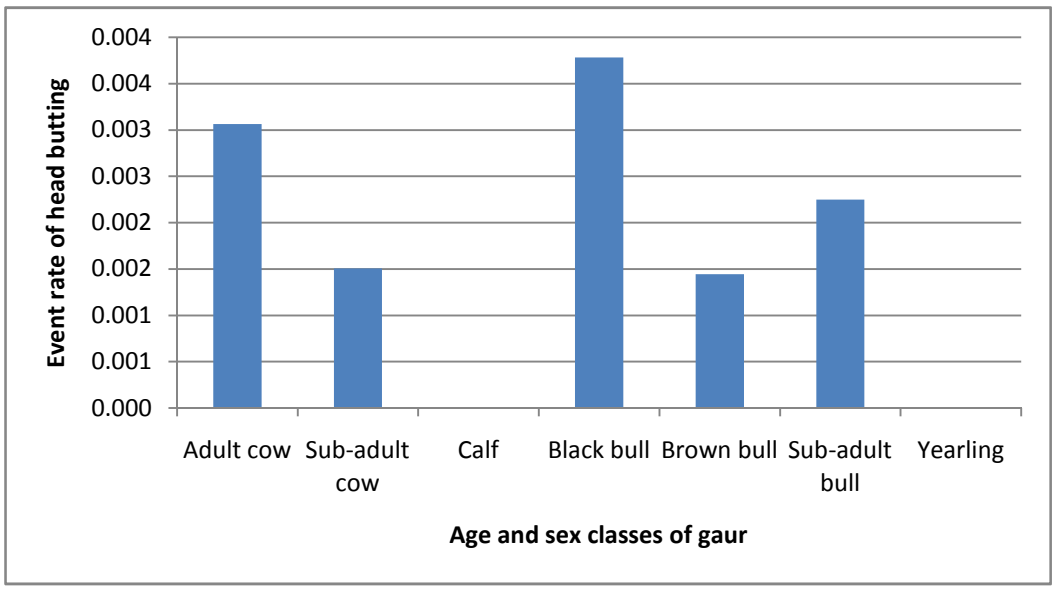


Figure 3.80: Event rate of head butting behaviour for different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Sexual behaviour

During the study period four types of activities by gaur males were grouped under the display of sexual behaviour *viz*. flehmen, tending, rutting call and mounting. Flehmen is the activity when a bull after smelling the vulva of a cow raises its head and curls up its lip so as to check whether the cow is in oestrus. Sometimes flehmen is also displayed by a bull after it smells the urine or feces of a cow. Tending behaviour is the activity when a bull accompanying a cow in oestrus moves in response to the movements of the cow. Rutting call is the vocalisation in which the bull raises its muzzle and produces a resonant 'u-u-u-u-u' sound. A total of 74 instances of display of sexual behaviour by gaur males were recorded in Bandhavgarh during the study period. The details of the display of sexual behaviour by different age classes of gaur bulls is given in table 3.7.

Table 3.7: Details of display of sexual behaviour by different age classes of gaur males in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Age classes of males	Sexual behaviours				Total
	Flehmen	Mounting	Tending	Rutting call	
Black bull	30	9	10	3	**52**
Brown bull	9	2	2	2	**15**
Sub-adult bull	5	2	0	0	**7**

*The table gives the number of records of different sexual activities made for each age class of gaur bulls.

The records of activities grouped under sexual behaviour were found to be highest for black bull (n=52). The event rate for the display of sexual behaviour by different age classes of gaur males and that of the display of sexual behaviour in different seasons by gaur males is given in figures 3.81 and 3.82. Among the different age classes of gaur males the event rate for the display of sexual behaviour was found to be highest for black bull (0.07/scan record). Among the different seasons the event rate for the display of sexual behaviour was found to be higher for summer (0.033/scan record) as compared to monsoon and winter.

Figure 3.81: Event rate for the display of sexual behaviour by different age classes of gaur males in Bandhavgarh Tiger Reserve (March 2012-February 2014).

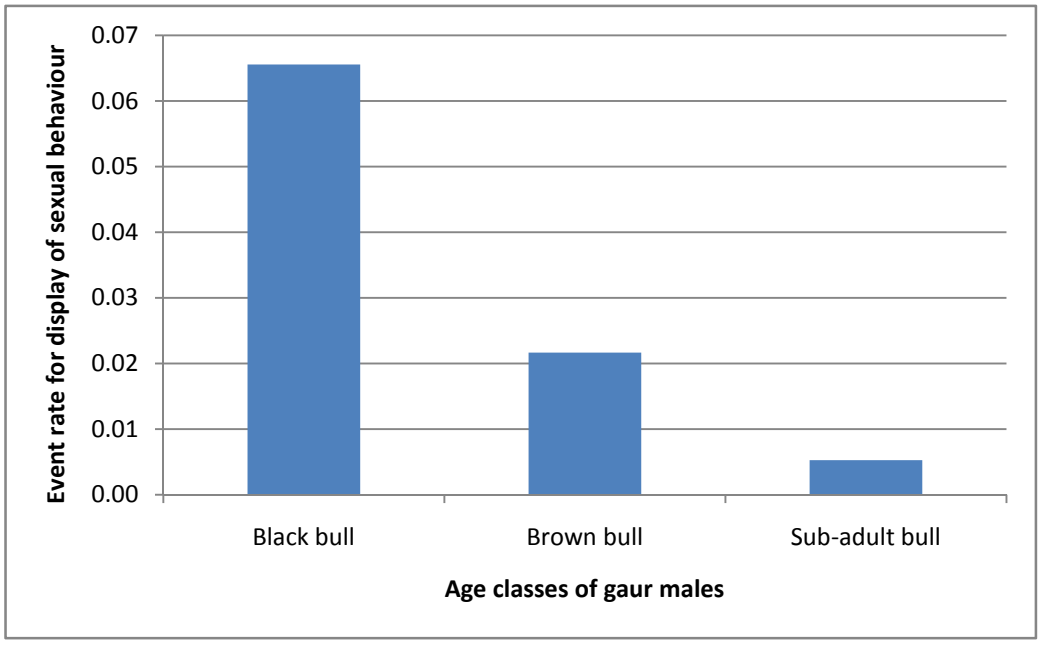
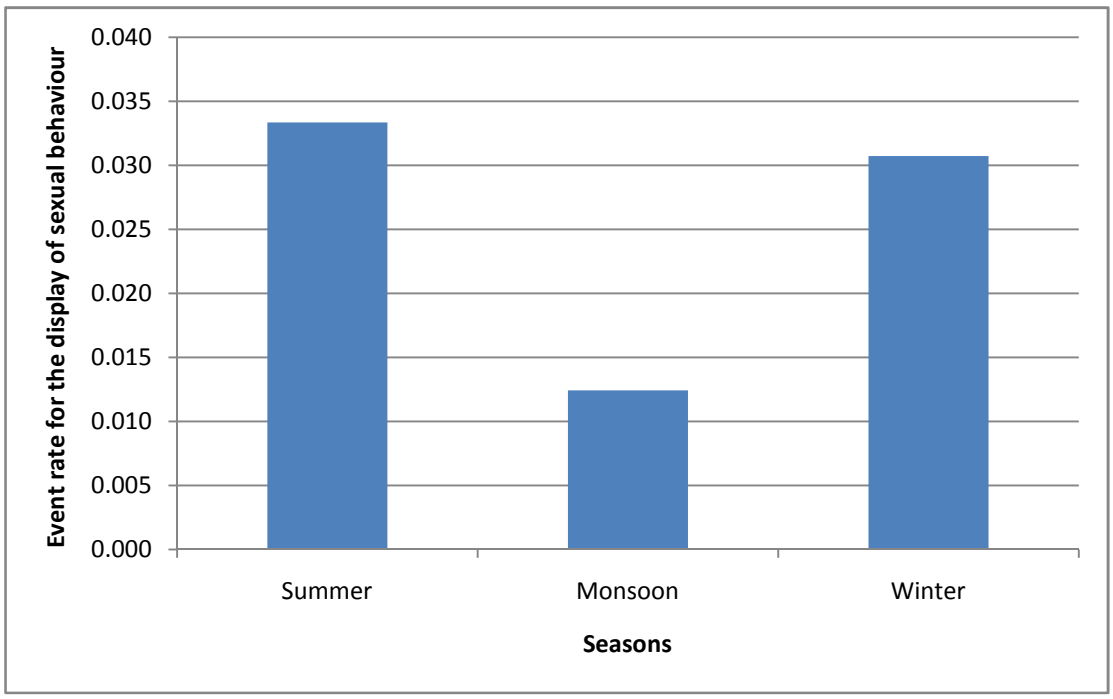


Figure 3.82: Event rate for the display of sexual behaviour in different seasons by gaur males in Bandhavgarh Tiger Reserve (March 2012-February 2014).

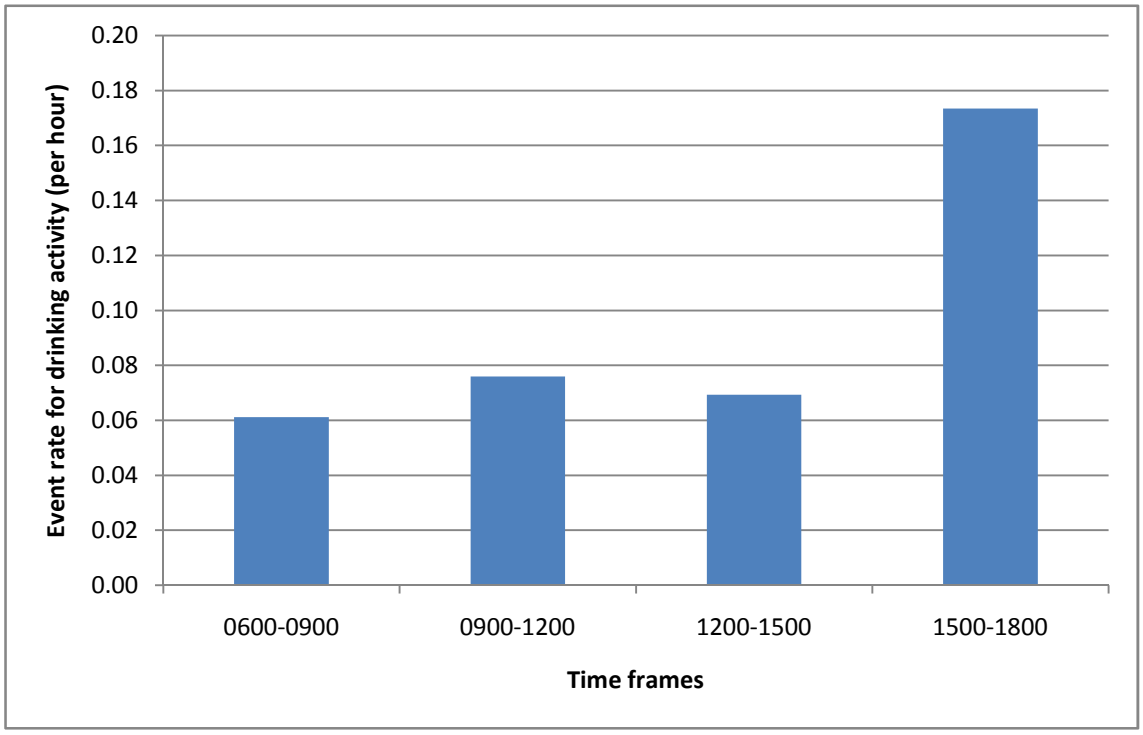


3.4.4. Other activities of gaur

Drinking

During the study period, the records of drinking activity for gaur were grouped into four time frames covering the entire day (0600-0900, 0900-1200, 1200-1500 and 1500-1800 hrs). Gaur were observed to drink water in all the four time frames of the day. A total of 37 instances of gaur drinking water were recorded during the study period. Event rate of the drinking activity was found to be highest in the time frame of 1500-1800 hrs (0.17/hr) and lowest in the time frame of 0600-0900 hrs (0.06/hr). The event rate of drinking activity is given in figure 3.83.

Figure 3.83: Event rate of drinking activity of gaur in different time frames of the day during the study period in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Leadership

Leadership among gaur individuals was observed when a group of gaur started moving from one place to another in a single file. During such travels an individual gaur would take up the lead position and it would be followed by the rest of the members of the group. During the study period 45 instances of leadership among gaur were recorded (table 3.8).

Table 3.8: Percentage frequency of leadership while moving among different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Age and sex class of gaur	Percentage frequency of leadership
Adult cow	91.1
Sub-adult cow	2.2
Sub-adult bull	2.2
Brown bull	4.4

(n=45)

The percentage frequency of leadership among different age and sex classes of gaur was found to be highest for adult cow (91.1%). The other age and sex classes of gaur which exhibited leadership were sub-adult cow (2.2%), sub-adult bull (2.2%) and brown bull (4.4%).

Vocalisation

During the study period four types of vocalisation were identified for gaur. These were communication calls, alarm calls, rutting calls and threatening vocalisation. The communication calls were heard mostly when the members of a group were

separated or a cow was separated from its calf. They usually sounded like a long, “moooo”. The alarm calls were made to alert all the members of the group about some perceived danger and sounded as a loud “Phooong”. The threatening vocalisation was a loud grunting noise made by gaur to threaten predators. These were made by assuming an alert position, the head held up facing in the direction of the predator and a grunting noise was made through the mouth and nostrils along with spray flying out from the mouth and nostrils. Black bulls and brown bulls were observed to make rutting calls which were a form of display of sexual behaviour. During the study period a total of 86 instances of gaur vocalisations were recorded (table 3.9).

Table 3.9: Details of the types of vocalisation recorded for different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Age and sex class of gaur	Types of vocalisations			
	Communication	Alarm	Rutting	Threatening
Adult cow	40	5	0	10
Sub-adult cow	11	0	0	0
Calf	6	0	0	0
Brown bull	3	0	2	0
Black bull	4	2	3	0

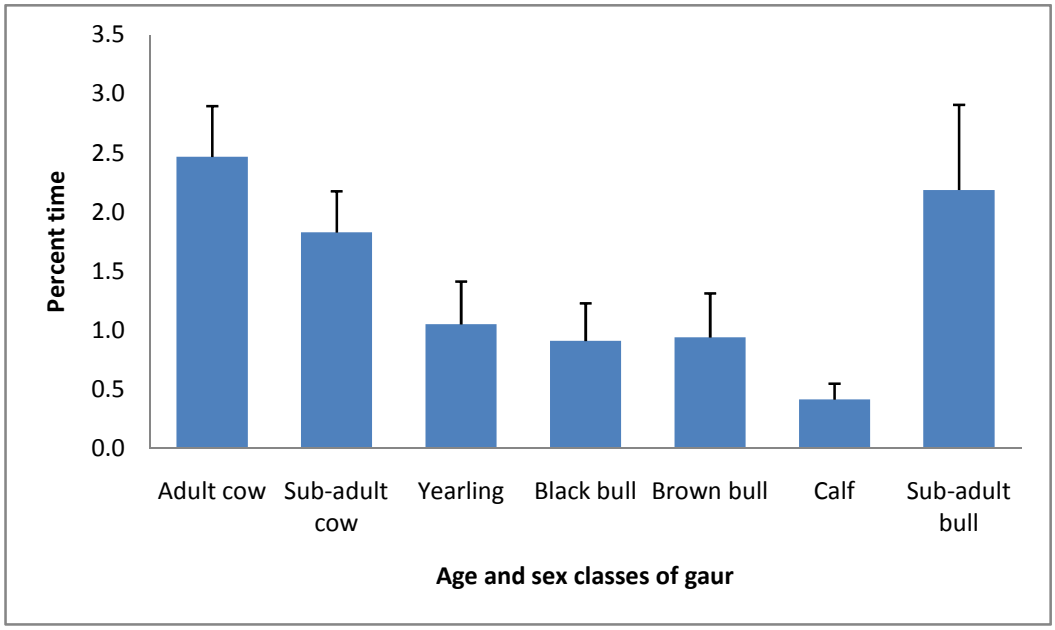
(n=86)

It was observed that among the different age and sex classes of gaur adult cow had the most number of records for communication calls (n=40), alarm calls (n=5) and threatening vocalisation (n=10). Rutting calls were only recorded for black bulls (n=3) and brown bulls (n=2).

Alert behaviour and response to predators

Whenever gaur were alerted they assumed the alert posture in which the animal faced a particular direction with its head raised above the shoulder height, its ears raised and it watched intently without any movement. The time spent in alert behaviour annually by each age and sex class of gaur was estimated through the scan records collected through scan sampling (fig. 3.84).

Figure 3.84: Percentage time spent annually in alert behaviour by different age and sex classes of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The percent time spent in alert behaviour was found to be highest for adult cow (2.5%) followed by sub-adult bull (2.2%) and sub-adult cow (1.8%). The difference in the time spent in alert behaviour annually by different age and sex classes of gaur was found to be significant (K.W: $\chi^2 = 42.380$, $p<0.05$).

3.5: DISCUSSION

The annual and seasonal activity budgets of gaur in general and all the age and sex classes of gaur in particular showed that the major activity of gaur in Bandhavgarh was feeding followed by moving and resting. Similar findings were reported by Vairavel (1998) and Gad (2011) for gaur from Parambikulam Tiger Reserve and Bhagwan Mahaveer Wildlife Sanctuary respectively. Temperature and food density are important factors which influence the activity budget and activity pattern of any animal (Vairavel 1998). The seasonal activity budgets for different age and sex classes of gaur showed that the time spent in activities like feeding, moving and resting had a similar pattern for most of the age and sex classes of gaur. Time spent in feeding did not differ much for summer and winter but it showed a significant decline in monsoon for all the age and sex classes of gaur. The reason for this pattern could be an increased availability of forage of higher nutritional value in monsoon as compared to summer and winter in the study area of Bandhavgarh Tiger Reserve. The time spent in moving was observed to be considerably low in summer as compared to monsoon and winter for all age and sex classes of gaur. The reason for this behavioural pattern might be that in summer the food resources of gaur (grasses and bamboo leaves) are more confined on a spatial scale as compared to monsoon and winter in the study area. Hence, probably the gaur remain confined to particular feeding areas for a longer time in summer as compared to monsoon and winter resulting in less time spent moving in summer.

The seasonal activity budgets for all the age and sex classes of gaur showed that the time spent resting was highest in summer followed by monsoon but was significantly low in winter. The mean monthly temperature in winter ranged from

10.2˚C to 19.1˚C which was considerably lower than that in summer (range: 27˚C – 43.8˚C) and monsoon (range: 23.8˚C – 33.3˚C) which probably resulted in gaur spending overall less time resting in winter. Annually and seasonally only the time spent for feeding showed significant difference (figure 3.32 and table 3.2) among different age and sex classes as the energy requirements of each age and sex class differ. Annually, highest time spent feeding was observed for sub-adult gaur (cows and bulls) and adult cow. The reason for adult bulls (black and brown bulls) spending less time for feeding as compared to adult cow and sub-adults may be that when in a group adult bulls spend a considerable time in searching for and tending to cows in oestrus.

The annual activity patterns and the seasonal activity patterns for all the age and sex classes of gaur and for gaur in general showed that feeding activity peaked in the early morning and late afternoon-evening hours whereas the resting activity was most prominent during the mid-day hours. Similar activity pattern for gaur was reported from Mudumalai, Parambikulam and Pench Tiger Reserves and Bhagwan Mahaveer Wildlife Sanctuary (Krishnan 1972, Vairavel 1998, Sankar *et al*. 2001 and Gad 2011). Also a similar activity pattern was reported by Lad and Gopal (1992) for the small gaur population in Bandhavgarh prior to its extinction. On many occasions it was observed that while feeding, gaur gradually moved to a water source or to a resting site in Bandhavgarh during the study period. Gaur were observed to move the most in the early morning time frame in Bandhavgarh (0600-0800 hrs). The time spent resting in the mid-day hours was observed to be considerably lower for gaur in winter compared to summer and monsoon which can be attributed to the lower temperatures prevalent in winter (range: 19.1˚C-10.2˚C) as compared to summer

(range: 27.2˚C-43.8˚C) and monsoon (range: 23.8˚C-33.3˚C). Overall the observations on activity pattern indicated synchronisation of the annual activity pattern for feeding, moving and resting among different age and sex classes of gaur in Bandhavgarh. Synchronisation in the activity pattern of gaur has also been reported by Vairavel (1998) in Parambikulam. Apart from gaur, synchronisation in activity pattern has been reported for the American bison, reindeer, lesser kudu, generuck and giraffe and European bison (Shult 1972, Gaare *et al*. 1975, Mitchell 1977, Leuthold and Leuthold 1978 and Cabon-Raczynska *et al*. 1983).

Gaur is a group living animal and many different types of social interactions are observed among the members of a gaur herd (Sankar *et. al* 2001). In the present study the social interactions observed among gaur individuals were classified as allogrooming, dominance-subordination interactions, and sexual behaviour.

Among gaur, allogrooming is an interaction which probably strengths social bonding, asserts hierarchical status and minimizes aggression (Sankar *et al*. 2001). In the present study it was observed that adult cows, sub-adult cows and calves were the age and sex classes which were involved the most in allogrooming interactions. Schaller (1967) and Sankar *et al*. (2001) also reported a high participation of adult cows in the allogrooming behaviour in Kanha and Pench Tiger Reserves respectively. Most of the allogrooming interactions initiated by adult cow, sub-adult cow and yearling were directed towards calf. Adult cows and sub-adult cows also directed considerable number of allogrooming interactions towards their own age and sex class. Calves groomed adult cow the most followed by their own age class. Black bull, brown bull and sub-adult bull directed majority of their allogrooming

interactions towards adult cow. Schaller (1967) reported an increase in the allogrooming behaviour of bulls towards cows during courtship. In the present study, of the 41 allogrooming interactions of bulls (black, brown and sub-adult) directed towards cows (adult and sub-adult), nine were accompanied with the display of sexual behaviour.

Various displays and forms of aggressive behaviour are displayed by dominant individuals among a gaur herd to establish their dominance over subordinate individuals. In the present study these interactions were classified as chasing, threatening, head to head fighting and head butting behaviours. It was observed that adult cows were involved in most number of the dominance-subordination interactions (n=108) whereas the frequency for the display of threatening, head to head fighting and head butting behaviour was highest for black bull (figs. 3.78, 3.79 and 3.80) and that for chasing was observed to be highest for adult cow (fig. 3.77). In the case of adult cows, the majority of the dominance-subordination interactions in all the four categories were directed towards sub-adult cows. Among all the age and sex classes the threatening behaviour was mainly displayed by adult cow and black bull. Of the five instances of display of threatening behaviour by black bull towards other black and brown bulls, four were lateral displays and on one occasion the subordinate brown bull made bellowing vocalisation while moving away from the black bull. On 12 occasions it was observed that while a group of gaur was resting or feeding, the oldest black bull remained with the group whereas the subordinate black or brown bulls maintained a distance of about 50 to 350 metres from the group. Among bulls size plays an important role in determining the hierarchical status in a gaur herd. It was observed that individuals belonging to the

subordinate age classes like the sub-adults (cow and bull), yearling and calves were mostly engaged in the head to head fighting behaviour as compared to the other types of rank indicating gestures. Schaller (1967) reported similar types of rank indicating gestures displayed by gaur in Kanha. Also similar types of rank indicating gestures were observed for American bison by Reinhardt (1985).

In the present study, activities grouped under sexual behaviour were flehmen, tending, mounting and rutting calls. It was observed that flehmen was the most common sexual behaviour displayed by gaur bulls followed by mounting. Rutting calls were made only by black and brown bulls. It was observed that black bulls engaged the most in the display of sexual behaviour as compared to brown bulls and sub-adult bulls. Black bulls exhibiting higher sexual activity as compared to brown bulls and sub-adult bulls has also been reported for gaur in Kanha and Pench (Schaller 1967 and Sankar *et al*. 2001). Gaur exhibit life-history traits of the slow pattern which are similar to other Bovini species (Ahrestani *et al*. 2011). The life-history theory predicts an increase in reproductive effort with the increase in age (Williams 1966, Pianka and Parker 1975 and Caswell 1982) and this seems to be true for gaur bulls. Maher and Byers (1987) have also reported a similar sexual behaviour pattern in American bison bulls. The display of sexual behaviour occurred in all the seasons but the frequency of the displays of sexual behaviour increased in summer and was the lowest in monsoon. Sankar *et al*. (2001) also reported an increase in the frequency of sexual behaviour among gaur bulls during summer in Pench Tiger Reserve.

Gaur is known to be an obligate drinker and needs water every day (Sankar *et al*. 2001). In the present study gaur were observed to drink water in all the time frames of the day (0600-0900, 0900-1200, 1200-1500 and 1500-1800 hrs) but the event rate of drinking activity was found to be highest in the late afternoon to evening hours (1500-1800 hrs). In Pench, gaur were observed to drink water mostly during the dawn and dusk hours (Sankar *et al*. 2001) but in Parambikulam the drinking activity of gaur was reported only in the noon hours (Vairavel 1998). Gad (2011) also reported the occurrence of drinking activity by gaur in Bhagwan Mahaveer Wildlife Sanctuary mainly in the early morning and late evening hours.

Leadership among gaur was evident only during the movement of a group of gaur from one place to another. Mostly an adult cow was observed leading the group. The two instances in which brown bulls lead the group, the group was a bachelor herd (comprising of males only). Black bulls were never seen leading groups. The high percentage of adult cow leading a group has also been reported from Kanha and Pench (Schaller 1967 and Sankar *et al*. 2001) Of the 45 instances of leadership that were observed during the study period, on 23 occasions the group consisted of at least one adult bull (brown or black bull) and of these 23 instances it was observed that in 17 instances the adult bull was the last member in the moving file of the gaur individuals. Schaller (1967) also reported similar findings in Kanha Tiger Reserve. This behaviour has also been reported in the African buffalo (Prins 1996).

In the present study, the different vocalisations of gaur were classified as communication calls, alarm calls, rutting calls and threatening vocalisation. It was evident that of the different types of vocalisation, communication calls were the

most prominent vocalisation made by gaur during the present study. During the study period it was observed that when a calf was killed by a tiger the mother cow called incessantly (communication call) for 2-3 days in succession. Communication calls were mostly made by adult cows followed by sub-adult cows. It was observed that threatening vocalisations were made only by adult cows when a tiger came very close to the gaur herd. In the present study only adult cows and black bulls were observed making alarm calls. Similar vocalisations have been reported for gaur in Kanha Tiger Reserve and Bhagwan Mahaveer Wildlife Sanctuary (Schaller 1967 and Gad 2011).

In Bandhavgarh, mostly gaur were observed to assume an alert posture whenever deer or langur alarm calls were heard, when a predator (tiger or leopard) came near to a group and when human beings approached a gaur group on foot. In the present study it was observed that adult cow spent most time in alert behaviour followed by sub-adult bull and sub-adult cow. The time spent in alert behaviour was found to be lowest for calf. Adult cows had to care for their calves which might be the reason for more time spent in alert behaviour by adult cow as compared to other age and sex classes of gaur in the present study. Also mostly adult cows lead a group and while leading a group the individual leading was observed to be more alert than others which could explain the observed high time spent in alert behaviour for adult cow in the present study. After adult cow, the age class with more time spent in alert behaviour was the sub-adult age class. The reason for this pattern might be that most of the rank indicating gestures were directed by the adult gaur towards sub-adult individuals and hence they may need to be more alert than the other age classes. The other reason could be that sub-adults were more vulnerable to predation and hence

were more alert. Yearlings and calves are also vulnerable to predation but since these individuals tend to stay close to the mother cow they probably spent less time in alert behaviour. In Bandhavgarh the potential predators of gaur are tiger, leopard and wild dogs. During the study period 10 interactions of gaur and tiger were observed where the tiger had come within 50 feet distance of the gaur herd. During these interactions, adult cows made threatening vocalisations and on two occasions a black bull chased away the tiger. Once a leopard was observed within 30 feet of a group of gaur. During this interaction the gaur did not make any threatening vocalisation but showed only an alert posture till the leopard passed out of sight.

Chapter IV

Food habits of reintroduced gaur

CHAPTER IV: FOOD HABITS OF REINTRODUCED GAUR

4.1: INTRODUCTION

The study of food habits of any wild animal species is of considerable importance since it gives an insight into the food preferences and feeding strategies of the species. Riney (1982) has discussed the relevance of food habits studies of large mammals in making management decisions. The study of food habits of reintroduced species may lead to valuable conservation implications. The problems that herbivores face in contrast to omnivores and carnivores are the availability and the physical and chemical characteristics of their diets. The food resources of herbivores vary between different habitat types and also show marked seasonal variations within a given habitat in response to changes in rainfall patterns (Philipson 1975, Sinclair 1975). The feeding habits of ungulates are influenced by the seasonal and spatial differences between plant communities in species composition, production, food quality and quantity (Jarman and Sinclair 1979). The 'Jarman-Bell Principle', as labelled by Geist (1974) states that large bodied ungulates are able to tolerate a lower quality diet as compared to smaller bodied species. Thus large herbivores can subsist on bulk and coarser diets as compared to smaller species. Small bodied animals, as a result of the maintenance of their body weight, require an intake of diet with higher proportions of protein and soluble carbohydrates at the expense of fibre (Bell 1971).

For large herbivores, Owen-Smith (1988) has characterised the dietary intake in terms of (i) the plant species eaten, (ii) the plant parts ingested, or (iii) the nutrient

contents of the ingested material. Rodgers (1988) identified four kinds of herbivore responses to utilization constraints posed by food resources:

1. Herbivores could grow in body size to levels where they become huge mobile fermentation chambers dependent on bulk input of a low quality fibrous diet. Large body size also means energetic considerations require a low input of energy and protein per unit body weight (Robbins 1983, Hudson and White 1984). Large size not only allows animals to use tall coarse grasses, but also to modify grassland structure by trampling and feeding and thus, in most situations, stimulate production of nutrient fresh shoots.

2. Herbivores could become smaller in size with very selective feeding habits and adaptations to allow greater diet selection.

3. Herbivores could migrate to areas of different levels and timing of grassland production and

4. Herbivores could become generalists or opportunists and switch diets away from grasses when nutrient production and accessibility becomes limiting. Herbivores would then change to higher quality browse items i.e. dicot leaf, stem, bark, flower and fruit.

Herbivore food choice is influenced by nutritional and non-nutritional factors. Nutritional factors include positive nutrients such as calories, non-structural carbohydrates, protein, fat and minerals such as calcium and sodium and negative nutrients such as digestibility reducers (fibers and tannins) and toxins (alkaloids and terpenes) (Freeland and Janzen 1974, Westoby 1978, Rosenthal and Janzen 1979).

Studies in rain forests of Africa, Central America and Asia (Hladik 1977, Glander 1978, Milton 1979, Oates *et al*. 1980, Davies *et al*. 1988) have shown that the crude protein content is a good predictor of food selection. The ratio of protein to fibre content has also been shown to be an important criteria for food selection (Jarman 1974, Leuthold 1970). Among digestibility reducers, fibre is a major deterrent of food selection for herbivores (Waterman 1983 and 1984). Among fibre, lignin is a primary factor causing decline in digestibility since it presents a physical barrier to digestive enzymes and also interferes with digestion by binding to the carbohydrate substrate and digestive enzymes in the gut (Waterman *et al*. 1980, Van Soest 1982). Tannins, a group of polyphenols (condensed tannins, total phenolics, oxytannins and prototannins), also act as digestibility reducers since they form insoluble complexes with proteins in food and with digestive enzymes, thereby preventing digestion (Swain 1979).

Food habits of the members belonging to the wild cattle group (cattle, buffalo, bison and saola) have been studied for bison (Reynolds *et al*. 1982, Bergman *et al*. 2001, Fortin *et al*. 2002, Courant and Fortin 2012), African buffalo (Sinclair 1977, Prins 1996), Asiatic wild water buffalo (Chaiyarat 2002), anoa (Pujaningsih *et al*. 2009), wild yak (Harris and Miller 1995, Cao *et al*. 2009), banteng (Halder 1976, Prayurasithi 1997, Pudyatmoko 2005, Bhumpakphan and McShea 2011) and gaur (Schaller 1967, Krishnan 1972, Moorthy 1989, Prabhakar 1992, Vairavel 1998, Sankar *et al*. 2001, Gad and Shyama 2009, Gad 2011, Ahrestani *et al*. 2012, Sankar *et al*. 2013). In the present study food habits of the reintroduced gaur population in Bandhavgarh Tiger Reserve were studied from March 2012 to February 2014.

4.2: METHODOLOGY

The data on the food plants and parts eaten by gaur was obtained from the scan sampling technique (Altman 1974) used for studying the behavioural patterns of gaur. Instantaneous scan samples were recorded at five-minute intervals and during the scans whenever an individual was observed feeding, the plant species and plant parts eaten by the individual was recorded. On such instances when the gaur being observed were far enough so as not to be able to identify the plant species being eaten, inspection of the feeding sites were made so as to identify the food plants after the gaur had left the site. Samples of the eaten food plant parts were collected for each season (summer, monsoon, winter) by hand clipping. These samples were sun dried and packed in paper bags in the field station and were later subjected to nutritional analysis in the laboratory at Wildlife Institute of India, Dehradun. Samples of a single item were pooled to obtain a single nutrient value for the item for each season. In the laboratory, the samples were kept in an oven at 60˚C for drying for a week. The oven-dried samples were finely ground in Cyclotech's grinding mill and kept in plastic bags for further analysis.

The samples of food plants of gaur collected from Bandhavgarh Tiger Reserve were analysed for the following positive and negative nutrients:

1. Positive nutrients - crude protein and minerals (Ca, Na, Mg, K, Fe, Zn).
2. Negative nutrients – fiber (neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin) and tannins.

Crude protein was estimated using Kjeldahl method (Maynard and Loosli 1969). The analysis of crude protein was done using the Auto Kjeldhal Nitrogen Analyzer (FOSS Analytical 2003a). The auto kjeldhal nitrogen analyzer consists of two

separate units, the block digester and the distillation, titration assembly. 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 was 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 (%) = Percent nitrogen

S = Volume of acid used against sample.

B = Volume of acid used against blank.

N = Normality of acid.

Therefore, Crude protein (CP) % = n X 6.25.

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

The fibre content in terms of neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin (acid detergent lignin) was estimated according to Van Soest's (1963 and 1967) method. The instrument, Fibre Analyzer (FOSS Analytical 2003b and 2003c) 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:

NDF or ADF (%) = $(W_3 – W_1)/W_2$ X 100

Where

W_1 = Empty crucible weight

W_2 = Sample weight

W_3 = Weight of crucible after extraction process

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:

Lignin (%) = $(W_5 – W_6)/W_2$ X 100

Where

W_5 = Weight after lignin extraction (crucible + lignin)

W_2 = Sample weight at ADF initiation

W_6 = Weight after ash (crucible + ash)

Condensed tannins present in food plants were analysed by vanillin assay using catechine as a standard (Hagerman 2002). Tannins with an acid-vanillin reagent form a red coloured complex, the absorbance of which can be measured in a spectrophotometer. 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 20 minutes (time taken for 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, 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.

Fresh dung samples of gaur were collected for each season (at least 50 samples per season). These samples were washed through a 0.1 mm mesh sieve under running water and were air dried and stored in paper bags in the field. In the laboratory the dung samples were ground over a 1mm mesh grinding machine and stored in plastic bags. For slide preparation of the fecal material the methodology described by Middleton and Sanchez (1994) was followed. To prepare slides a small amount of the fecal material was boiled on a microscope slide in a few drops of Hoyer's solution over a spirit lamp. The material was spread evenly. After that a few drops of Hertwig's mounting medium was placed on the material and it was boiled again and while the solution was still hot, a cover slip was placed on the material. Hoyer's solution clears the fecal material of pigments whereas Hertwig's solution acts as a mounting medium. Four slides were prepared from each dung sample. For the preparation of reference slides of the plant material of the major food plants of gaur, the plant samples were ground over a 1 mm mesh grinding machine and the same methodology described above for slide preparation was followed. The slides were then observed under a compound light microscope.

Phenological study of the major tree, shrub and grass species in the study area was carried out. For this purpose ten individuals of each selected tree, shrub and grass patch were tagged in the study area. The plant species that were selected for phenological studies were as follows: Trees- *Shorea robusta, Madhuca indica, Diospyros melanoxylon, Boswellia serrata, Chloroxylon swietenia, Anogeissus latifolia, Terminalia tomentosa, Zizyphus mauritiana, Buchanania lanzan, Phyllanthus emblica* and *Dendrocalamus strictus*; Shrubs- *Phoenix acaulis, Wrightia tinttoria and Woodfordia floribunda* and Grasses- *Aristida setacea,*

Saccharum spontaneum, Phragmites karka, Vetiveria zizanoides and *Imperata cylindrica*. Changes in the phenology of the marked trees and shrubs were quantified based on ocular estimation in terms of percentage availability of vegetative phases (young leaves, matured leaves, no leaves) and reproductive phases (buds, flower, young fruit and mature fruit) every fortnight (Borges 1989). Phenological data for the major grass communities (1 sq.m plots) was recorded in terms of percentage availability of vegetative phase (mature and young shoots), reproductive phase (flowering and seeding) and changes in the grass colour (green, green yellow, yellow, yellow brown, brown) every week.

A multispectral (LANDSAT 7 ETM+), high-resolution (30 m) satellite imagery from the Global Land Cover Facility (GLCF) was used to generate the landuse/landcover (LULC) map of the study area. For the quantification of vegetation (tree, shrub and ground layer) in Bandhavgarh Tiger Reserve (BTR) the digitized map of BTR was gridded (2 km X 2 km) in a GIS domain and systematic vegetation plots were laid in field for vegetation quantification. A ten metre radius plot was laid down to enumerate tree density, shrub density was enumerated in a five metre radius plot and the point intercept method (Jonasson 1988) was used to estimate the percentage ground cover (grass, herb, bare soil, leaf litter and rock) in 1 sq.m. plot. The abundance (density/cover) of the major food plants of gaur was estimated in each vegetation plot and this information was used to map their abundance and distribution on the BTR map in a GIS domain using the software ArcGIS 9.2 version (ESRI 2006).

The food plants of the captive elephants in Bandhavgarh Tiger Reserve were also recorded throughout the study period to get an understanding of the overlap between the food plants of gaur and elephant in the study area. The food plants of captive elephants were recorded through opportunistic sightings and by interviewing the Mahouts (elephant riders).

4.3: DATA ANALYSIS

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):

$P_i = (n_i / N) X 100$

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.

As rainfall and temperature has an effect on activity (Joshua 1992), the entire year was divided into three seasons *viz*. summer (March-June), monsoon (July-October) and winter (November-February). The percentage time spent feeding on different plant species and plant parts by gaur was estimated for each season. For the estimation of percentage time spent feeding on major food plants annually by gaur the feeding records obtained during the entire study period (six seasons) were pooled together. The statistical package SPSS was used for data analysis (Norusis 1993). The Kolmogorov-Smirnov test was used to test the data for normality (Siegel 1956) and since the data was found to be non-normal, non parametric tests such as Kruskal-Wallis and Mann-Whiteny were used to analyse the data (Siegel 1956). The

percentage time spent feeding on major food plants by gaur was tested for significant difference across the seasons.

It was hypothesized that food selection by gaur was related to the nutritional composition of the food items. Hence the time spent feeding was correlated with the values of the positive nutrients (crude protein and minerals), negative nutrients (NDF, ADF, lignin and tannins) and the ratio of crude protein to NDF, ADF and lignin for the three seasons. Since the data was non-normal Spearman's rank correlation (Siegel 1956) was used as the correlation test.

The slides prepared from the dung samples of gaur were used to calculate the percentage frequency occurrence of monocot and dicot plant fragments (monocot : dicot ratio) in the gaur dung samples for each season. The sample slides were observed from left to right starting at the upper left hand corner under the 10X objective of the microscope. A field with at least 8 to 10 fragments was observed and the fragments were grouped into three categories *viz*. monocot, dicot and unknown. In this manner ten fields were observed on each slide. The reference slides prepared from the plant material of the major food plants of gaur were used to identify plant fragments with distinguishing characters (trichomes, cellular patterns) for each plant species and photographs were taken of such fragments. These photographs were used as a reference key for the identification of the plant fragments on the dung sample slides and the percentage frequency occurrence of the plant fragments of major food plants of gaur was calculated simultaneously with the monocot : dicot ratio for each season.

The percentage availability of different vegetative and reproductive phases of the plant species selected for phenological study was estimated for each season and the results were compared with the time spent feeding by gaur on these plant species in each season. The density of different tree and shrub species in the study area was estimated from the vegetation plot data. These density estimates were used to calculate the proportion of the major food plants (tree and shrub) of gaur in the study area. Also the proportion of ground cover constituting the food items of gaur (grasses and herbs) in the study area was estimated from the vegetation plot data. The proportion of the major food plants of gaur in the study area and the proportion time spent feeding by gaur on the major food plants was used to calculate the Ivlev's (1961) index of selectivity for different food items of gaur as follows:

IVI (Ivlev's index of selectivity) = U – A/U + A

Where,

U = Proportion of resource utilized.

A = Proportion of resource available.

A positive index indicated that a particular food item was used more than its availability whereas a negative index indicated that a particular food item was used less than its availability.

Compositional analysis (Aebischer *et al*. 1993) was also performed to determine the selection of the different food items by gaur in the different seasons. Compositional analysis was performed using the percentage time spent feeding on the major food items by different age and sex classes of gaur in different seasons and the percentage availability of these food items in different seasons. The Resource Selection program for Windows (RSW) (Leban 1999) was used to perform the compositional analysis.

4.4: RESULTS

4.4.1: Food plants of gaur

During the study period a total of 82 species of food plants belonging to 29 families were recorded. The food plants eaten by gaur were classified into five categories such as trees, shrubs, herbs, grasses and climbers. The 82 species of food plants recorded comprised of 34 tree species, 8 shrub species, 14 herb species, 23 grass species and 3 climber species (table 4.1). Season-wise a total of 52, 53 and 50 food plants were recorded for summer, monsoon and winter respectively.

Table 4.1: Food plants of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Sr. no.	Plant species (Trees)	Family	Parts eaten	Season
1	*Aegle marmelos*	Rutaceae	Le	S
2	*Albizzia procera*	Fabaceae	Le	M, W
3	*Anogeissus latifolia*	Combretaceae	Le	S, W
4	*Bauhinia Racemosa*	Fabaceae	Le	S
5	*Bauhinia veriegata*	Fabaceae	Le	S, W
6	*Boswellia serrata*	Burseraceae	Le	M, W
7	*Bridelia retusa*	Euphorbiaceae	Le	S, W
8	*Buchanania lanzan*	Anacardiaceae	Le	S, M, W
9	*Cassia fistula*	Fabaceae	Le	M, W
10	*Chloroxylon swietenia*	Meliaceae	Le, Fl	S, M, W
11	*Dalbergia paniculata*	Fabaceae	Le	S, W
12	*Dendrocalamus strictus*	Poaceae	Le, Sh	S, M, W
13	*Diospyros melanoxylon*	Ebenaceae	Le	S, M
14	*Ficus bengalensis*	Moraceae	Le	W
15	*Ficus hispida*	Moraceae	Le	S
16	*Ficus religiosa*	Moraceae	Le	W
17	*Flacourtia ramontchi*	Bixaceae	Le	S, M
18	*Grewia tiliifolia*	Tiliaceae	Le	S
19	*Lagerstroemia parviflora*	Lythraceae	Le	S
20	*lannea grandis*	Anacardiaceae	Le	S

21	*Madhuca indica*	Sapotaceae	Le, Fr, Fl	S, M, W
22	*Miliusa tomentosa*	Annonaceae	Le	S, W
23	*Mitragyna parviflora*	Rubiaceae	Le	S
24	*Phyllanthus emblica*	Euphorbiaceae	Le, Fr	S, M, W
25	*Randia uliginosa*	Rubiaceae	Le	W
26	*Semecarpus anacardium*	Anacardiaceae	Le	S, W
27	*Shorea robusta*	Dipterocarpaceae	Le, Flb, Fl	S, M, W
28	*Syzygium cuminii*	Myrtaceae	Le, Fr	S, W
29	*Terminalia arjuna*	Combretaceae	Le	S
30	*Terminalia bellerica*	Combretaceae	Le, Fr	S, W
31	*Terminalia chebula*	Combretaceae	Le	W
32	*Terminalia tomentosa*	Combretaceae	Le	S, M
33	*Ziziphus mauritiana*	Rhamnaceae	Le, Fr	S, M, W
34	*Ziziphus xylopyra*	Rhamnaceae	Le, Fr	S, W
	Plant species (Shrubs)			
35	*Gloriosa sps*	Colchicaceae	Le	M, W
36	*Holarrhena antidysenterica*	Apocynaceae	Le	W
37	*Lantana camara*	Verbinaceae	Le	S, M
38	*Mimosa hamata*	Fabaceae	Le	M
39	*Phoenix acaulis*	Arecaceae	Le	S, M, W
40	*Randia dumetorum*	Rubiaceae	Le	S
41	*Woodfordia floribunda*	Lythraceae	Le	S, M, W
42	*Wrightia tinttoria*	Apocynaceae	Le	M, W
	Plant species (Herbs)			
43	*Eranthemum purpurascens*	Acanthaceae	Sh	S, W
44	*Anthraxon spp.*	Poaceae	Sh	M
45	*Asparagas racemosus*	Asparagaceae	Sh	S,M
46	*Bulbostylis barbata*	Cyperaceae	Sh	M, W
47	*Cassia tora*	Fabaceae	Sh	S, M
48	*Desmodium heterocarpus*	Fabaceae	Sh	M
49	*Desmodium pulchellum*	Fabaceae	Sh	M, W
50	*Euphorbia hirta*	Euphorbiaceae	Sh	M
51	*Leucas aspera*	Lamiaceae	Sh	M
52	*Leucas biflora*	Lamiaceae	Sh	M
53	*Ocimum tenuiflorum*	Lamiaceae	Sh	M
54	*Oplismenus spp.*	Poaceae	Sh	M, W
55	*Achyranthes aspera*	Amaranthaceae	Sh	M, W
56	*Sida spp.*	Malvaceae	Sh	S, M, W
	Plant species (Grasses)			
57	*Aristida setacea*	Poaceae	Sh	S, M, W
58	*Andropogon spp.*	Poaceae	Sh	M

59	*Apluda mutica*	Poaceae	Sh	S
60	*Bothriochloa spp*	Poaceae	Sh	S, M, W
61	*Chloris dolichostachya*	Poaceae	Sh	S, M, W
62	*Cynodon dactylon*	Poaceae	Sh	S, M, W
63	*Cyperus spp.*	Cyperaceae	Sh	S, M
64	*Dicanthium sps.*	Poaceae	Sh	S
65	*Digitaria spp.*	Poaceae	Sh	M
66	*Eragrostis spp.*	Poaceae	Sh	S, M, W
67	*Heteropogon contortus*	Poaceae	Sh	S, M, W
68	*Imperata cylindrica*	Poaceae	Sh	S, M
69	*Lipocarpha chinensis*	Cyperaceae	Sh	M
70	*Paspalidium flavidum*	Poaceae	Sh	M
71	*Phragmites karka*	Poaceae	Sh	S, M, W
72	*Saccharum spontaneum*	Poaceae	Sh	S, M, W
73	*Setaria glauca*	Poaceae	Sh	M
74	*Seteria pumila*	Poaceae	Sh	M
75	*Sorghum halepense*	Poaceae	Sh	S
76	*Sporobolous pulchelus*	Poaceae	Sh	W
77	*Themeda triandra*	Poaceae	Sh	S, M, W
78	*Thysanolaena maxima*	Poaceae	Sh	M
79	*Vetiveria zizanoides*	Poaceae	Sh	S, M, W
	Plant species (Climbers)			
80	*Butea superba*	Fabaceae	Le	S, M, W
81	*Bauhinia Vahilii*	Fabaceae	Le	S, M, W
82	*Ziziphus oenoplia*	Rhamnaceae	Le	W

Le- leaves, Flb- Floral bud, Fl- flower, Fr-fruit, Sh- shoot.

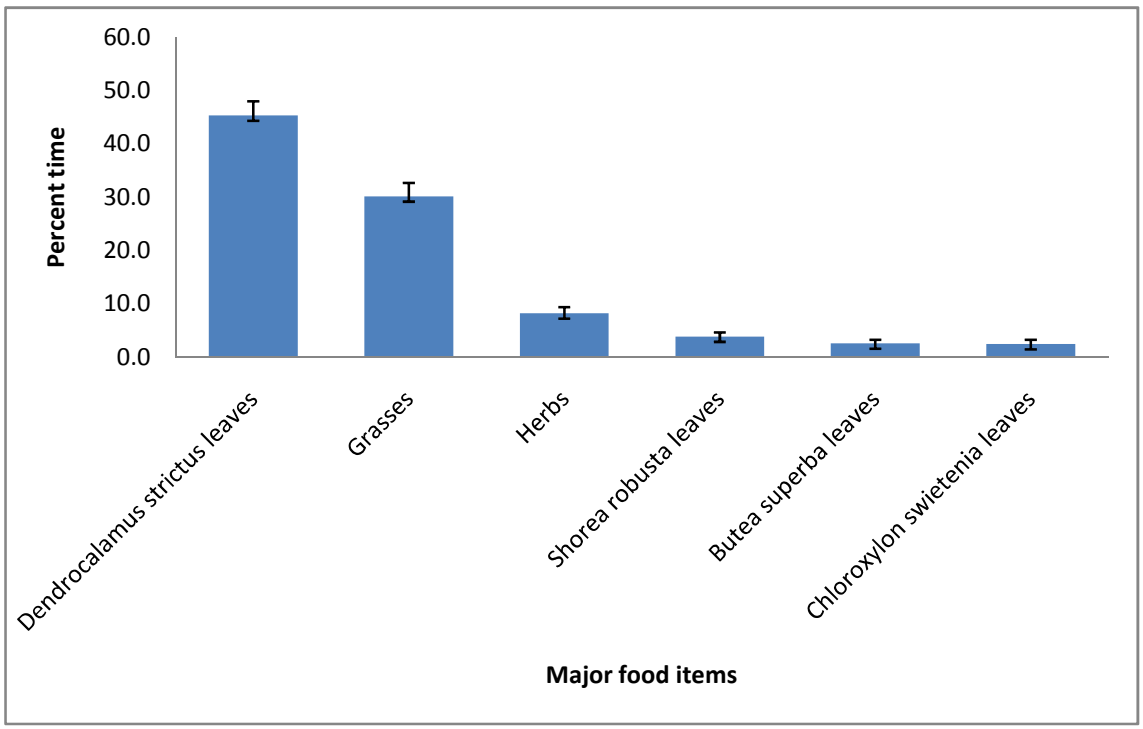
S-summer, M-monsoon, W-winter.

The different plant parts eaten by gaur were classified as leaf (for trees, shrubs and climbers), shoot (for grasses and herbs), floral bud, flower and fruit. Leaves and shoots comprised the major portion of gaur diet in the study area. Gaur were also observed to feed on the fruits of *Madhuca Indica*, *Phyllanthus emblica*, *Syzizium cuminii*, *Terminalia bellerica*, *Zizyphus mauritiana* and *Zizyphus xylopyra*. During the study period gaur were observed to feed on the floral buds of *Shorea robusta* and the flowers of *Shorea robusta*, *Madhuca Indica* and *Chloroxylon swietenia*.

4.4.2: Percentage time spent feeding by gaur on major food plants

A total of 6,724 feeding records were collected for gaur in Bandhavgarh Tiger Reserve during the study period through the scan sampling (Altman 1974) technique. Of the total feeding records, 2,946 were collected in summer, 1,957 in monsoon and 1,821 in winter. Overall, the major food items identified for gaur in Bandhavgarh Tiger Reserve based on the percent time spent feeding by gaur were bamboo leaves (*Dendrocalamus strictus* leaves), grasses, herbs, *Shorea robusta* leaves, *Butea superba* leaves (climber) and *Chloroxylon swietenia* leaves. Annually these food items combined to constitute about 93% of the total time spent feeding by gaur in the study area. It was observed that annually gaur spent the major portion of their time feeding on bamboo leaves and grasses (fig.4.1). Annually the time spent feeding on bamboo leaves was the highest (45.3%) followed by grasses (30.2%), herbs (8.3%), *Shorea robusta* leaves (3.9%), *Butea superba* leaves (2.6%) and *Chloroxylon swietenia* leaves (2.5%).

Figure 4.1: Percentage time spent feeding by gaur on major food items annually in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The different species of grasses and herbs that were mainly consumed by gaur in different seasons are given in tables 4.2, 4.3 and 4.4.

Table 4.2: Major grasses and herbs eaten by gaur in summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Grasses
Saccharum spontaneum
Vetiveria zizanoides
Phragmites karka
Herbs
Sida spp.

Table 4.3: Major grasses and herbs eaten by gaur in monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Grasses
Saccharum spontaneum
Vetiveria zizanoides
Phragmites karka
Aristida setacea
Andropogon spp.
Digitaria spp.
Heteropogon contortus
Herbs
Oplismenus spp.
Anthraxon spp.
Sida spp.

Table 4.4: Major grasses and herbs eaten by gaur in winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Grasses
Saccharum spontaneum
Vetiveria zizanoides
Phragmites karka
Heteropogon contortus
Bothriochloa spp
Herbs
Oplismenus spp.
Sida spp.

Based on the time spent feeding on different food items by gaur, the major food items identified for gaur in summer were grasses, bamboo leaves, young *Shorea robusta* leaves and herbs (fig.4.2). In summer, the percentage time spent feeding by gaur was highest for grasses (45.9%) followed by bamboo leaves (33.1%), young *Shorea robusta* leaves (7.8%) and herbs (5.0%). In monsoon, the major food items

identified for gaur were bamboo leaves, grasses, herbs, young bamboo shoots, *Butea superba* leaves and *Chloroxylon swietenia* leaves (fig.4.3). The percent time spent feeding by gaur in monsoon was observed to be highest for bamboo leaves (32.9%) followed by grasses (28.1%), herbs (19.7%), young bamboo shoots (9.1%), *Butea superba* leaves (3.4%) and *Chloroxylon swietenia* leaves (2.9%). For winter, the major food items identified for gaur were bamboo leaves, grasses, herbs, *Chloroxylon swietenia* leaves and *Butea superba* leaves (fig.4.4). In winter, the percent time spent feeding by gaur was highest for bamboo leaves (63.9%) followed by grasses (17.3%), herbs (4.4%), *Chloroxylon swietenia* leaves (3.7%) and *Butea superba* leaves (3.3%).

Figure 4.2: Percentage time spent feeding by gaur on major food items in summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

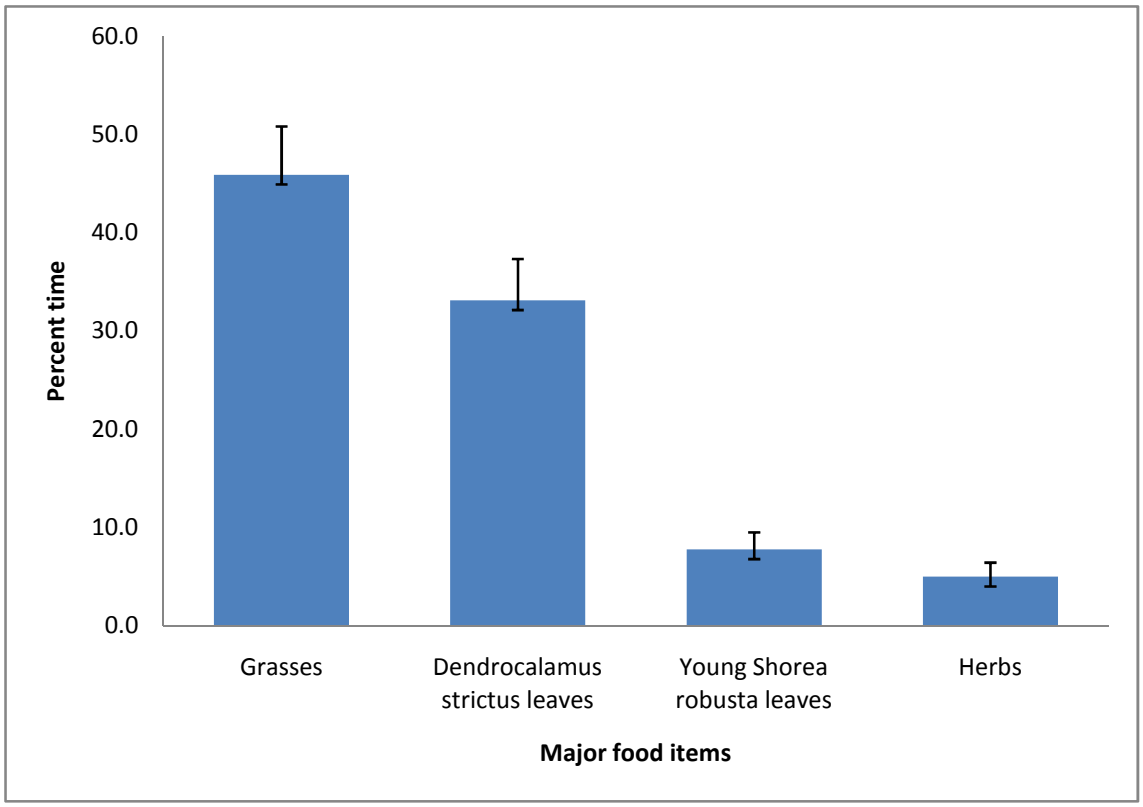


Figure 4.3: Percentage time spent feeding by gaur on major food items in monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

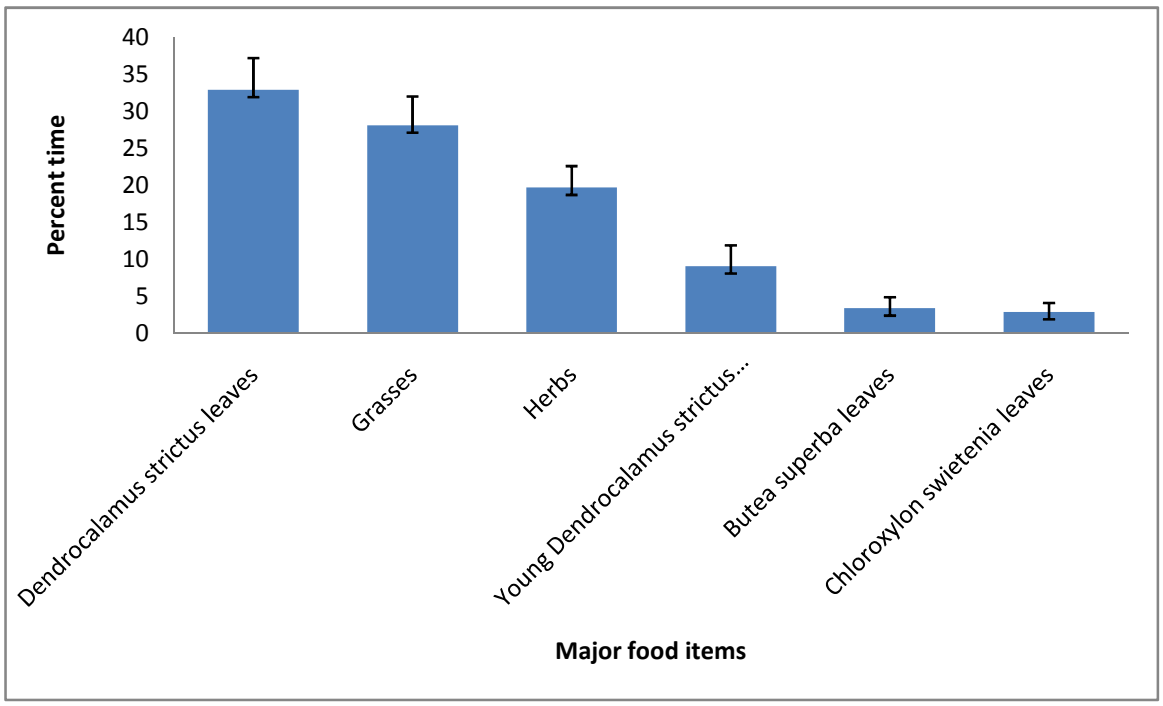
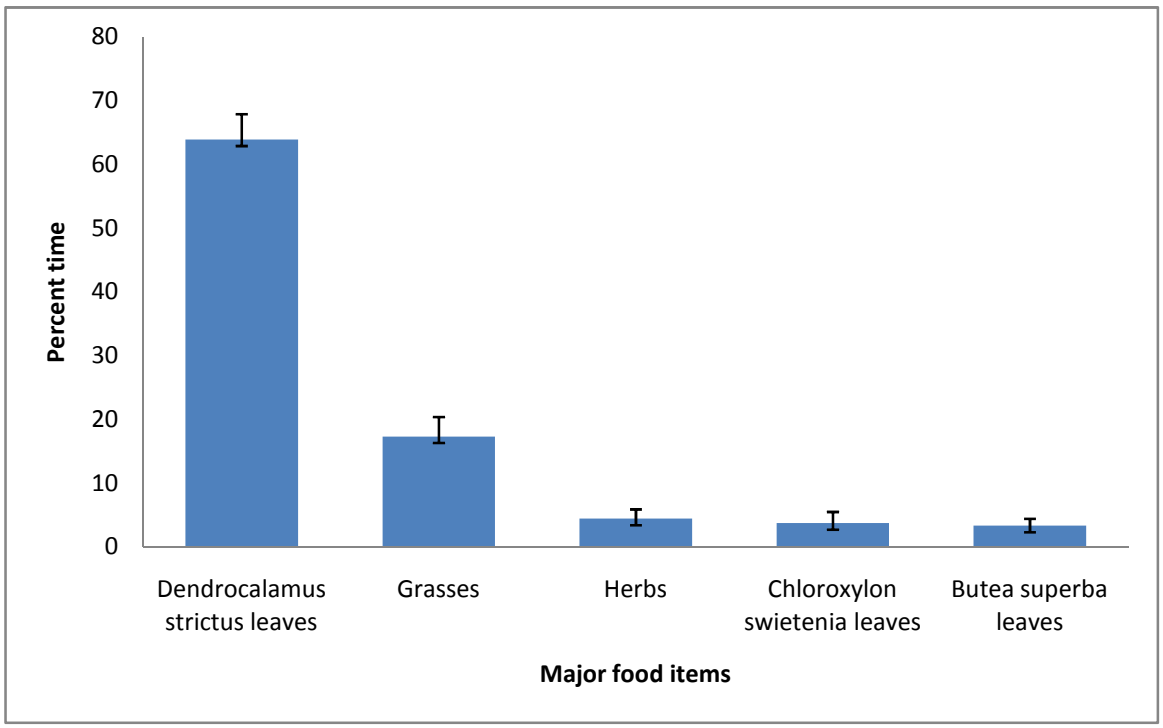


Figure 4.4: Percentage time spent feeding by gaur on major food items in winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).

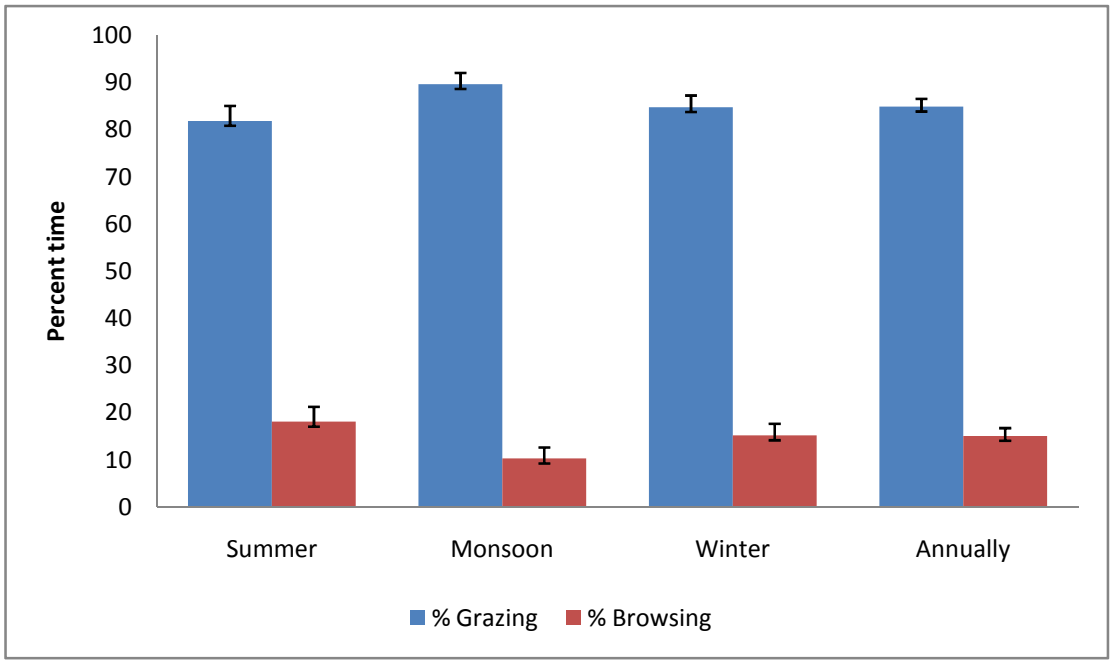


It was observed that bamboo leaves, grasses and herbs formed the major food items of gaur in all the seasons whereas *Shorea robusta* leaves were eaten by gaur mainly in summer and young bamboo shoots were consumed only in monsoon. *Butea superba* and *Chloroxylon swietenia* leaves were consumed by gaur mainly in monsoon and winter. The percentage time spent feeding by gaur on bamboo leaves differed significantly across the three seasons (Kruskal Wallis: $\chi^2 = 30.771$, $p<0.05$). Also, the percentage time spent feeding on bamboo leaves was seen to differ significantly between summer and winter (Mann Whitney: $Z = -4.802$, $p<0.05$) and monsoon and winter (M.W: $Z = -4.544$, $p<0.05$) but there was no significant difference between summer and monsoon. For grasses, the percentage time spent feeding by gaur differed significantly across the three seasons (K.W: $\chi^2 = 20.053$, $p<0.05$). Between two seasons, the percentage time spent feeding by gaur on grasses was found to differ significantly between summer and winter (M.W: $Z = -4.007$, $p<0.05$) and monsoon and winter (M.W: $Z = -3.336$, $p<0.05$). The percent time spent feeding by gaur on herbs was also found to differ significantly across the three seasons (K.W: $\chi^2 = 42.473$, $p<0.05$). Between two seasons, the percent time spent feeding on herbs was found to be significantly different between summer and monsoon (M.W: $Z = -5.409$, $p<0.05$) and monsoon and winter (M.W: $Z = -5.737$, $p<0.05$) but there was no significant difference in the time spent feeding on herbs between summer and winter. The difference in the time spent feeding by gaur on both, *Butea superba* leaves and *Chloroxylon swietenia* leaves between monsoon and winter was found to be non-significant.

The percentage time spent grazing and browsing by gaur in different seasons and annually is given in figure 4.5. The time spent grazing included the time spent

feeding by gaur on monocotyledonous plant items like bamboo leaves, young bamboo shoots, grasses and monocot herbs (mainly *Oplismenus* and *Anthraxon* spp) whereas time spent browsing included the time spent feeding by gaur on dicotyledonous plant items like leaves of trees, shrubs, climbers and dicot herbs (mainly *Sida* spp). Annually the percent time spent grazing by gaur was 84.9% whereas that spent browsing was 15.1%. The time spent grazing by gaur was observed to be highest in monsoon (89.7%) followed by winter (84.8%) and summer (81.9%) but the difference across the seasons was found to be non-significant (K.W. $\chi^2 = 2.439$, $p>0.05$). In summer gaur spent about 18.1% time browsing followed by winter (15.2%) and monsoon (10.3%) but the difference was found to be non-significant (K.W. $\chi^2 = 2.310$, $p>0.05$) across the seasons.

Figure 4.5: Percentage time spent by gaur in grazing and browsing in different seasons and annually in Bandhavgarh Tiger Reserve (March 2012-February 2014).



4.4.3: Nutritional contents of the food plants of gaur

During the study period a total of 68 food plant samples were analysed for nutritional contents. The results obtained for the nutritional analysis of the major food items of gaur in the different seasons are given below.

Crude protein

The crude protein content of major food items of gaur in different seasons is shown in figures 4.6 to 4.8. In summer the crude protein content was found to be highest in herbs (9%) whereas for monsoon and winter it was found to be the most in *Butea superba* leaves (11.6% and 6.9% respectively). For grasses the crude protein was observed to be highest in monsoon (3.2%) followed by summer (3%) and winter (2.3%). Bamboo leaves had higher crude protein content in monsoon (7.7%) as compared to winter (5.9%) and summer (5.7%). The crude protein in herbs was observed to be highest in summer (9%) and lowest in monsoon (4.2%). The young leaves of *Shorea robusta* in summer had higher crude protein content (6.2%) compared to the mature leaves of *Shorea robusta*, which had similar crude protein content in monsoon and winter (5.2%). The crude protein content for *Butea superba* leaves was observed to be highest in monsoon (11.6%) whereas for *Chloroxylon swietenia* leaves it was found to be highest in winter (4.8%).

Figure 4.6: Crude protein content of major food items of gaur in summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

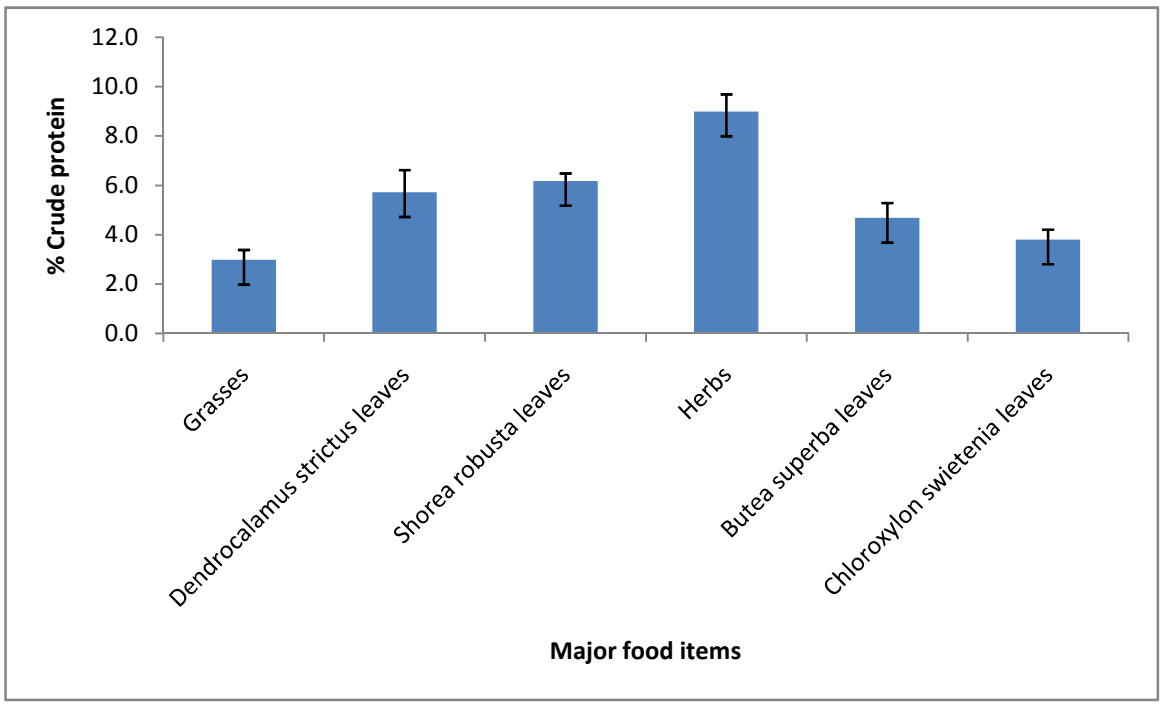


Figure 4.7: Crude protein content of major food items of gaur in monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

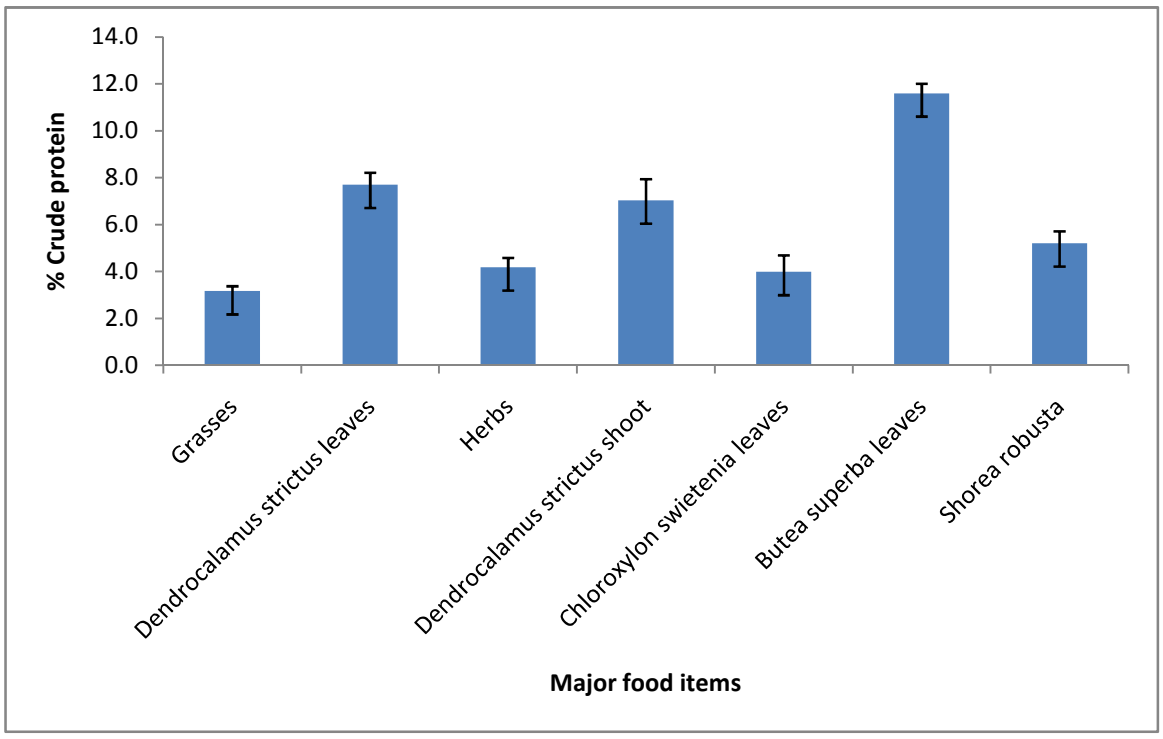
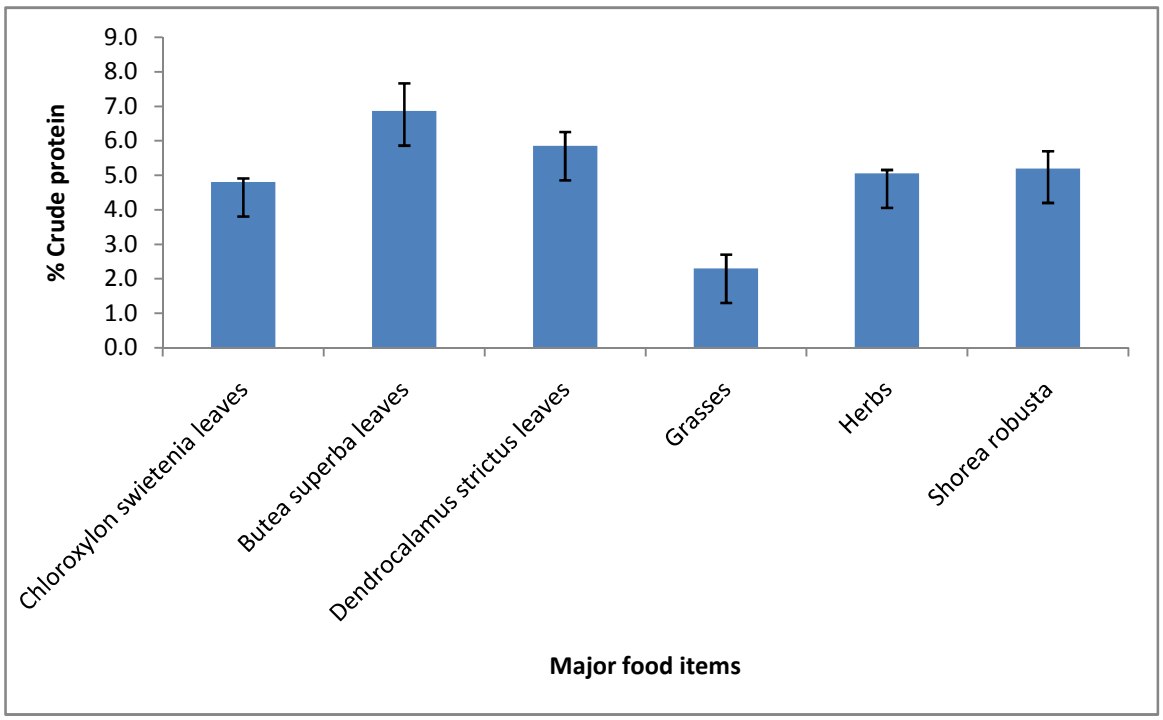


Figure 4.8: Crude protein content of major food items of gaur in winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Neutral detergent fibre (NDF) and Acid detergent fibre (ADF)

The NDF and ADF content of the major food items of gaur for the three seasons has been shown in figures 4.9, 4.10 and 4.11. The NDF content was observed to be highest for herbs (71.3%), young bamboo shoots (70.2%) and *Chloroxylon swietenia* leaves (69.7%) in summer, monsoon and winter respectively. In summer the ADF content was highest for *Chloroxylon swietenia* leaves (48.2%) whereas in monsoon and winter it was found to be highest for herbs (52.4% and 52.6% respectively). For grasses the NDF content was found to be highest in winter (62.5%) and the ADF content was highest in monsoon (46%). The NDF content in bamboo leaves was observed to be similar in all the seasons (range: 58-59) whereas the ADF content was observed to be highest in monsoon (48.2%) compared to the other two seasons.

For *Butea superba* leaves the NDF content was found to be highest in monsoon (62.4%) and the ADF content was highest in summer (45.7%).

Figure 4.9: NDF and ADF content of major food items of gaur in summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

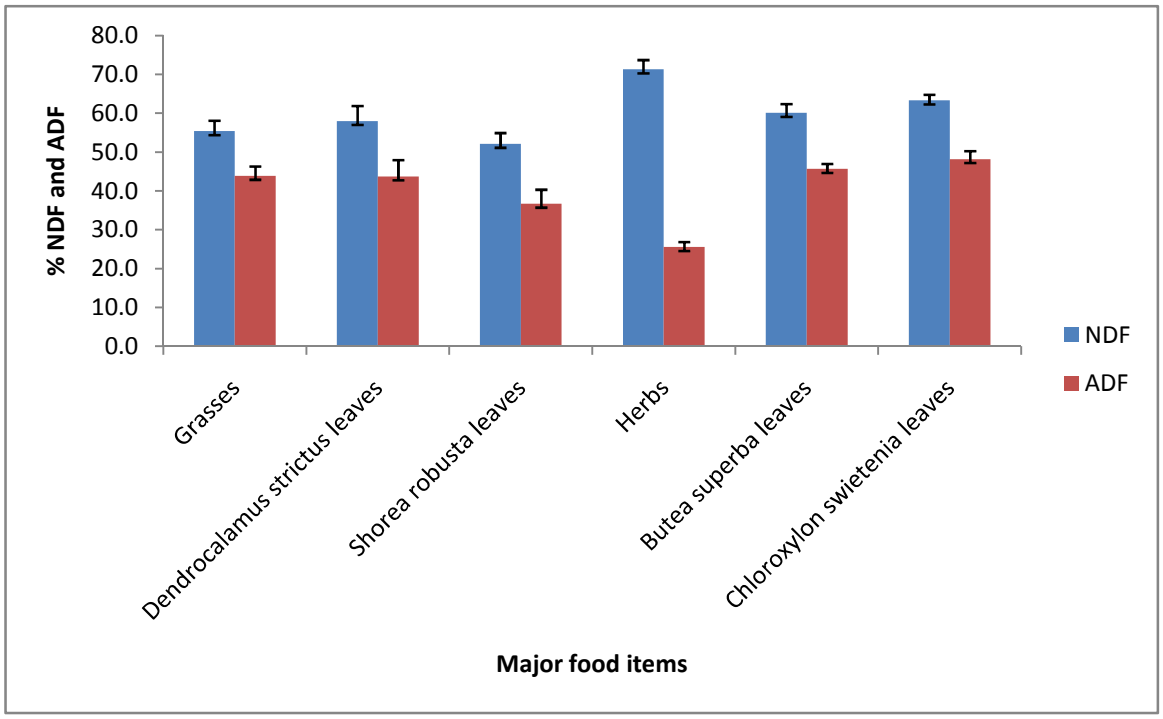


Figure 4.10: NDF and ADF content of major food items of gaur in monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

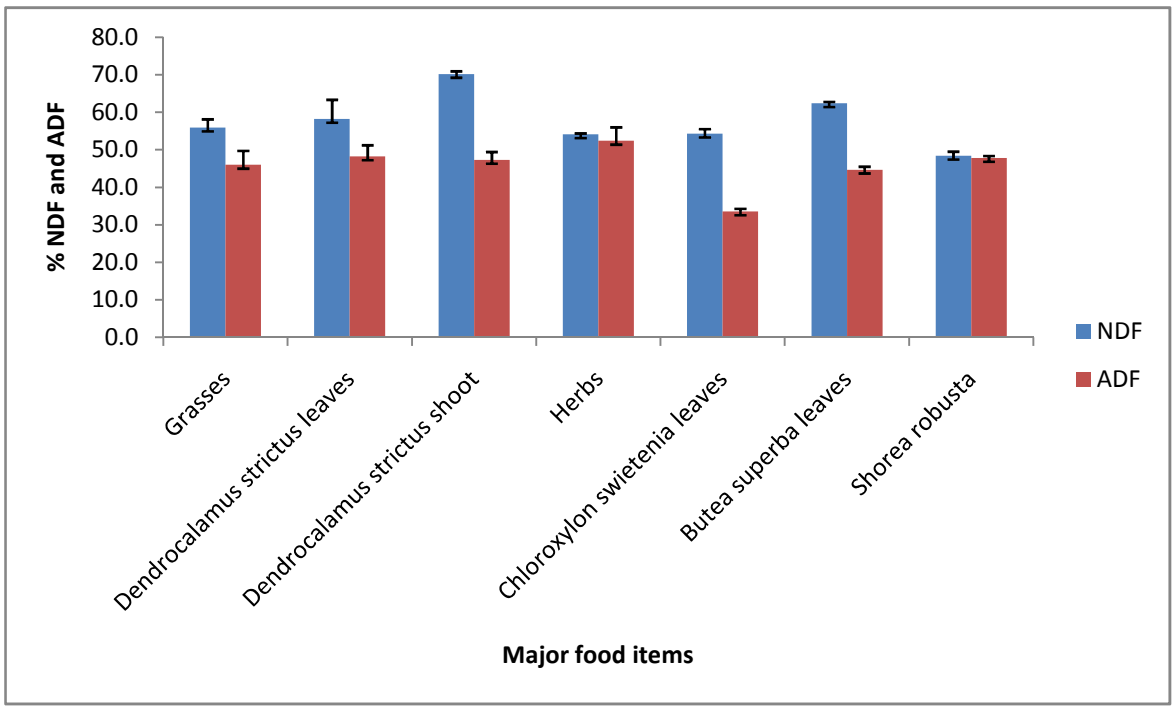
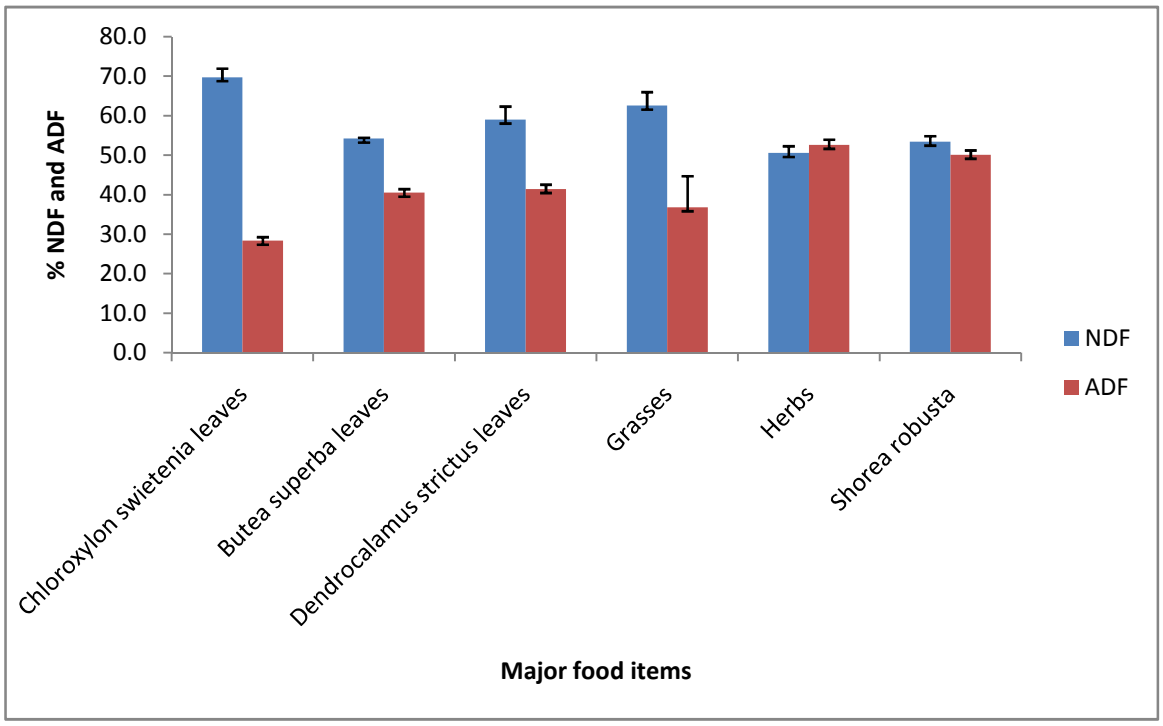


Figure 4.11: NDF and ADF content of major food items of gaur in winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Lignin

The lignin content in the major food items of gaur in different seasons is given in figures 4.12 to 4.14. In summer the lignin content was found to be highest in *Chloroxylon swietenia* leaves (14.2%) whereas it was lowest in grasses (11.7%). In monsoon and winter the lignin content was highest in *Shorea robusta* leaves (15.3% and 15.9% respectively) and was lowest in *Chloroxylon swietenia* leaves (5.3% and 9.4% respectively). Grasses showed higher lignin content in winter (13.2%) as compared to summer (11.7%) and monsoon (9.5%) whereas the lignin content in bamboo leaves was highest in summer (12.4%) and lowest in monsoon (8.9%). The lignin content in herbs was highest in monsoon (13.9%) as compared to summer and winter (12.6% and 11.9% respectively).

Figure 4.12: Lignin content in major food items of gaur in summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

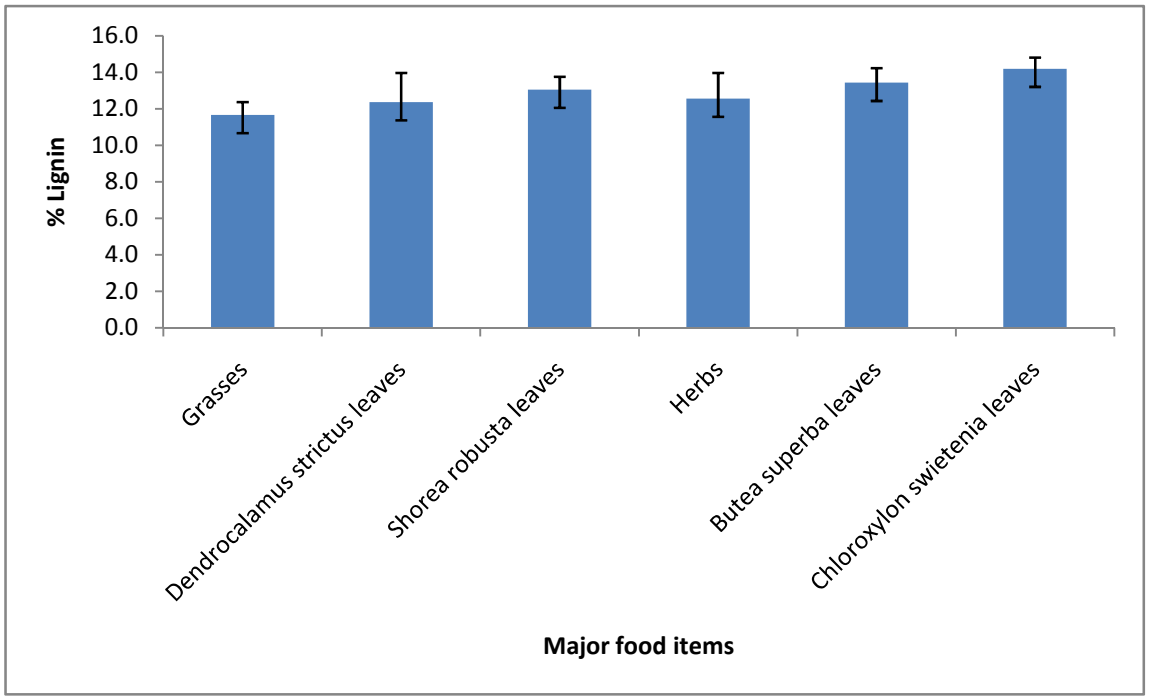


Figure 4.13: Lignin content in major food items of gaur in monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

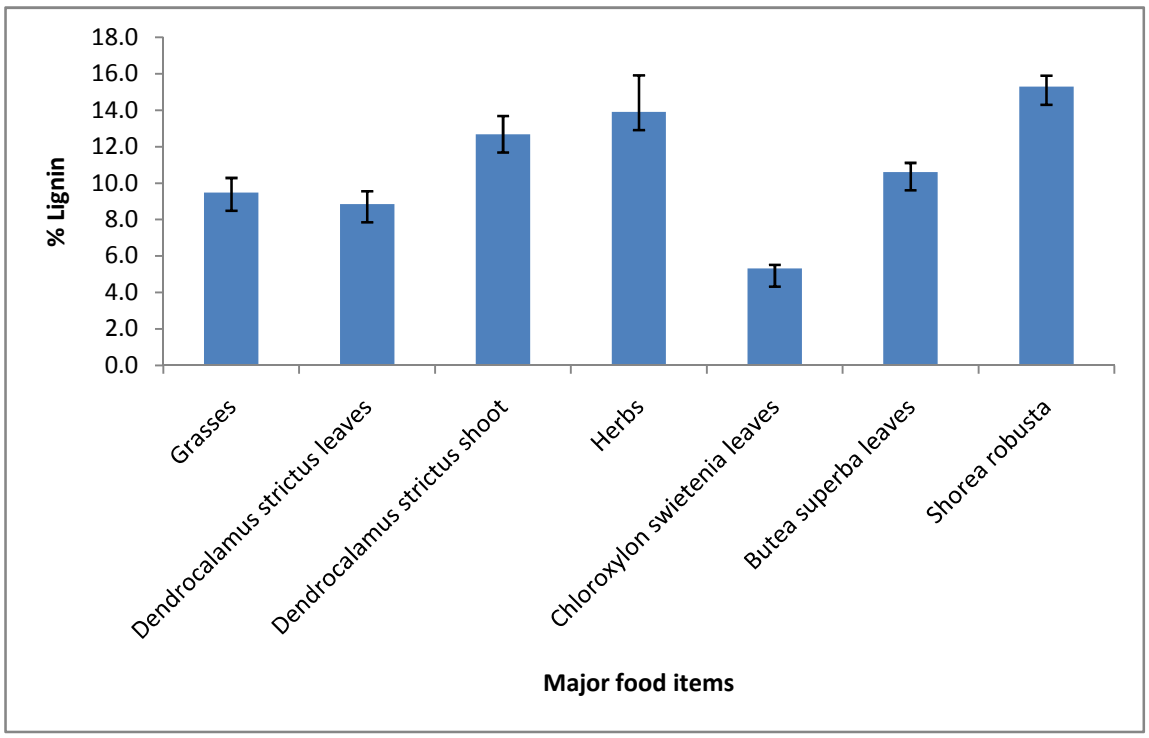
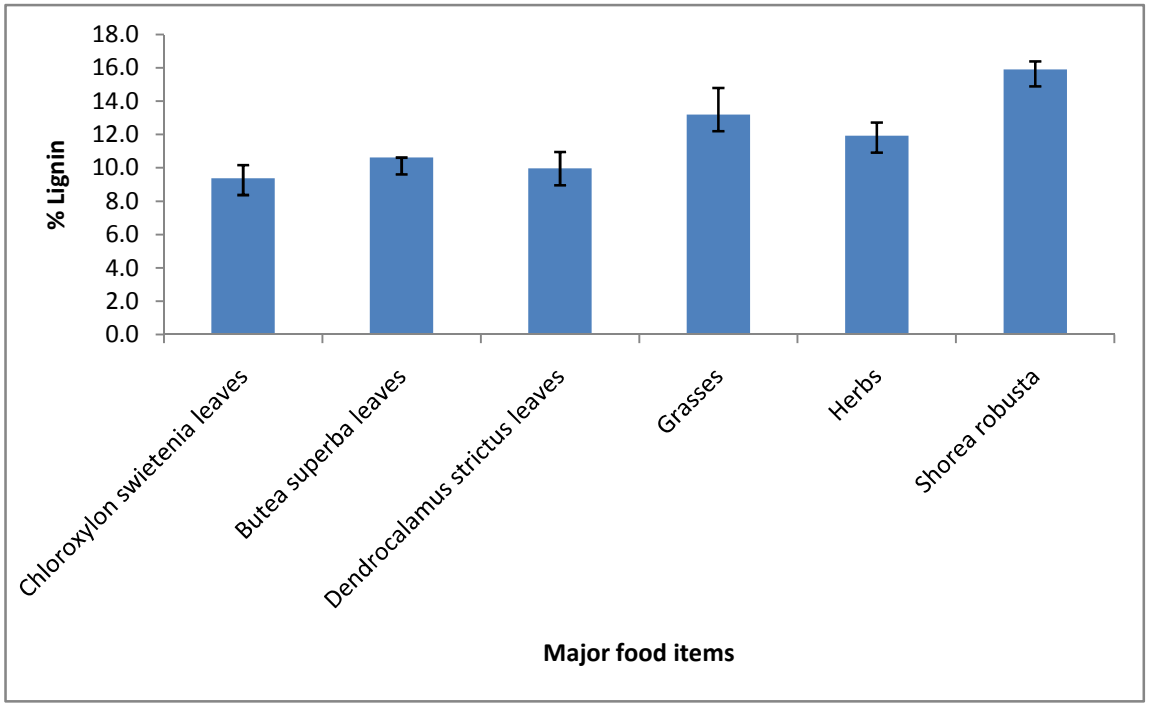


Figure 4.14: Lignin content in major food items of gaur in winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



Minerals

The mineral contents in the major food items of gaur for different seasons are given in tables 4.5 to 4.7. In summer herbs had the highest Potassium, Magnesium and Zinc content (1.71%, 0.53% and 0.0047% respectively). For summer the Sodium and Calcium content was found to be highest in *Chloroxylon swietenia* leaves (0.09% and 2.53% respectively) whereas the Iron content was found highest in *Butea superba* leaves (0.14%). In monsoon, Sodium and Magnesium content were observed to be highest in bamboo leaves (0.075% and 0.29% respectively) whereas Potassium and Zinc were found to be most in bamboo shoots (2.91% and 0.006% respectively). Also, in monsoon the Calcium content was found highest in *Chloroxylon swietenia* leaves (1.0%) whereas the Iron content was found to be highest in herbs (0.2%). In winter, *Butea superba* leaves had the highest content of Sodium, Calcium and Iron (0.08%, 1.55% and 0.13% respectively) whereas the Potassium and Zinc content was found to be highest in herbs (1.85% and 0.006%). The Magnesium content in winter was found to be highest in bamboo leaves (0.36%).

Table 4.5: Mineral contents in major food items of gaur in summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Food items	Minerals					
	% K	% Na	% Ca	% Mg	% Zn	% Fe
Grasses	0.53	0.08	1.21	0.23	0.0044	0.08
***Dendrocalamus strictus* leaves**	1.08	0.08	0.99	0.27	0.0037	0.11
***Shorea robusta* leaves**	0.82	0.04	0.66	0.27	0.0028	0.02
Herbs	1.71	0.07	1.45	0.53	0.0047	0.08
***Butea superba* leaves**	0.39	0.07	2.32	0.43	0.003	0.13
***Chloroxylon swietenia* leaves**	0.35	0.09	2.53	0.49	0.0032	0.12

Table 4.6: Mineral contents in major food items of gaur in monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Food items	Minerals					
	% K	% Na	% Ca	% Mg	% Zn	% Fe
Grasses	1.11	0.058	0.6	0.18	0.005	0.09
***Dendrocalamus strictus* leaves**	0.85	0.075	0.7	0.29	0.004	0.18
***Dendrocalamus strictus* shoot**	2.91	0.06	0.3	0.14	0.006	0.05
Herbs	1.4	0.065	0.6	0.28	0.005	0.2
Chloroxylon swietenia leaves	0.62	0.059	1.0	0.21	0.003	0.03
***Butea superba* leaves**	0.61	0.064	0.9	0.21	0.002	0.07
***Shorea robusta* leaves**	0.45	0.036	0.5	0.17	0.002	0.05

Table 4.7: Mineral contents in major food items of gaur in winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Food items	Minerals					
	% K	% Na	% Ca	% Mg	% Zn	% Fe
***Chloroxylon swietenia* leaves**	0.57	0.06	1.3	0.18	0.0029	0.03
***Butea superba* leaves**	0.61	0.08	1.55	0.21	0.0029	0.13
***Dendrocalamus strictus* leaves**	0.66	0.06	1.15	0.36	0.0027	0.05
Grasses	0.6	0.05	0.48	0.14	0.0049	0.05
Herbs	1.85	0.07	0.65	0.34	0.006	0.07
***Shorea robusta* leaves**	0.48	0.03	0.5	0.18	0.002	0.05

Tannins

The tannin content in the major food items of gaur in different seasons is given in figures 4.15, 4.16 and 4.17. In all the seasons the tannin content was found to be the highest in *Chloroxylon swietenia* leaves (figs. 4.15 to 4.17). In grasses the tannin content was found to be highest in summer (0.5 g/100 g catechine equivalent) as compared to monsoon (0.25 g/100 g c.e.) and winter (0.25 g/100 g c.e.). The tannin content in bamboo leaves was found to be similar in monsoon and winter (0.5 g/100

g c.e.) whereas it was lower in summer (0.2 g/100 g c.e.). The tannin content in herbs was highest in summer (0.75 g/100 g c.e.) and lowest in winter (0.25 g/100 g c.e.). The tannin content in *Shorea robusta* leaves and *Butea superba* leaves was found to be highest in winter (1.8 g/100 g c.e. and 2.25 g/100 g c.e. respectively).

Figure 4.15: Tannin content in major food items of gaur in summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

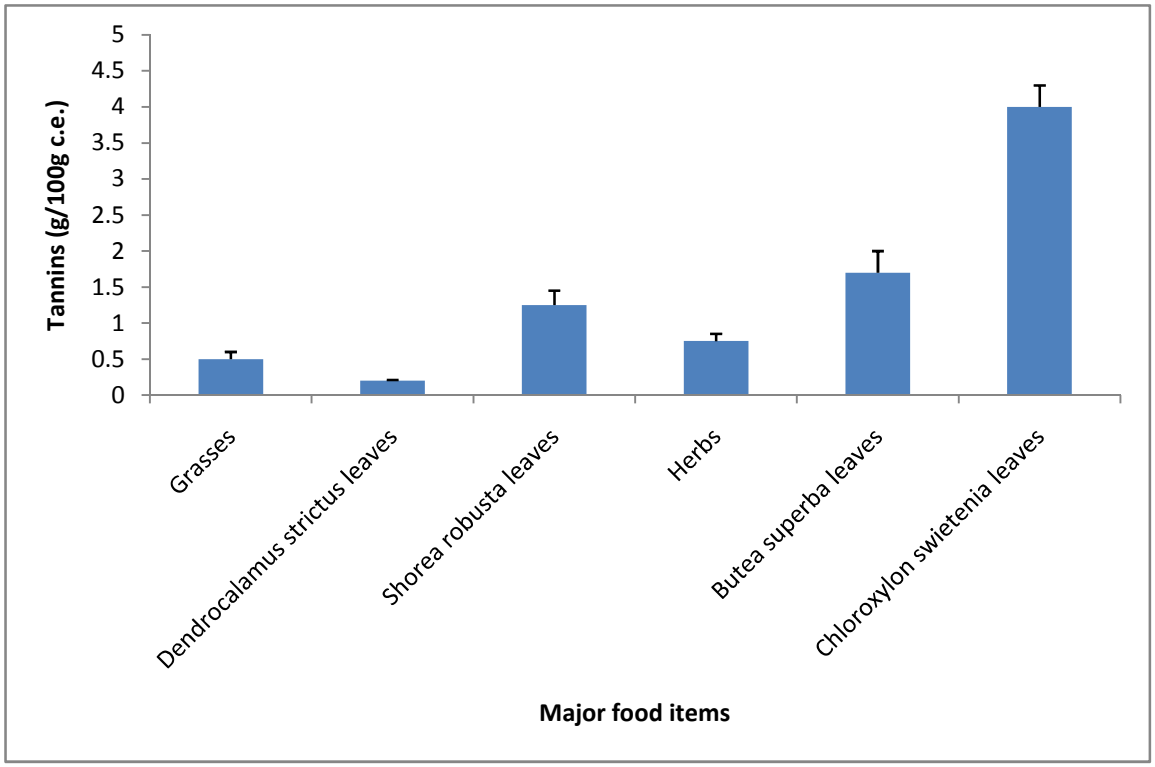


Figure 4.16: Tannin content in major food items of gaur in monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

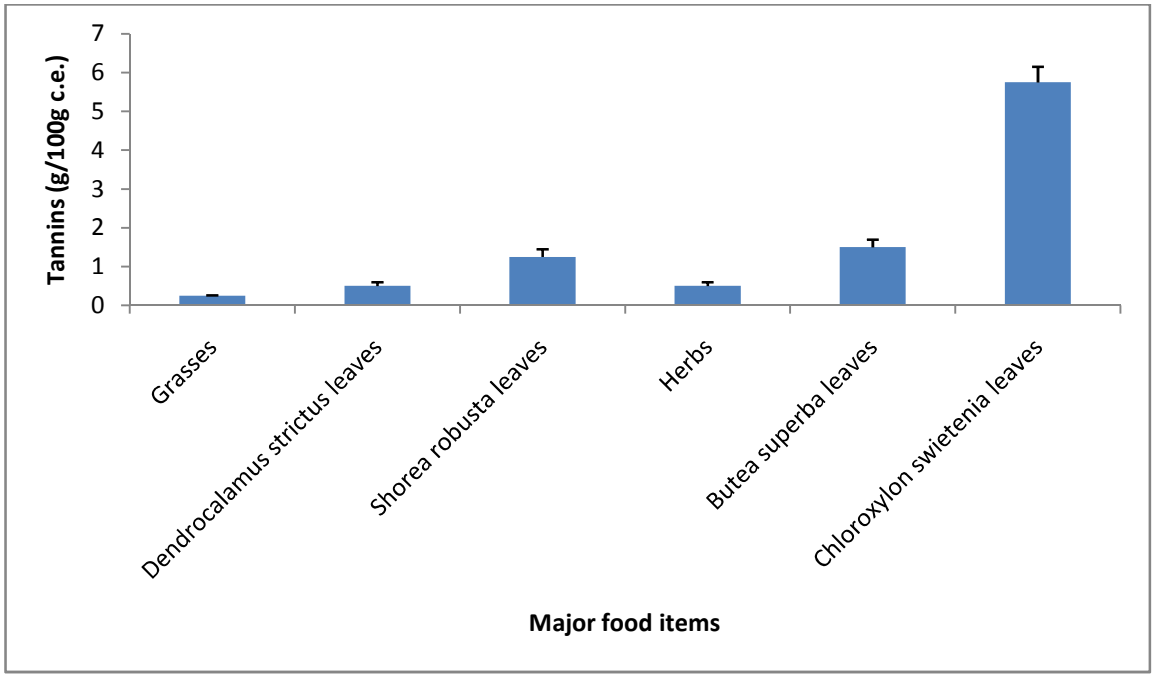
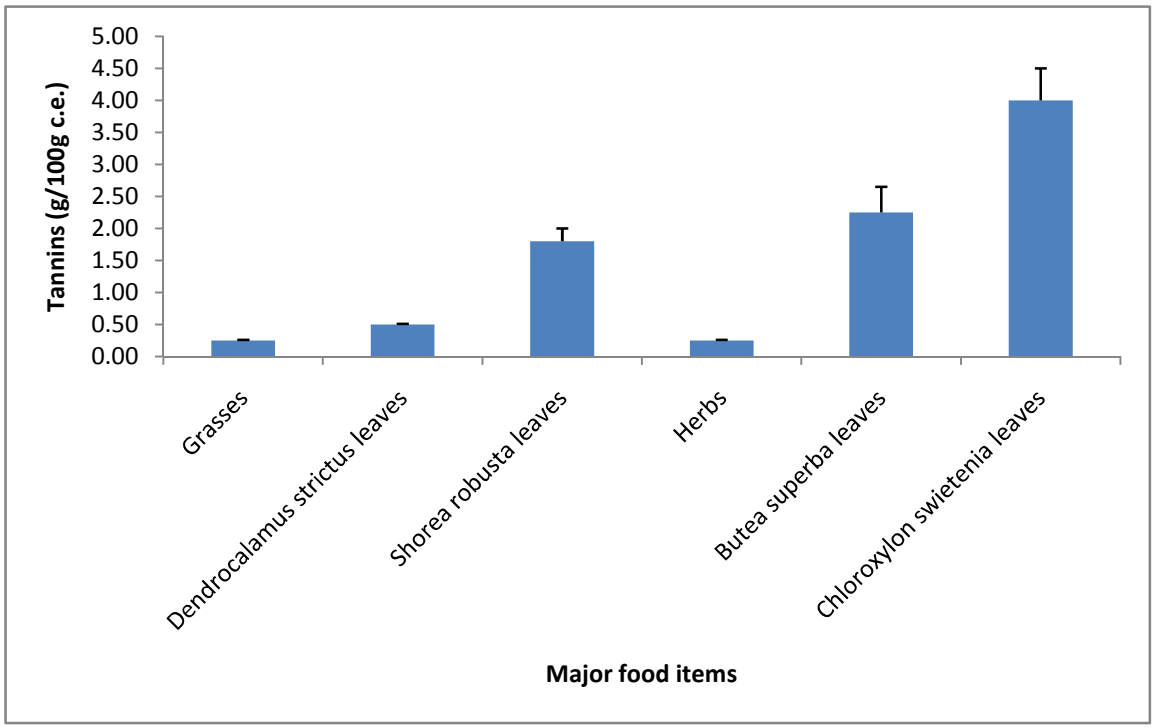


Figure 4.17: Tannin content in major food items of gaur in winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



4.4.4: Correlation analysis

A Spearman's correlation test was performed to check if the percentage time spent feeding by gaur on the major food items across the seasons was correlated to the nutritional contents of the food items (table 4.8). Percent time spent feeding was found to be negatively correlated to crude protein in summer (correlation coefficient = -0.086, n=6, $p>0.05$) and winter (c.c. = -0.257, n=6, $p>0.05$) but the correlation was observed to be non-significant. In monsoon the time spent feeding showed no correlation with crude protein. In the case of fibre content, time spent feeding was observed to be negatively correlated to NDF in summer whereas the correlation was found positive in monsoon and winter but none of them were found significant. ADF showed negative correlation with time spent feeding in summer (c.c. = -0.429, n=6, $p>0.05$) and winter (c.c. = -0.086, n=6, $p>0.05$) whereas the correlation was found to be positive in monsoon (c.c. = 0.429, n=7, $p>0.05$) but all correlations were non-significant.

The correlation between percent time spent feeding and lignin content was observed to be negative in summer (c.c. = -0.943, n=6, $p<0.05$) and was found to be significant. The percent time spent feeding was observed to be negatively correlated to lignin in monsoon (c.c. = -0.321, n=7, $p>0.05$) and winter (c.c. = -0.314, n=6, $p>0.05$) as well but the correlation was non-significant. The percent time spent feeding was found to be negatively correlated to tannin content in summer and the correlation was found to be significant (c.c. = -0.886, n=6, $p<0.05$). The correlations between percent time spent feeding and tannin content in monsoon and winter were also found to be negative but were non-significant (c.c. = -0.725 and -0.58 respectively, n=6, $p>0.05$). Since the ratio of crude protein to fibre has been shown

to influence food selection (Gupta 1991), the percent time spent feeding by gaur was correlated with the ratio of crude protein with NDF, ADF and lignin for the major food items. The correlation of percent time spent feeding with all the three ratios (CP/NDF, CP/ADF and CP/Lignin) was observed to be negative for all the seasons but all the correlations were found to be non-significant (table 4.8).

For minerals the time spent feeding was observed to be positively correlated only to Potassium and Zinc in summer whereas the correlation for all the other minerals in summer was found negative. In summer, of all the correlations only the negative correlation of Magnesium with time spent feeding was found to be significant (c.c. = -0.812, n=6, $p<0.05$). In monsoon, time spent feeding was positively correlated to Iron content (c.c. = 0.821, n=7, $p<0.05$) and the correlation was significant. All the other correlations of minerals with time spent feeding in monsoon were found to be positive (non-significant) except for Calcium which showed no correlation. In winter, the time spent feeding was found to be negatively correlated to Calcium and Iron contents (c.c. = -0.2 and -0.15 respectively, n=6, $p>0.05$) whereas all the other minerals showed positive correlation with time spent feeding but none of the correlations were significant (table 4.8).

Table 4.8: Correlation of percent time spent feeding by gaur with nutrient contents of major food items in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

NUTRIENTS	SUMMER (n=6)		MONSOON (n=7)		WINTER (n=6)	
	correlation coefficient with % feeding	*P*	correlation coefficient with % feeding	*P*	correlation coefficient with % feeding	*P*
Potassium	0.486	>0.05	0.6	>0.05	0.6	>0.05
Calcium	-0.771	>0.05	0.0	>0.05	-0.2	>0.05
Magnesium	-0.812	**<0.05**	0.5	>0.05	0.319	>0.05
Zinc	0.314	>0.05	0.536	>0.05	0.348	>0.05
Iron	-0.58	>0.05	0.821	**<0.05**	-0.152	>0.05
Sodium	-0.088	>0.05	0.5	>0.05	0.058	>0.05
Crude Protein (CP)	-0.086	>0.05	0.0	>0.05	-0.257	>0.05
Acid detergent fibre (ADF)	-0.429	>0.05	0.429	>0.05	-0.086	>0.05
Neutral detergent fibre (NDF)	-0.657	>0.05	0.357	>0.05	0.314	>0.05
Lignin	-0.943	**<0.05**	-0.321	>0.05	-0.314	>0.05
Tannins*	-0.886	**<0.05**	-0.725	>0.05	-0.58	>0.05
CP/ADF	-0.086	>0.05	-0.071	>0.05	-0.265	>0.05
CP/NDF	-0.086	>0.05	-0.107	>0.05	-0.395	>0.05
CP/Lignin	-0.086	>0.05	-0.107	>0.05	-0.029	>0.05

* For tannins, (n=6) in monsoon.

4.4.5: Phenology of major food plants of gaur in Bandhavgarh Tiger Reserve

The percentage availability of different vegetative phenophases (young leaves, mature leaves and no leaves) of major food plants of gaur in the study area in different seasons is given in figures 4.18 to 4.24. Young leaves of *Shorea robusta* were available only in summer whereas mature leaves formed the major portion of the foliage in all the seasons (fig.4.18). The reproductive phases (floral buds and flowers) of *Shorea robusta* were mainly recorded during the early part of summer

(March and April). For *Dendrocalamus strictus* it was observed that the percentage of young leaves available was highest during summer (23.5%) whereas the availability of mature leaves was observed to be highest in winter (94.9%). *Dendrocalamus strictus* were observed to shed leaves during summer and a considerable proportion of the plant was recorded to be leafless during this season (34.5%). The *Chloroxylon swietenia* trees were observed to be mainly leafless during summer (86.4%) which was also the time of the year when they were recorded in reproductive phases (floral buds, flowers and fruits). The percentage of young leaves of *Chloroxylon swietenia* was observed to be highest in monsoon (18%) whereas the percentage of mature leaves was the most during winter (86.2%). The foliage of the climber *Butea superba* consisted mainly of mature leaves in all the seasons (fig.4.21) whereas young leaves were available in summer (21.4%) and monsoon (8.3%). *Butea superba* was observed to flower in late monsoon (September-October) and the climbers were observed with mature fruits for the most part of the year except from August to October.

Figure 4.18: Vegetative phenology of *Shorea robusta* in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

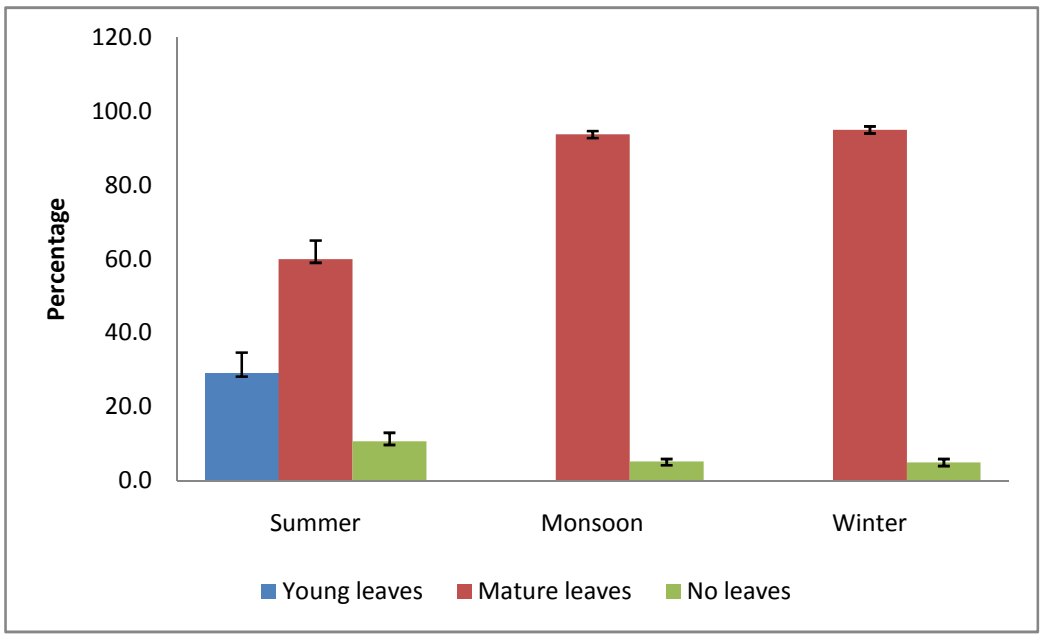


Figure 4.19: Vegetative phenology of *Dendrocalamus strictus* in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

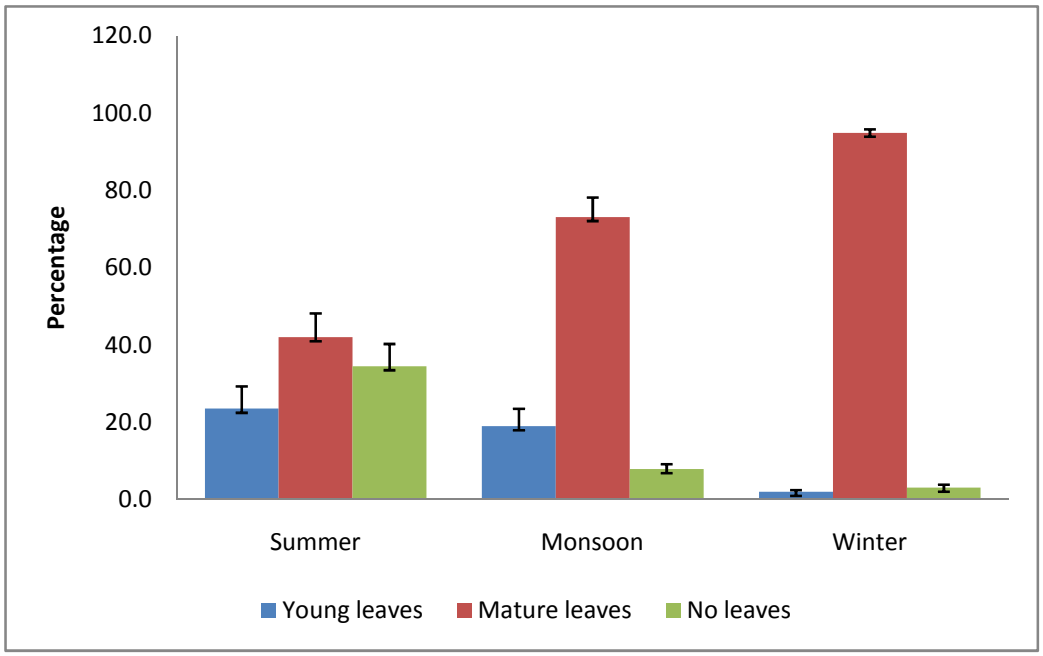


Figure 4.20: Vegetative phenology of *Chloroxylon swietenia* in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

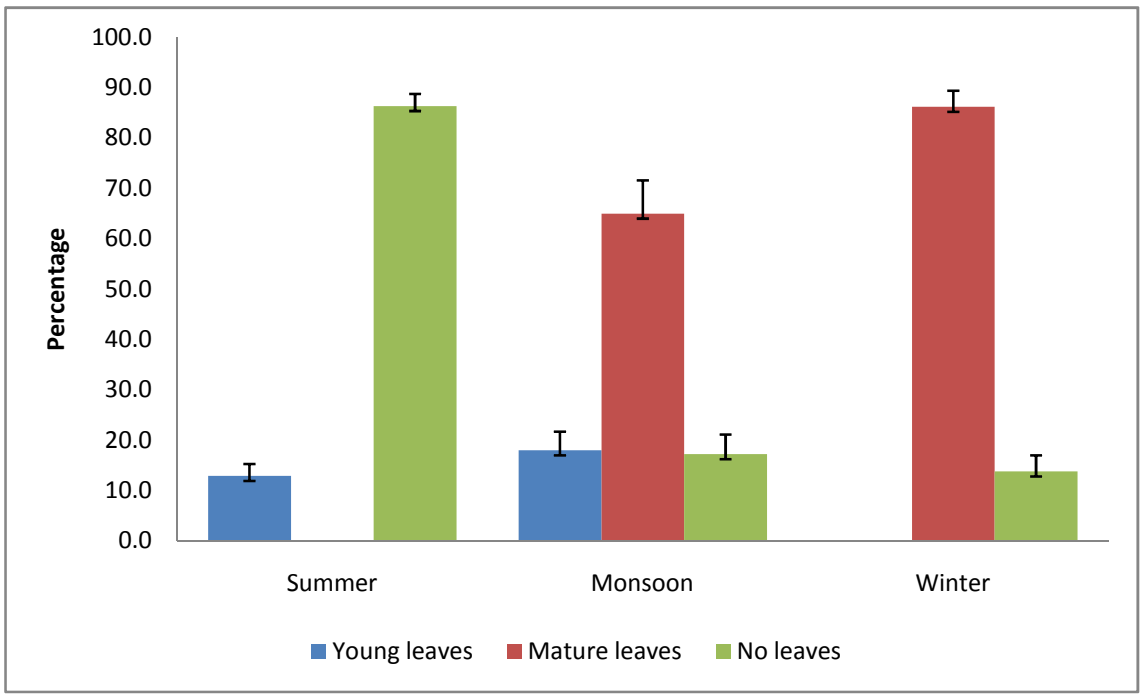
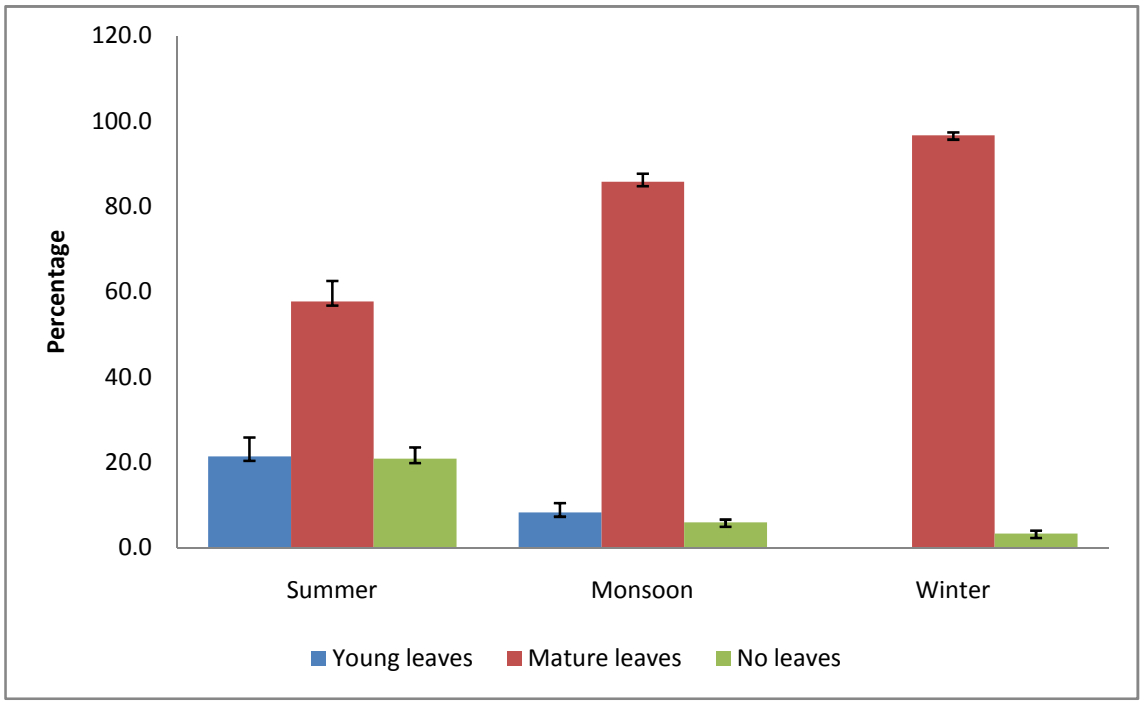


Figure 4.21: Vegetative phenology of *Butea superba* in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The phenology of the major grass species like *Saccharum spontaneum*, *Vetiveria zizanoides* and *Phragmites karka* was found to be very similar in the study area. For all the three species of grasses it was observed that the percentage of young shoots was the highest in monsoon followed by summer and winter whereas the percentage of mature shoots was the highest in winter for all the three species (figs. 4.22 to 4.24). In terms of reproductive phenology, all the three species mainly flowered in monsoon (August-September) and it was observed that some flowering also occurred in early winter (November-December).

Figure 4.22: Vegetative phenology of *Saccharum spontaneum* in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

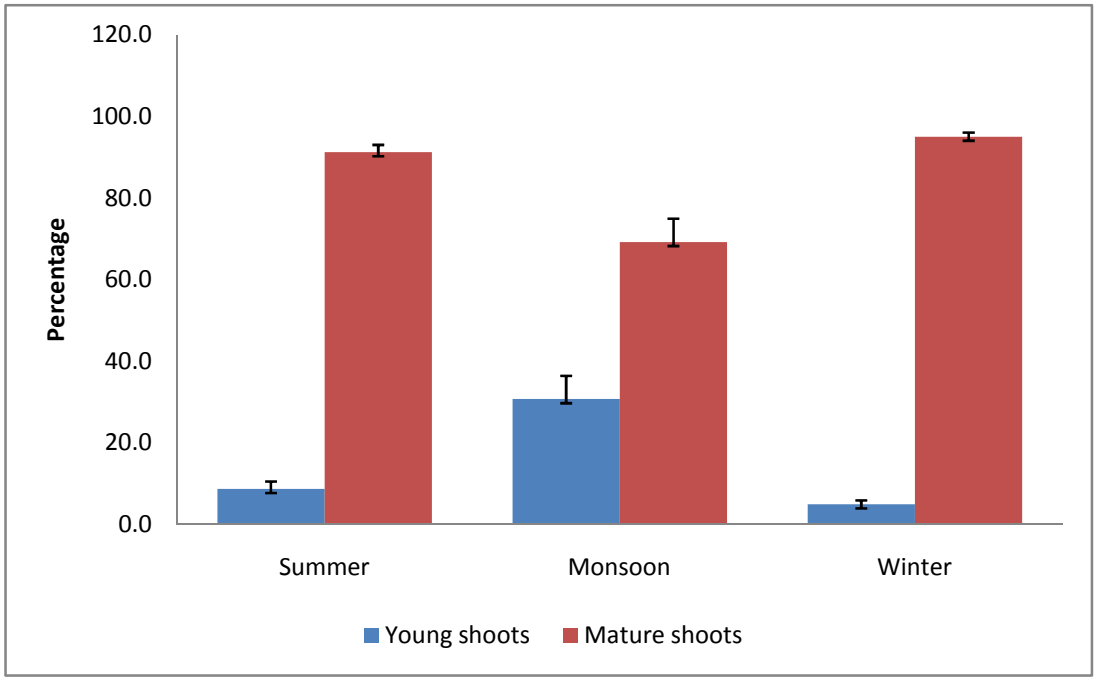


Figure 4.23: Vegetative phenology of *Vetiveria zizanoides* in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

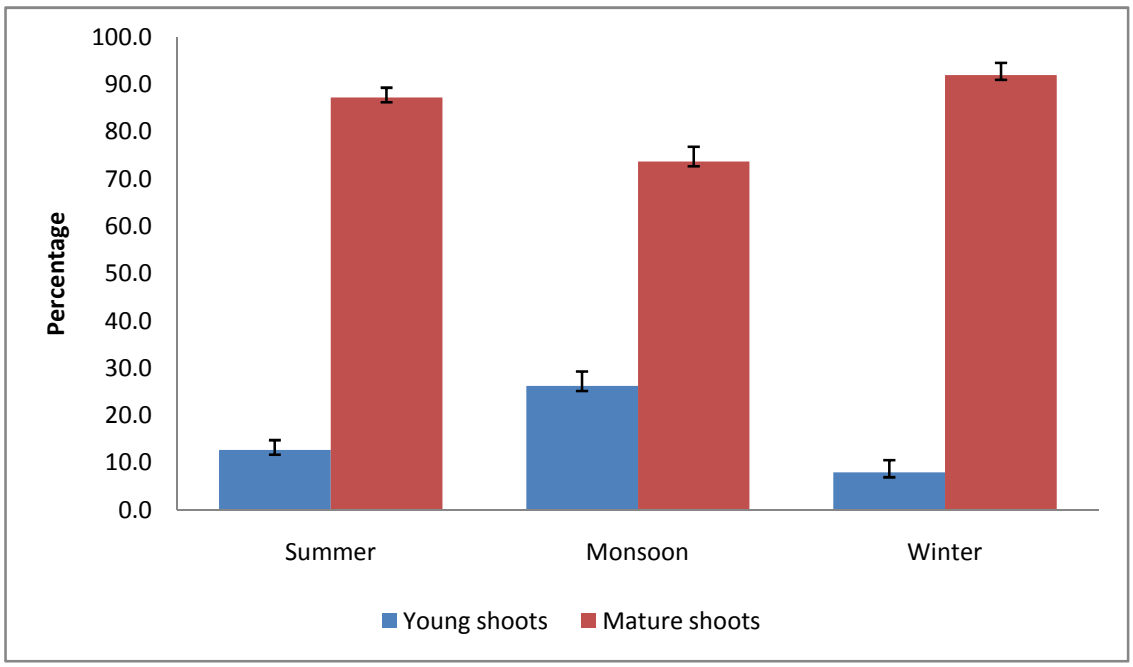
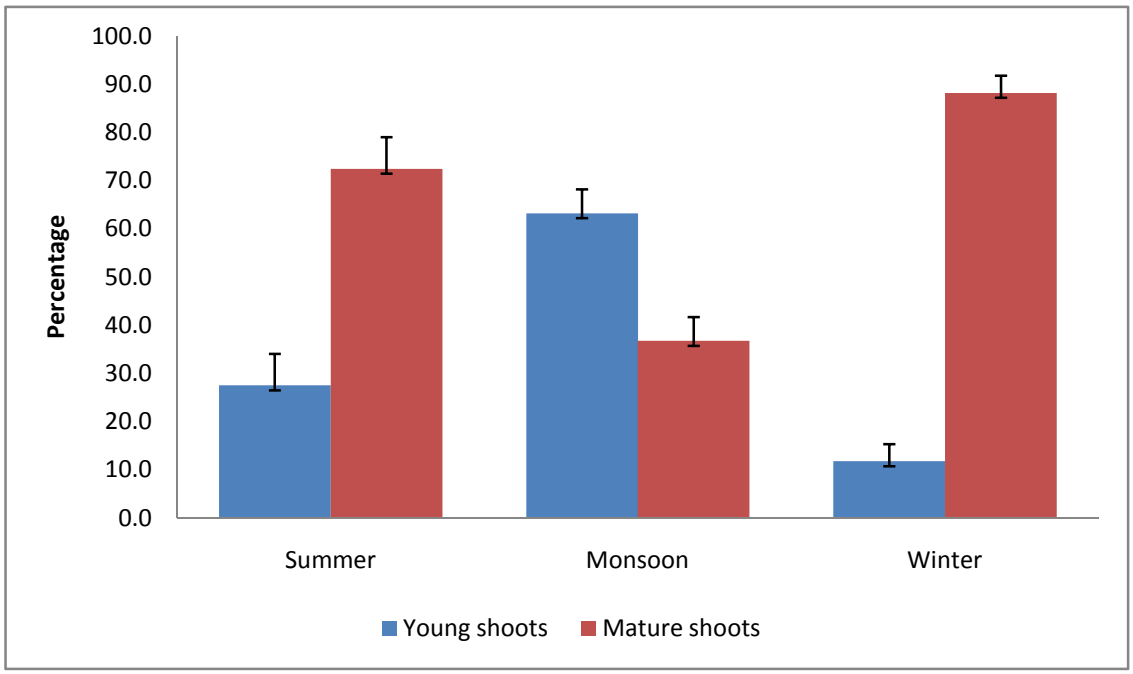


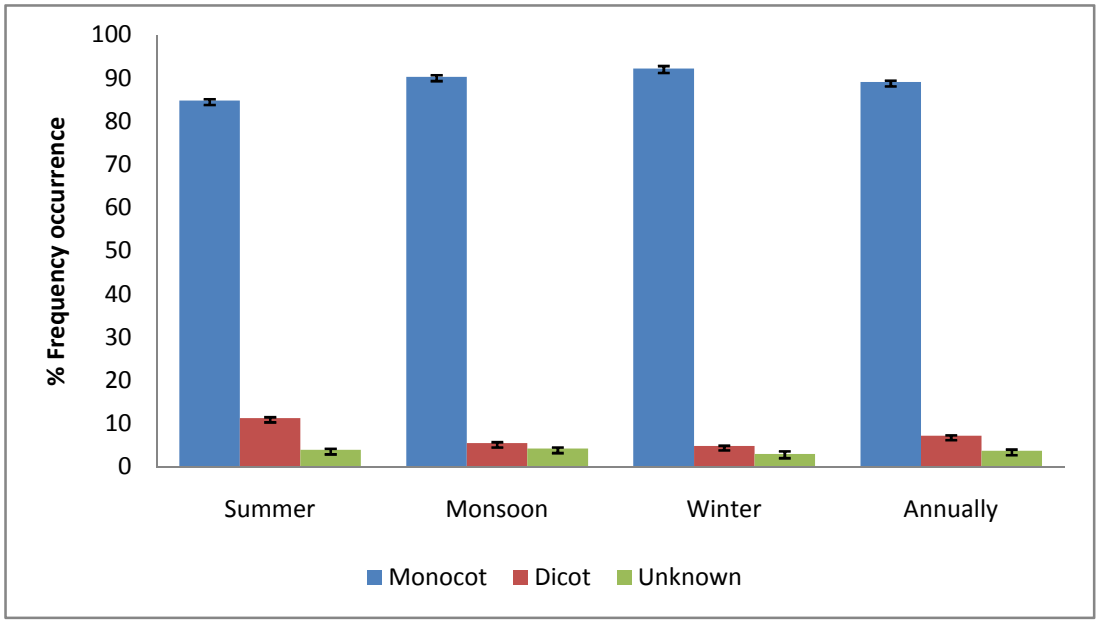
Figure 4.24: Vegetative phenology of *Phragmites karka* in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).



4.4.6: Diet composition of gaur through dung analysis

A total of 301 dung samples were analysed during the study period (summer-101, monsoon-100, winter-100). The percentage frequency occurrence of monocot and dicot plant fragments in the dung samples of gaur in different seasons and annually is given in figure 4.25. It was observed that the percentage frequency occurrence of monocot plant fragments in the gaur dung samples was high in all the seasons as compared to that of the dicot plant fragments (fig. 4.25). The percentage frequency occurrence of dicot plant fragments was observed to be the most in summer (11.3%) as compared to monsoon and winter (5.5% and 4.8% respectively). Annually, it was observed that the percentage frequency occurrence of monocot plant fragments in the gaur dung samples was 89.1% whereas that of dicot fragments was 7.2%.

Figure 4.25: Percentage frequency occurrence of monocot and dicot plant fragments in the dung samples of gaur in different seasons and annually in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The percentage frequency occurrence of plant fragments of major food plant species of gaur in the gaur dung samples in different seasons is given in table 4.9.

Table 4.9: Percentage frequency occurrence of plant fragments of major food plant species of gaur in the dung samples in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Food plant species	Percentage frequency occurrence of plant fragments in different seasons.		
	Summer	Monsoon	Winter
Saccharum spontaneum	30 (3.6)	6.8 (1.1)	10.6 (1.7)
Phragmites karka	9.8 (1.4)	4.3 (1.2)	2.4 (0.6)
Vetiveria zizanoides	5.1 (1.2)	1.3 (0.4)	2.5 (0.7)
Dendrocalamus strictus	20.2 (3.4)	17.1 (2.7)	30.5 (2.2)
Oplismenus spp.	0.0	14.7 (2.4)	3.1 (0.9)
Shorea robusta	5.4 (1.5)	0.8 (0.4)	0.5 (0.2)
Chloroxylon swietenia	0.0	0.5 (0.3)	0.5 (0.2)
Butea superba	0.8 (0.3)	0.1 (0.1)	0.2 (0.1)

Standard errors are given in parenthesis.

The percentage frequency occurrence of bamboo fragments was observed to be highest in winter (30.5%) as compared to summer (20.2%) and monsoon (17.1%). The percentage frequency occurrence of the fragments of the herb *Oplismenus* was observed to be the most in monsoon (14.7%) as compared to winter (3.1%). Percentage frequency occurrence of *Saccharum spontaneum* fragments was observed to be 30% in summer, 6.8% in monsoon and 10.6% in winter. Among dicotyledonous species the percentage frequency occurrence of *Shorea robusta* was observed to be highest in summer (5.4%) followed by monsoon (0.8%) and winter (0.5%).

4.4.7: Availability of the major food plants of gaur in Bandhavgarh Tiger Reserve

A total of 726 vegetation plots were laid in the study area during the study period. The density of major food plants of gaur (trees and climbers) is given in table 4.10. The percentage grass and herb cover and the percentage of green and dry grass available in different seasons in the study area are given in tables 4.11 and 4.12.

Table 4.10: Density of major food plants of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Food plant species	Density (per meter square)
Shorea robusta	0.041 (±0.003)
Dendrocalamus strictus	0.039 (±0.003)
Chloroxylon swietenia	0.011 (±0.002)
Butea superba	0.002 (±0.001)

Table 4.11: Percentage grass and herb cover in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Seasons	% Grass cover	% herb cover
Summer	19.2 (±1.4)	9.1 (±0.9)
Monsoon	41.3 (±2.4)	19.7 (±1.4)
Winter	20.3 (±2.0)	8.4 (±0.6)

Table 4.12: Percentage availability of green and dry grass in different seasons in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Seasons	% Green grass	% Dry grass
Summer	55.6 (±4.2)	44.4 (±2.3)
Monsoon	96.4 (±2.3)	3.6 (±3.1)
Winter	32.9 (±5.1)	67.1 (±1.3)

It was found that among the major food plants of gaur in Bandhavgarh, *Shorea robusta* had the highest density (0.041/m^2) followed by *Dendrocalamus strictus* (0.039/m^2), *Chloroxylon swietenia* (0.011/m^2) and *Butea superba* (0.002/m^2). The percent grass cover was found to be significantly higher in monsoon (41.3%) as compared to summer (19.2%) and winter (20.3%) (K.W: χ^2 = 63.341, $p<0.05$). Similarly, the percent herb cover was also found to be significantly higher in monsoon (19.7%) as compared to summer (9.1%) and winter (8.4%) (K.W: χ^2 = 66.806, $p<0.05$). The percentage availability of green grass was observed to be higher in monsoon and summer as compared to the percentage availability of dry grass whereas the availability of dry grass was higher than that of green grass in winter (table 4.12).

4.4.8: Selection of major food items by gaur in different seasons

The Ivlev's selectivity index (IVI), calculated for the major food items of gaur in different seasons in Bandhavgarh is given figures 4.26, 4.27 and 4.28. It was observed that the utilisation of bamboo leaves as a food item by gaur was higher than its availability in all the seasons (figs. 4.26 to 4.28). The utilisation of grasses as a food resource was observed to be more than its availability in summer whereas it was lower than its availability in monsoon and winter. The utilisation of herbs by

gaur as a food item was observed to be proportional to its availability in monsoon whereas it was found lower than its availability in summer and winter. Gaur utilised *Butea superba* leaves more than its availability in monsoon and winter whereas the use of *Chloroxylon swietenia* leaves by gaur was found to be lower than its availability in monsoon and winter. *Shorea robusta* leaves were used less by gaur than their availability in summer whereas the utilisation of young bamboo shoots in monsoon was observed to be lower than their availability.

Figure 4.26: Ivlev's selectivity index of major food items of gaur in summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

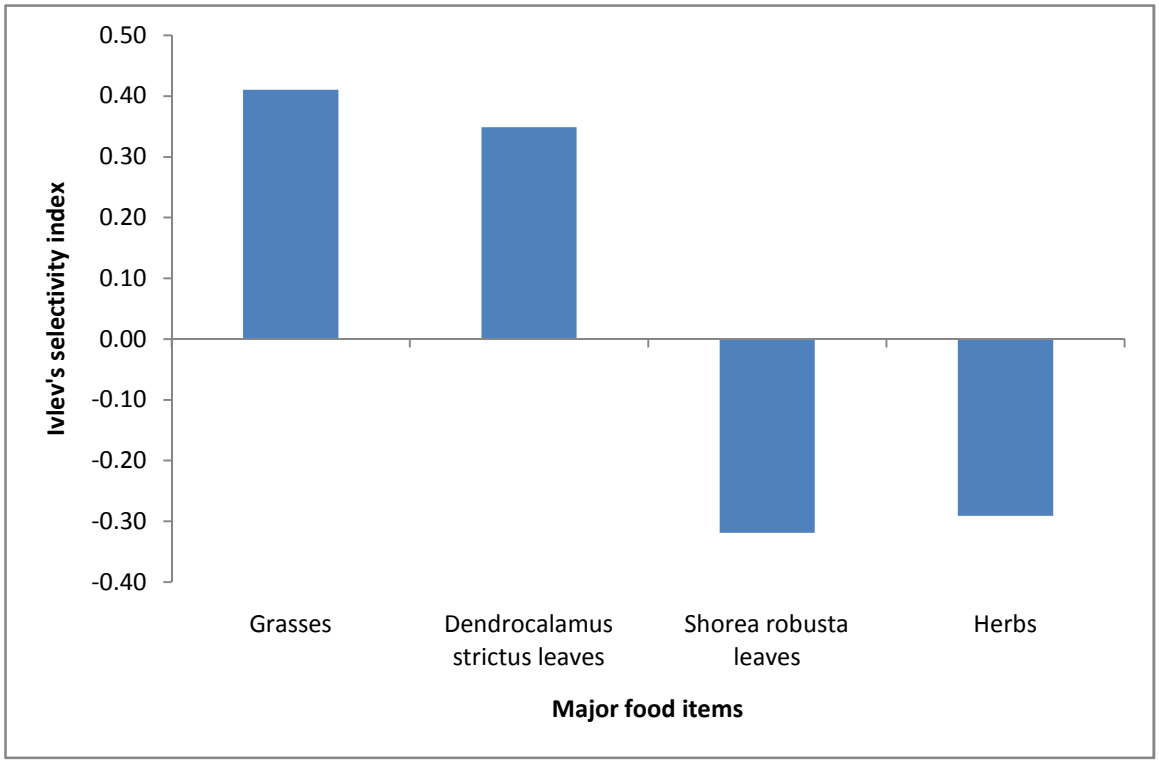


Figure 4.27: Ivlev's selectivity index of major food items of gaur in monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

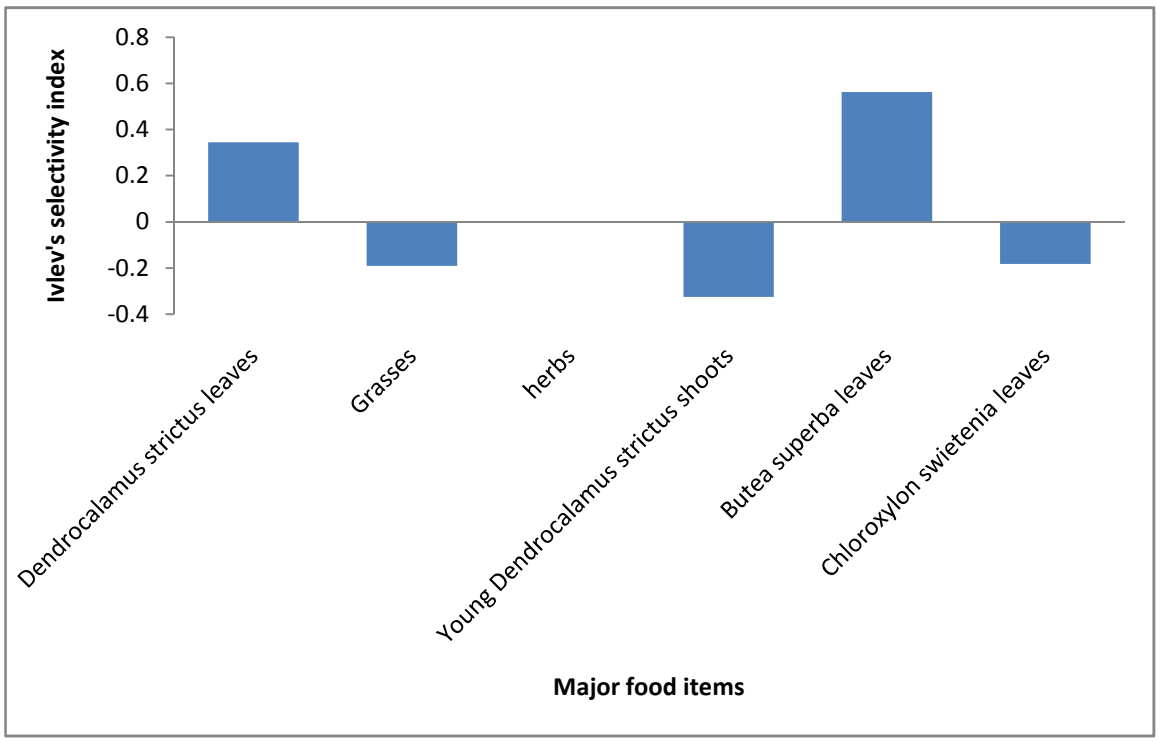
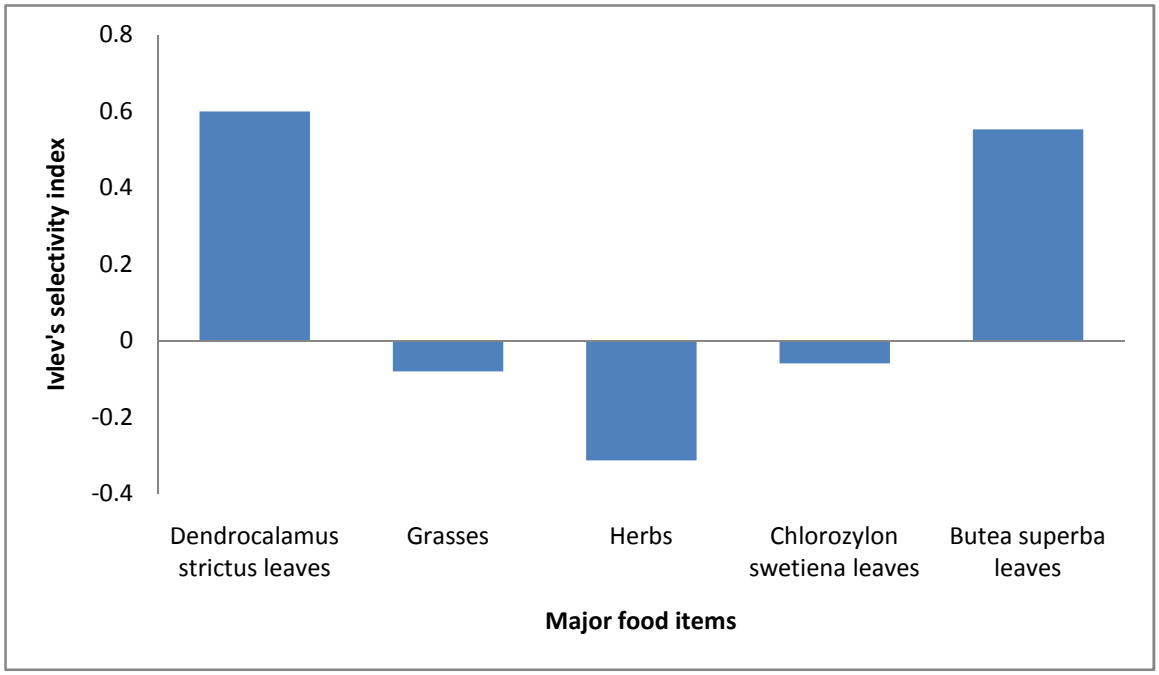


Figure 4.28: Ivlev's selectivity index of major food items of gaur in winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



The simplified matrices giving the ranking of the major food items based on their selection by gaur in different seasons obtained through compositional analysis are given in tables 4.13, 4.14 and 4.15.

Table 4.13: Simplified ranking matrix of major food items of gaur in summer based on comparing the percent time spent feeding on the major food items by different age and sex classes of gaur and the availability of the major food items in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Food item	Gra	Den le.	Sho le.	Her	But le.	Dio le.	Chl le.	Rank
Gra		3	3	3	3	3	3	6
Den le.	-3		3	3	3	3	3	5
Sho le.	-3	-3		-3	1	3	3	3
Her	-3	-3	3		1	3	3	4
But le.	-3	-3	-1	-1		3	3	2
Dio le.	-3	-3	-3	-3	-3		-1	0
Chl le.	-3	-3	-3	-3	-3	1		1

Gra-Grasses, Den le-Dendrocalamus strictus leaves, Sho le-Shorea robusta leaves, Her-Herbs, But le- Butea superba leaves, Dio le-Diospyros melanoxylon leaves, Chl le- Chloroxylon-swietenia leaves.

Table 4.14: Simplified ranking matrix of major food items of gaur in monsoon based on comparing the percent time spent feeding on the major food items by different age and sex classes of gaur and the availability of the major food items in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Food item	Den le.	Gra	Her	Den sh.	But le.	Chl le.	Sho le.	Rank
Den le.		3	3	3	3	3	3	6
Gra	-3		-1	1	-1	1	3	3
Her	-3	1		1	-1	1	3	4
Den sh.	-3	-1	-1		-1	-1	3	1
But le.	-3	1	1	1		3	3	5
Chl le.	-3	-1	-1	1	-3		3	2
Sho le.	-3	-3	-3	-3	-3	-3		0

Den le-Dendrocalamus strictus leaves, Gra-Grasses, Her-Herbs, Den sh-Dendrocalamus strictus shoot, But le- Butea superba leaves, Chl le-Chloroxylon swietenia leaves, Sho le-Shorea robusta leaves.

Table 4.15: Simplified ranking matrix of major food items of gaur in winter based on comparing the percent time spent feeding on the major food items by different age and sex classes of gaur and the availability of the major food items in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Food item	Den le.	Gra	Her	Chl le.	But le.	Sho le.	Dio le.	Rank
Den le.		3	3	3	3	3	3	6
Gra	-3		3	1	-1	3	3	4
Her	-3	-3		-3	-3	3	3	2
Chl le.	-3	-1	3		-1	3	3	3
But le.	-3	1	3	1		3	3	5
Sho le.	-3	-3	-3	-3	-3		1	1
Dio le.	-3	-3	-3	-3	-3	-1		0

Den le-Dendrocalamus strictus leaves, Gra-Grasses, Her-Herbs, Chl le-Chloroxylon swietenia leaves, But le- Butea superba leaves, Sho le-Shorea robusta leaves, Dio le-Diospyros melanoxylon leaves.

Compositional analysis showed that in summer, grasses were the most preferred food item of gaur whereas in monsoon and winter bamboo leaves was the most

preferred food item of gaur in the study area. The selection of major food items by gaur in summer was in the following order: Grasses > Bamboo leaves > Herbs > Shorea robusta leaves > Butea superba leaves > Chloroxylon swietenia leaves > Diospyros melanoxylon leaves (χ^2 = 50.3, df = 6, p<0.0001) (table 4.13). In monsoon, the selection of major food items by gaur was in the following order: Bamboo leaves > Butea superba leaves > Herbs > Grasses > Chloroxylon swietenia leaves > Young Bamboo shoots > Shorea robusta leaves (χ^2 = 38.5, df = 6, p<0.0001) (table 4.14). The selection of major food items in winter by gaur was in the following order: Bamboo leaves > Butea superba leaves > Grasses > Chloroxylon swietenia leaves > Herbs > Shorea robusta leaves > Diospyros melanoxylon leaves (χ^2 = 52.2, df = 6, p<0.0001) (table 4.15).

4.4.9: Land use and Land cover map of Bandhavgarh Tiger Reserve

The land use/land cover (LULC) map of the study area is given in figure 4.29. The overall habitat was classed into 11 different vegetation/land cover classes *viz* agriculture, bamboo forest, grassland, open-mixed forest, mixed forest, sal forest, riparian forest, habitation, plantation, rocky outcrop and scrubland. The area and percentage of different vegetation and land cover classes in Bandhavgarh Tiger Reserve is given in table 4.16.

1. **Agriculture land:** This is represented by irrigation and rain fed lands in Bandhavgarh, which breaks the connectivity between forest patches. The main crops include wheat, corn, mustard and edible vegetables.

2. **Bamboo Forest:** The dense bamboo distribution occurs mainly in the core area of Bandhavgarh Tiger Reserve. Some bamboo patch areas also occur along with mixed

forest in the National Park area. Due to strict protection measures and ban in forestry operations, the natural regeneration of bamboo occurs in all areas (Gopal 1989).

3. **Grassland:** Grassland patches occur in the valleys and along the streams (nalas) and also near the villages. The major grass species includes *Bothriochloa odorata, Digitaria sanguinalis, Cynodon dactylon, Dichanthium annulatum, Saccharum spontaneum* and *Vetiveria zizanoides.*

4. **Open-Mixed Forest:** This occurs in patches near to the villages. The major tree species includes *Anogeissus latifolia, Acacia catechu, Butea monosperma, Acacia leucophloea, Soymida febrifuga, Careya arborea, Maduca indica, Ziziphus xylopyrus,* and *Capparis deciduas.* The major shrub species found are *Holarrhena antidysenterica, Mimosa hamata* and *Woodfordia floribunda* and major climbers are *Bauhinia vahlii* and *Butea superba.* The major grass species are *Aristida depressa, Cymbopogon martini, Heteropogon contortous* and *Themeda quadrivalvis*.

5. **Mixed Forest:** This is distributed throughout the park and provides good canopy cover to the animals. Few patches of mixed forest also occur in riparian areas, where alluvial black clayey soil is present especially in Kallwah range. The major tree species includes *Anogeissus latifolia, Acacia catechu, Dendrocalamus strictus, Holarrhena antidysenterica, Terminalia tomentosa, Phyllanthus emblica, Pterocarpus marsupium, Lagerstroemia parviflora, Terminalia chebula, Kydia calycina, Salmalia malabarica, Diospyros melanoxylon* and *Ziziphus mauritiana*.

6. **Sal Forest:** Sal (*Shorea robusta*) patches in Bandhavgarh constitute 60 to 90 % of the top canopy. The associated species are *Anogeissus latifolia, Buchanania lanzan, Diospyros melanoxylan, Phyllanthus emblica, Kydia calycina, Madhuca indica* and *Terminalia arjuna.*

7. **Riparian Forest**: This type is restricted to perennial and semi perennial rivers and streams. The canopy is dominated by species like *Dendrocalamus strictus, Ficus bengalensis, Ziziphus mauritiana, Butea monosperma, Syzygium cuminii and Terminalia arjuna.*

8. **Habitation:** This is found in buffer area of Bandhavgarh Tiger Reserve, where livestock grazing pressure is very high.

9. **Plantation:** Very few patches of plantation are found in buffer areas with species like *Shorea robusta*, *Dendrocalamus strictus* and *Tectona grandis*.

10. **Rocky Outcrop:** This is found in Bandhavgarh Fort and other hilly areas in the Sanctuary.

11. **Scrubland:** This is found in the fringes of National Park and in Sanctuary area in association with *Acacia catechu* and *Lantana camara*.

Figure 4.29: Land use and land cover map of Bandhavgarh Tiger Reserve with a 5 km buffer (March 2012-February 2014).

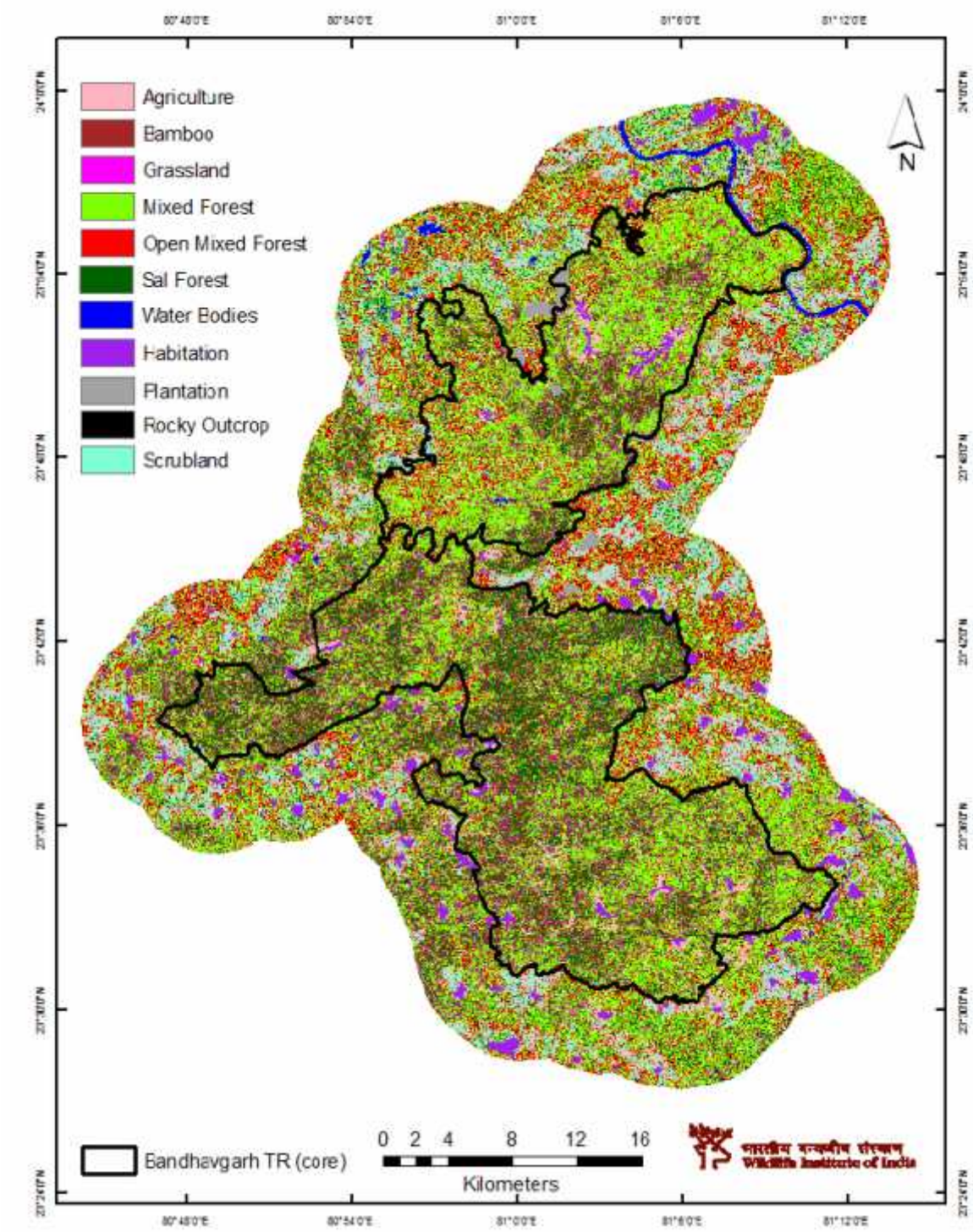


Table 4.16: Area and percentage of different vegetation and land cover classes in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Vegetation/Land cover type	Area (km^2)	Percentage
Agricultural land	69.2	3.9
Bamboo forest	221.9	12.6
Grassland	115.3	6.5
Mixed forest	706.9	40.2
Open-mixed forest	196.4	11.1
Sal forest	231.1	13.1
Water body	73.2	4.1
Habitation	32.1	1.8
Plantation	4.5	0.2
Rocky outcrop	33.8	1.9
Scrubland	74.2	4.2
Total area	**1758.6**	

In Bandhavgarh Tiger Reserve, the mixed forest was found to be the most dominant vegetation type that covered the highest percentage of area (40.2%) whereas the area under plantation covered the lowest percent area (0.2%). In addition, the bamboo forest covered an area of 12.6%, grasslands 6.5%, whereas Sal forest covered about 13.1% area in the entire Tiger Reserve.

4.4.10: Mapping the abundance and distribution of the major food plants of gaur in Bandhavgarh Tiger Reserve

The mapping of the abundance and distribution of major food plants of gaur in Bandhavgarh Tiger Reserve is given in figures 4.30 to 4.36. It was observed (fig. 4.30) that the areas having high bamboo density are mainly located in the Bandhavgarh National Park area as compared to the Panpatha Wildlife Sanctuary. The abundance and distribution of *Chloroxylon swietenia* and *Shorea robusta* also showed a similar pattern to bamboo wherein the areas having high density of

Chloroxylon swietenia and *Shorea robusta* are mainly located in the National Park area as compared to the Wildlife Sanctuary area (figs. 4.31 and 4.32). The abundance of *Butea superba* climber was observed to be mostly low throughout the Bandhavgarh Tiger Reserve (fig. 4.33). The percentage grass cover was high in most areas of the National Park and Wildlife Sanctuary in monsoon as compared to summer and winter (figs. 4.34 to 4.36). In summer the distribution of percentage grass cover showed a similar pattern in both National Park and Wildlife Sanctuary (fig. 4.34) but in winter the Wildlife Sanctuary had more areas with higher grass cover as compared to National Park (fig. 4.36).

Figure 4.30: Abundance and distribution of Bamboo (*Dendrocalamus strictus*) in Bandhavgarh Tiger Reserve (March 2012-February 2014).

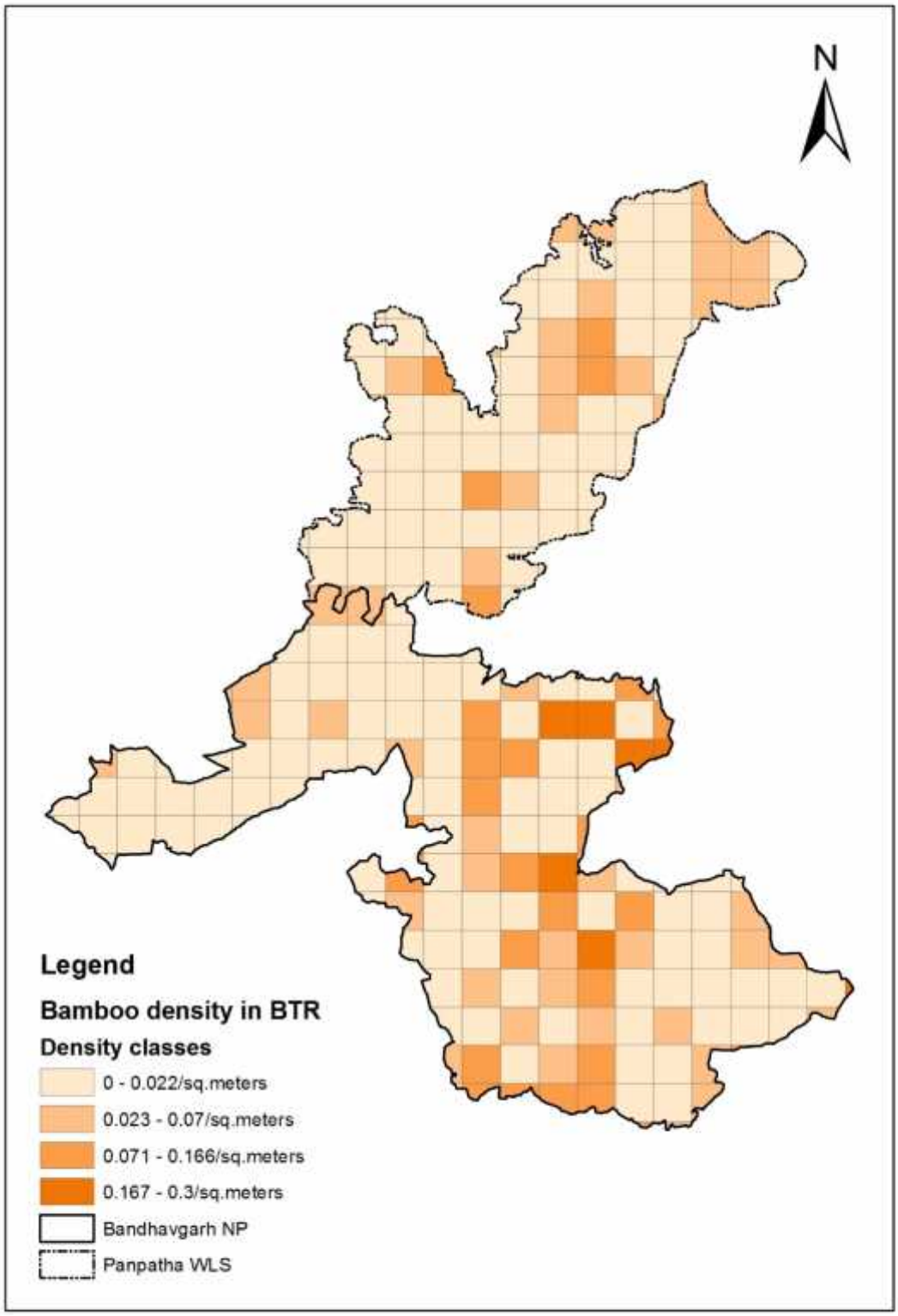


Figure 4.31: Abundance and distribution of *Chloroxylon swietenia* in Bandhavgarh Tiger Reserve (March 2012-February 2014).

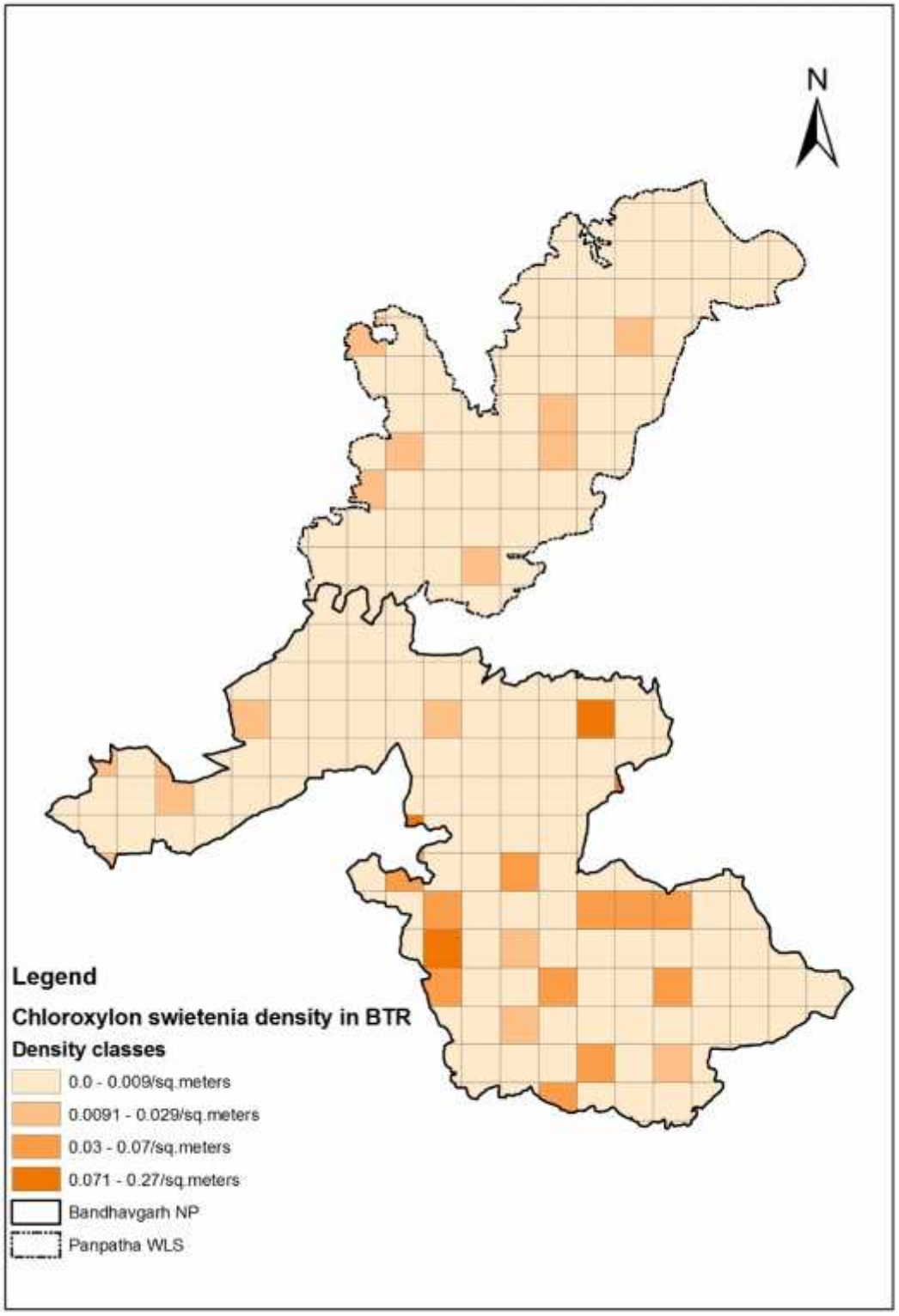


Figure 4.32: Abundance and distribution of *Shorea robusta* in Bandhavgarh Tiger Reserve (March 2012-February 2014).

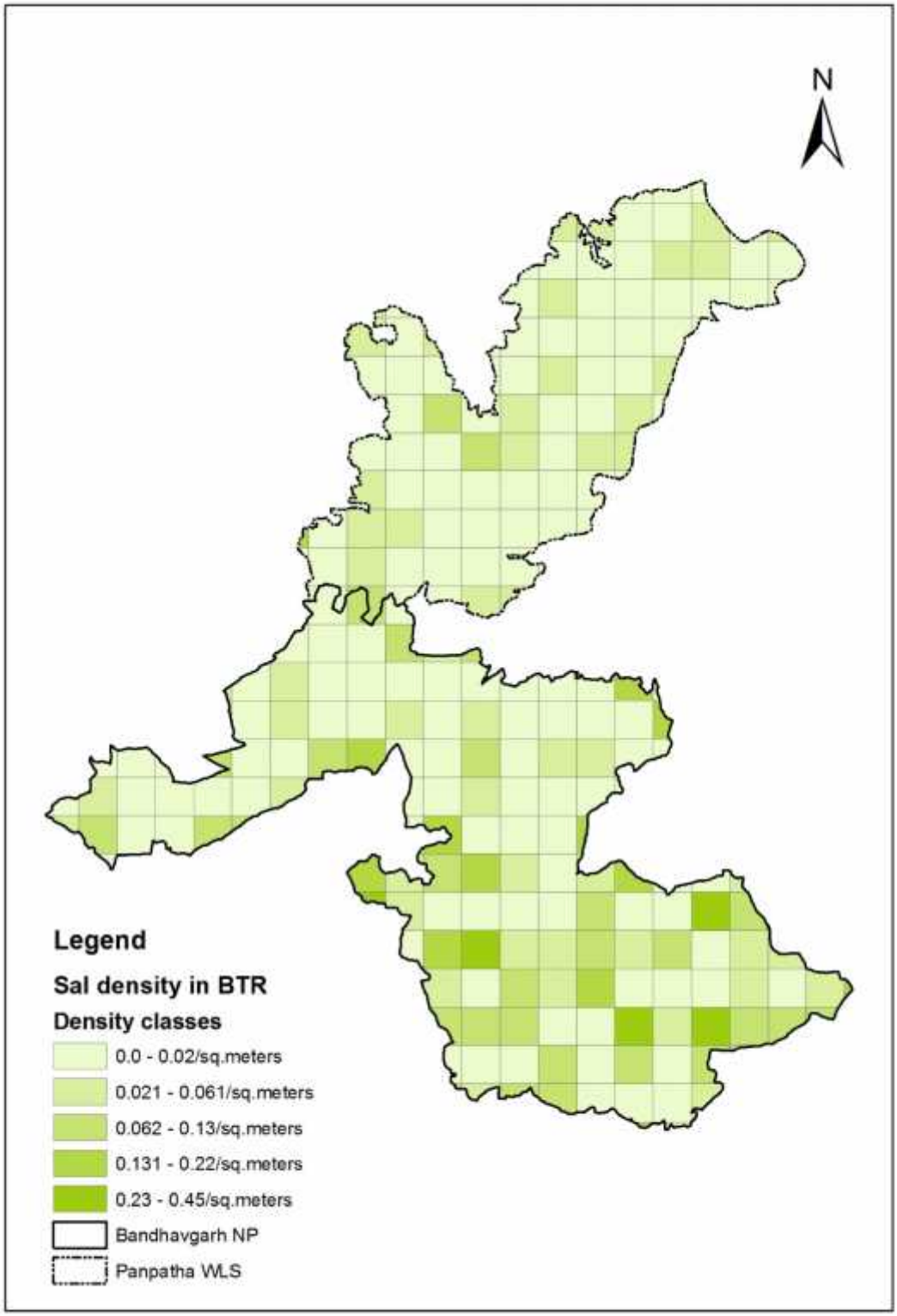


Figure 4.33: Abundance and distribution of *Butea superba* in Bandhavgarh Tiger Reserve (March 2012-February 2014).

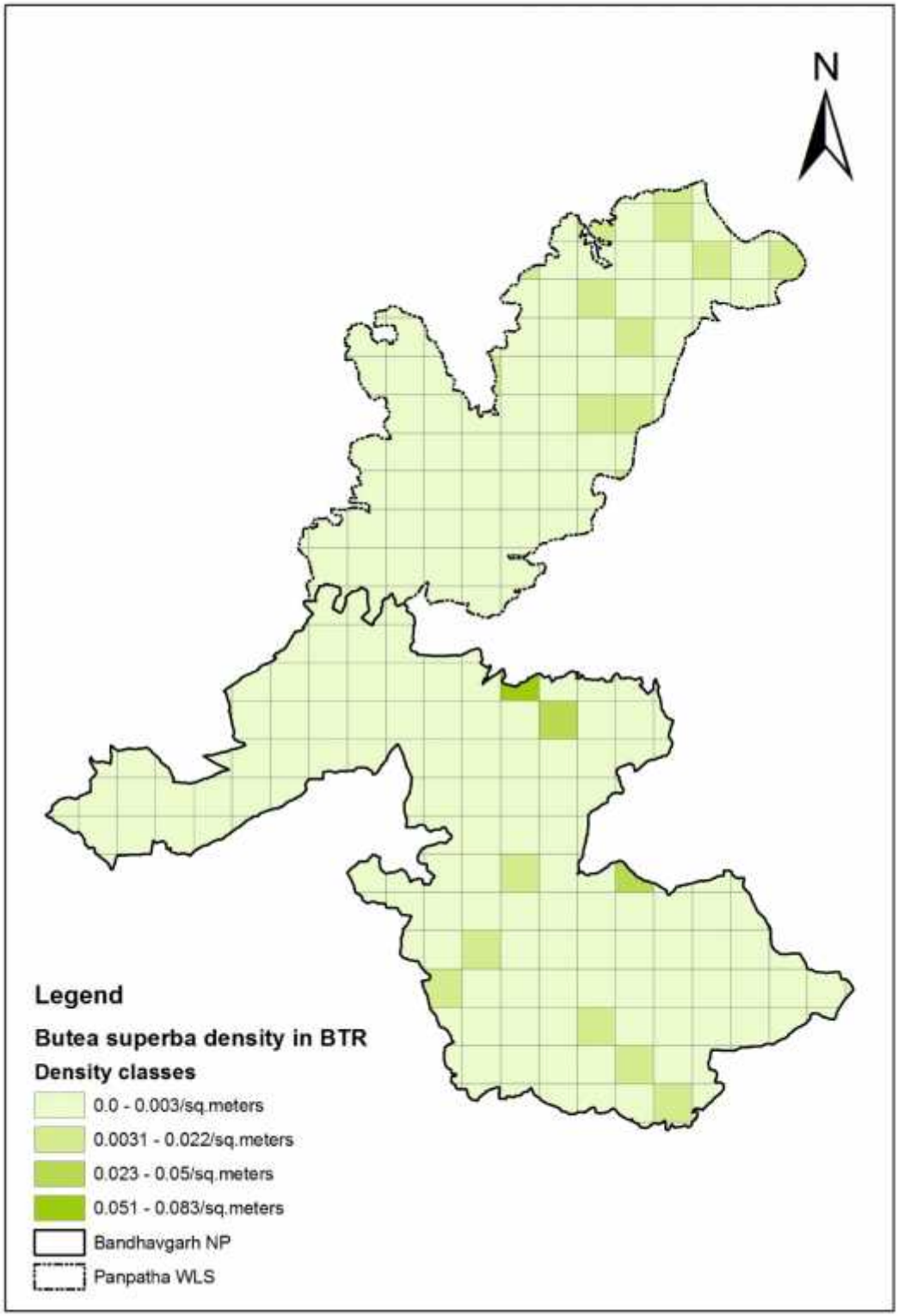


Figure 4.34: Abundance and distribution of percent grass cover in summer in Bandhavgarh Tiger Reserve (March 2012-February 2014).

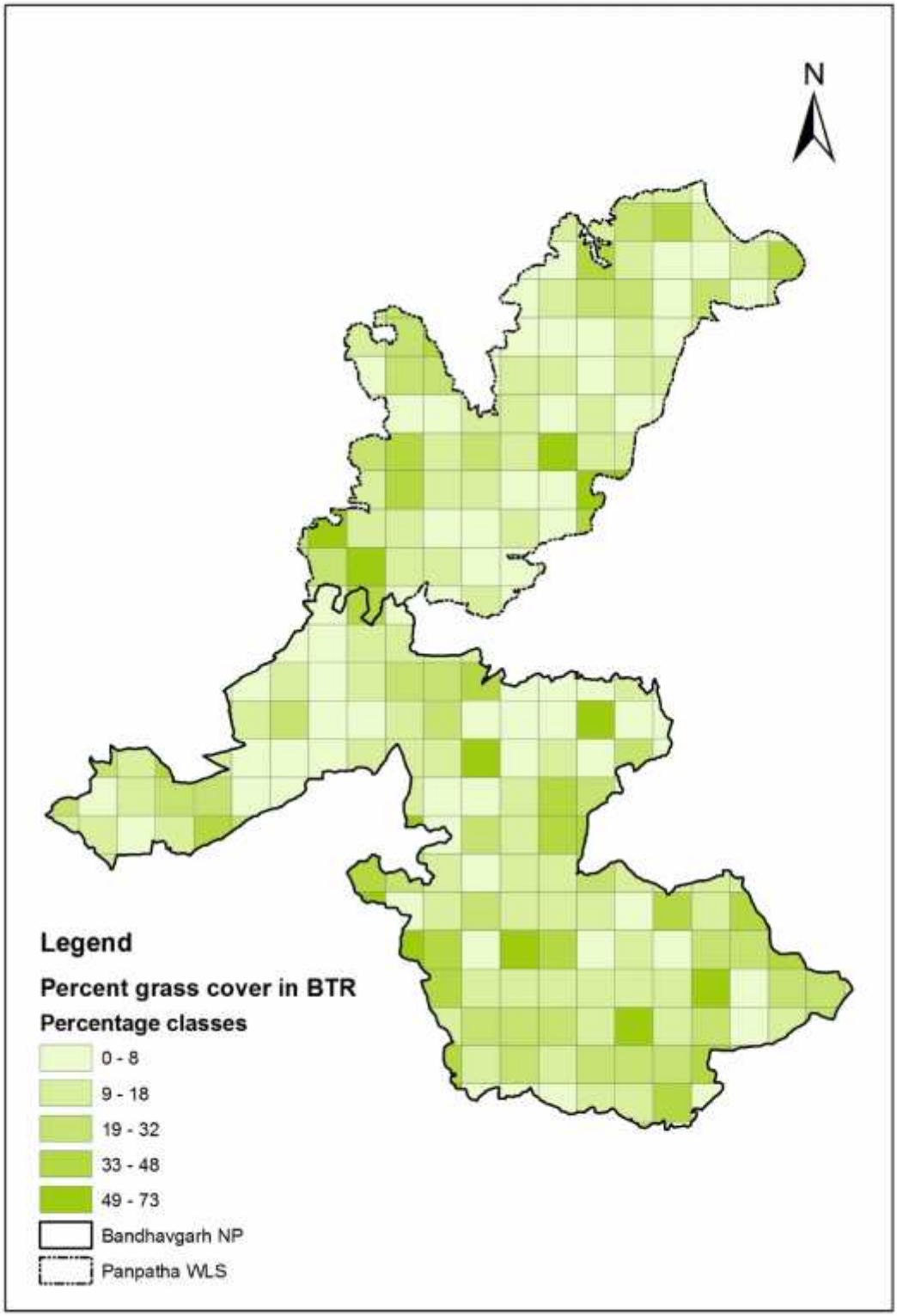


Figure 4.35: Abundance and distribution of percent grass cover in monsoon in Bandhavgarh Tiger Reserve (March 2012-February 2014).

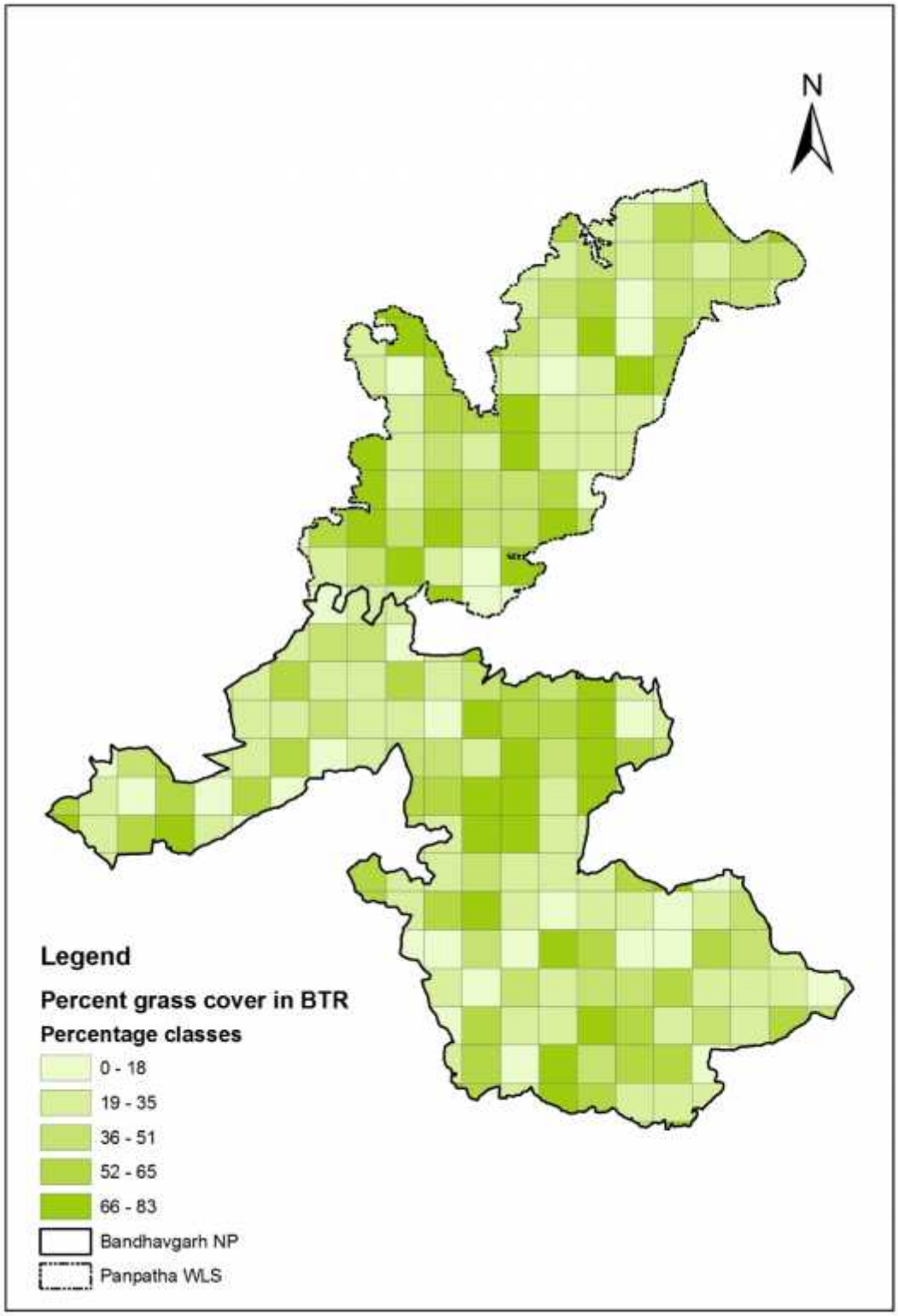
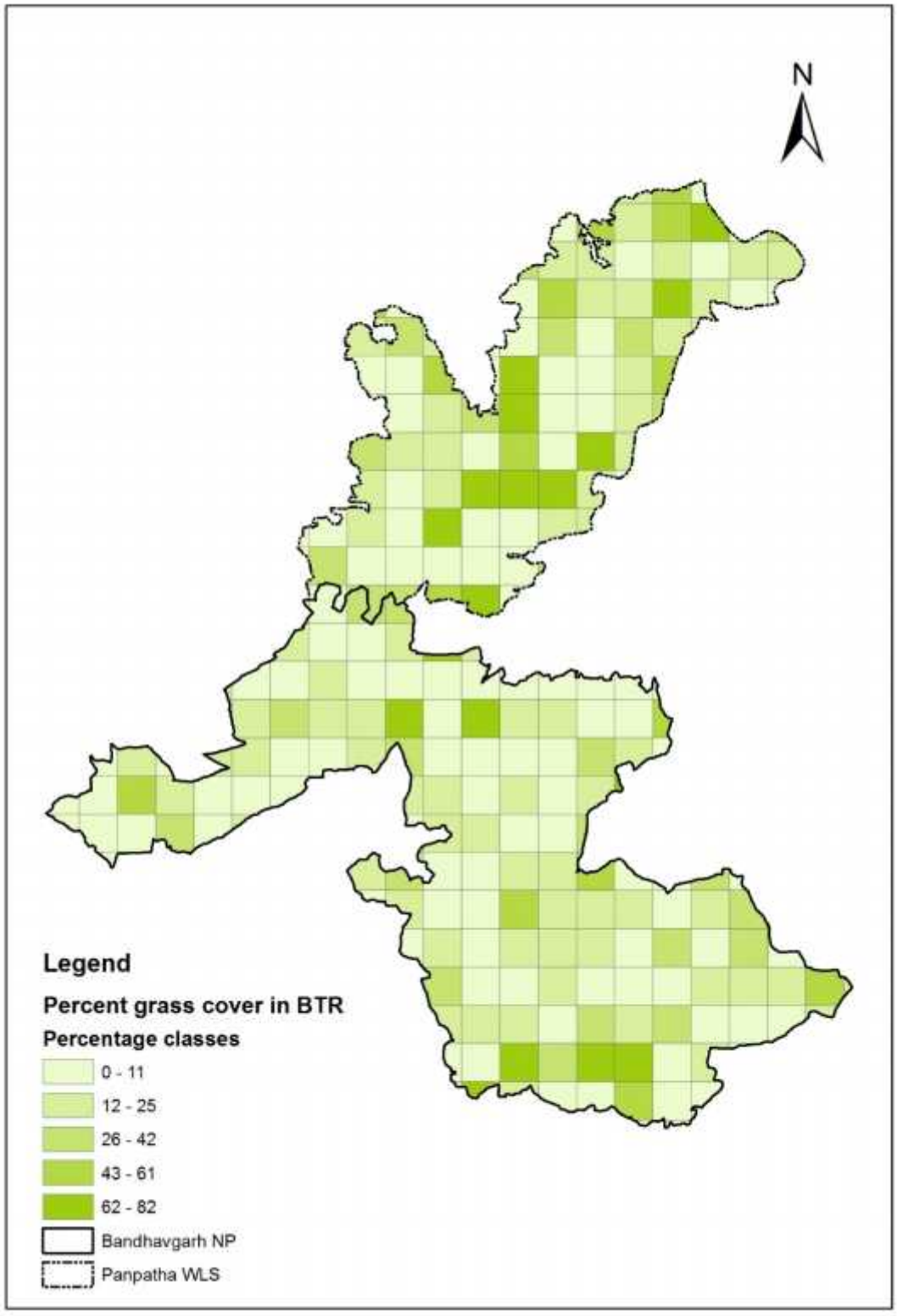


Figure 4.36: Abundance and distribution of percent grass cover in winter in Bandhavgarh Tiger Reserve (March 2012-February 2014).



4.4.11: Food plants of captive elephants in Bandhavgarh Tiger Reserve

A total of 62 food plants eaten by the captive elephants in Bandhavgarh Tiger Reserve were identified during the study period (table 4.17). In total there were 13 captive elephants (8 adults and 5 calves) distributed in different groups in the study area. Of the 62 species of food plants eaten by the captive elephants in the study area, 59 species were eaten by gaur (table 4.17). Thus, of the 82 food plants recorded for gaur (table 4.1) in the present study, 59 were common for gaur and the captive elephants. Hence, in terms of species of food plants eaten by captive elephants, an overall overlap of 72% with the species of food plants of gaur was observed. In summer, of the 52 food plants recorded for gaur (table 4.1), 24 were observed to be common between gaur and captive elephants showing an overlap of 46.2% in terms of species of food plants. Similarly, the overlap observed in terms of food plants species between gaur and captive elephants in monsoon was 69.8% and in winter was 66%.

Table 4.17: Food plants of captive elephants in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Sr. no.	Plant species (Trees)	Family	Parts eaten	Season
1	*Aegle marmelos**	Rutaceae	Le	S
2	*Albizzia procera**	Fabaceae	Le	M, W
3	*Anogeissus latifolia**	Combretaceae	Le	W
4	*Bauhinia veriegata**	Fabaceae	Le	S, W
5	*Boswellia serrata**	Burseraceae	Le	M, W
6	*Bridelia retusa**	Euphorbiaceae	Le	S
7	*Buchanania lanzan**	Anacardiaceae	Le	S, M, W
8	*Cassia fistula**	Fabaceae	Le	S, M, W
9	*Chlorozylon swetiena**	Meliaceae	Le	M, W
10	*Dendrocalamus strictus**	Poaceae	Le, Sh	S, M, W
11	*Diospyros melanoxylon**	Ebenaceae	Le, Roots	S, M, W

12	*Ficus bengalensis**	Moraceae	Le	S, M, W
13	*Grewia tiliifolia**	Tiliaceae	Le	S
14	*Lagerstroemia parviflora**	Lythraceae	Le	S, W
15	*lannea grandis**	Anacardiaceae	Le	M, W
16	*Madhuca indica**	Sapotaceae	Le, Fr, Fl	S, M, W
17	*Miliusa tomentosa**	Annonaceae	Le	W
18	*Mitragyna parviflora**	Rubiaceae	Le	S, M
19	*Mangifera indica*	Anacardiaceae	Le, Fr	S, M, W
20	*Phyllanthus emblica**	Euphorbiaceae	Le, Fr	S, M, W
21	*Randia uliginosa**	Rubiaceae	Le	M
22	*Semecarpus anacardium**	Anacardiaceae	Le	M, W
23	*Shorea robusta**	Dipterocarpaceae	Le, Flb, Fl	S, M, W
24	*Syzygium cuminii**	Myrtaceae	Le, Fr	S, M, W
25	*Tectona grandis*	Lamiaceae	Le	W
26	*Terminalia arjuna**	Combretaceae	Le	S, M, W
27	*Terminalia bellerica**	Combretaceae	Le, Fr	S, M
28	*Terminalia chebula**	Combretaceae	Le	M
29	*Terminalia tomentosa**	Combretaceae	Le	M, W
30	*Zizyphus mauritiana**	Rhamnaceae	Le, Fr	W
31	*Zizyphus xylopyra**	Rhamnaceae	Le, Fr	M, W
32	*Kydia calycina*	Malvaceae	Le	M, W
	Plant species (Shrubs)			
33	*Gloriosa spp**	Colchicaceae	Le	M, W
34	*Holarrhena antidysenterica**	Apocynaceae	Le	M, W
35	*Mimosa hamata**	Fabaceae	Le	M
36	*Phoenix acaulis**	Arecaceae	Le	S, M, W
37	*Woodfordia floribunda**	Lythraceae	Le	M, W
38	*Wrightia tinttoria**	Apocynaceae	Le	S, M, W
	Plant species (Herbs)			
39	*Anthraxon spp.**	Poaceae	Sh	M, W
40	*Desmodium heterocarpus**	Fabaceae	Sh	M
41	*Desmodium pulchellum**	Fabaceae	Sh	M
42	*Euphorbia hirta**	Euphorbiaceae	Sh	M, W
43	*Leucas aspera**	Lamiaceae	Sh	M
44	*Leucas biflora**	Lamiaceae	Sh	M, W
	Plant species (Grasses)			
45	*Aristida setacea**	Poaceae	Sh	M, W
46	*Andropogon spp.**	Poaceae	Sh	M
47	*Bothriochloa spp**	Poaceae	Sh	S, M, W
48	*Chloris dolichostachya**	Poaceae	Sh	M, W
49	*Cynodon dactylon**	Poaceae	Sh	M, W

50	*Cyperus spp.**	Cyperaceae	Sh	S, M, W
51	*Dicanthium spp.**	Poaceae	Sh	M
52	*Digitaria spp.**	Poaceae	Sh	M
53	*Heteropogon contortus**	Poaceae	Sh	M, W
54	*Imperata cylindrica**	Poaceae	Sh	M, W
55	*Phragmites karka**	Poaceae	Sh	S, M, W
56	*Saccharum spontaneum**	Poaceae	Sh	S, M, W
57	*Sorghum halepense**	Poaceae	Sh	S, M
58	*Themeda triandra**	Poaceae	Sh	M, W
59	*Thysanolaena maxima**	Poaceae	Sh	M
60	*Vetiveria zizanoides**	Poaceae	Sh	S, M, W
	Plant species (Climbers)			
61	*Butea superba**	Fabaceae	Le	S, M, W
62	*Bauhinia Vahilii**	Fabaceae	Le	S, W

Le- leaves, Flb- Floral bud, Fl- flower, Fr-fruit, Sh- shoot.

S – summer, M – monsoon, W – winter.

* - food plants eaten by gaur.

4.5: DISCUSSION

Gaur has been described as a generalist feeder (Sankar *et al*. 2001) and is known to feed on a large variety of food plants across many different forest types in India (Schaller 1967, Krishnan 1972, Vairavel 1998, Sankar *et al*. 2001, Gad 2011, Sankar *et al*. 2013). In the present study gaur were observed to feed on 82 species of food plants (table 4.1) which indicates the polyphagous feeding habit of this mega-herbivore. Schaller (1967) reported that such a varied diet of gaur has enabled it to colonize a wide range of vegetation types across its distributional range in the country.

In the present study it was observed that bamboo leaves and grasses formed the bulk of gaur diet in all the seasons. Annually, the percentage time spent grazing by gaur in Bandhavgarh Tiger Reserve was about 84.9% whereas that spent browsing was

15.1% (fig. 4.5). During the study period it was observed that the time spent browsing by gaur was very low as compared to the time spent grazing by gaur in all the seasons. The analysis of gaur dung samples also showed a very high percentage frequency occurrence of monocot plant fragments (summer: 84.8%, monsoon: 90.3% and winter: 92.2%) in all the seasons as compared to dicot plant fragments (fig. 4.25) which indicates that browse species do not form a major portion of the gaur diet in any season in Bandhavgarh Tiger Reserve. Schaller (1967) reported that grasses formed the major portion of gaur diet in summer in Kanha Tiger Reserve. A short study conducted on the small gaur population of Bandhavgarh before its extinction reported that gaur were seen to graze mainly in summer and winter whereas it preferred to browse in monsoon (Lad and Gopal 1992). Vairavel (1998) reported that in Parambikulam Tiger Reserve the time spent grazing by gaur was observed to be high in all seasons as compared to browsing. In Pench Tiger Reserve and Bhagwan Mahaveer Wildlife Sanctuary, gaur has been reported to browse mainly in summer whereas graze predominantly in monsoon and post-monsoon (Sankar *et al*. 2001 and Gad 2011). A study conducted in the Bandipur and Mudumalai Tiger Reserves found that gaur were grazers throughout the year (Ahrestani *et al*. 2012). Apart from gaur, studies on the feeding habits of African buffalo have reported that in some parts of Africa the African buffalo is known to be a primary grazer throughout the year whereas in others it supplements its diet to a large extent with browse in the dry seasons (Jarman 1971, Sinclair 1977, Mloszewski 1983 and Prins 1996).

Among the nutritional contents, crude protein and fibre contents are mainly considered to influence the selection of food plants among herbivores (Gupta 1991).

The main digestion inhibitors present in plant material are considered to be lignin and tannins (Waterman 1983) which interfere with the digestive process among herbivores. The correlation analysis between percent time spent feeding and different nutritional parameters of the major food items of gaur during the present study showed that lignin content and tannin content were good predictors for food selection by gaur since the correlations between percent time spent feeding by gaur and lignin and tannin content were found to be negative in all the seasons. The correlations between time spent feeding and lignin and tannin content were found to be significant in summer whereas they were non-significant in monsoon and winter. The crude protein content of grasses was found to be highest in monsoon (3.2%) whereas the lignin content was observed to be highest in winter (13.2%). Bamboo leaves had the highest crude protein content in monsoon (7.7%) whereas the lignin content was observed to be highest in summer (12.4%). Browse species like *Shorea robusta* in summer and *Butea superba* in monsoon and winter had higher crude protein levels as compared to grasses and bamboo leaves (figs. 4.6 to 4.8) but they also had higher levels of lignin as compared to bamboo leaves and grasses in summer and monsoon (figs. 4.12 and 4.13). In winter bamboo leaves had the lowest content of lignin as compared to grasses, *Shorea robusta* leaves and *Butea superba* leaves (fig. 4.14).

In general the presence of toxins (alkaloids, terpenoids etc.) and digestibility reducing compounds like tannins has been found to be higher in leaves of woody and herbaceous dicots (Owen-Smith 1988). Similarly, in the present study it was observed that among the major food plants of gaur, the tannin content in leaves of dicots like *Shorea robusta*, *Butea superba* and *Chloroxylon swietenia* was higher

compared to that in bamboo leaves and grasses throughout the year (figs. 4.15 to 4.17). Minson (1976) has reported that herbivores can obtain nutrition from fibre contents like unlignified and partially lignified cellulose and hemicellulose but lignin is indigestible. A high fibrous diet increases the digestive efficiency by increasing the retention time of the food in the gut (Owen-Smith 1988). Gaur is a mega-herbivore and all large herbivores, owing to their large body sizes are known to subsist on poorer quality diets (Bell 1971). Prins (1996) has reported that in situations where the available food is low in crude protein content, ruminants may increase the grazing time so as to compensate for the lower quality of diet. In the present study it was observed that the crude protein content of the bamboo leaves and grasses which formed the major food items of gaur was highest in monsoon as compared to summer and winter and the seasonal activity budgets of gaur (chapter 3, figs. 3.2, 3.3 and 3.4) showed that the percentage time spent feeding by gaur in monsoon (34%) was the lowest compared to summer and winter (42.5%, and 39.7% respectively). Thus gaur in Bandhavgarh seem to compensate for the lower crude protein contents in their main food items (bamboo leaves and grasses) in summer and winter by increasing their feeding time in summer and winter as compared to monsoon.

The phenological studies of major food plants of gaur in Bandhavgarh Tiger Reserve showed that among the browse species only the *Chloroxylon swietenia* trees remained mainly leafless in summer whereas *Shorea robusta* trees and *Butea superba* climbers bore leaves throughout the year. Young leaves of *Shorea robusta* emerged in the early part of summer (March-April) which formed a major food item of gaur in the study area. It was observed that the percentage of young bamboo

leaves was highest in summer followed by monsoon (fig. 4.19). Overall it was observed that the bamboo plants were never completely leafless especially in summer when they bore about 65% leaves. The phenology of major grass species like *Saccharum, Vetiveria* and *Phragmites* showed that the percentage availability of young shoots was the highest in monsoon and was lowest in winter. It was also observed that the percentage availability of green grass was higher than that of dry grass in summer and monsoon whereas the percentage of dry grass was higher in winter (table 4.12).

Long-term studies on gaur in Pench Tiger Reserve and Bhagwan Mahaveer Wildlife Sanctuary (Sankar *et al*. 2001 and Gad 2011) have reported that gaur grazes mainly in monsoon and post monsoon but switches over to browsing in summer. It has been reported by Sankar *et al*. (2001) that in Pench Tiger Reserve, during summer the herbaceous layer almost dried up which resulted in poor quality of food resources for gaur and that this was the probable reason for gaur feeding mainly on available browse species in summer. Gad (2011) has also reported that due to a decrease in the green vegetation in summer in Bhagwan Mahaveer Wildlife Sanctuary, gaur switched to browsing mainly in summer. In Bandhavgarh Tiger Reserve the continued availability of bamboo leaves and green grasses throughout the year seems to be the reason that the time spent grazing by gaur does not show any significant difference across the seasons and is high throughout the year.

The land use/land cover map of Bandhavgarh Tiger Reserve showed that of all the vegetation types, the mixed forests covered the largest area in the reserve. Bamboo (*Dendrocalamus strictus*), which formed the major food resource of gaur in the

study area is widely distributed in Bandhavgarh Tiger Reserve. About 12.6% area is covered by bamboo forest in the reserve and apart from that bamboo also forms a major part of the mixed forest vegetation type in Bandhavgarh Tiger Reserve. Presently the entire reintroduced gaur population is distributed in the National Park zone of the reserve which has more areas with high bamboo density as compared to the Wildlife Sanctuary zone of the reserve (fig. 4.30). In the present study the utilisation of bamboo as a food resource by gaur was observed to be higher than its availability in all the seasons and also the use of bamboo leaves as a food resource by gaur was highest compared to other food items in monsoon and winter. Grasses are the other major food resource of gaur in Bandhavgarh Tiger Reserve and its utilisation was the highest compared to other food items by gaur in the dry season. The percentage area under grasslands in Bandhavgarh Tiger Reserve is quiet low (table 4.16) and hence management of grasslands, especially in summer is very important as the time spent feeding by gaur on grasses is the highest in summer and also gaur use grasses more than their availability in summer.

In Bandhavgarh Tiger Reserve, most of the grasslands become dry by the end of winter and systematic burning of the grasslands is undertaken by the forest staff during this time of the year. Presently, there are 12 villages located inside the core area of Bandhavgarh Tiger Reserve. Between 2011 and 2013 three villages (Kallwah, Kumarwah and Magdhi) were relocated from the core area of Bandhavgarh Tiger Reserve and the village relocated sites have been transformed into grasslands having mainly species like *Saccharum spontaneum* and *Vetiveria zizanoides*. These grasslands (on the relocated sites) have been observed to be used

extensively by gaur during the study period and have become important feeding sites for gaur in the study area.

During the study period there were 13 captive elephants in Bandhavgarh Tiger Reserve. There was observed to be an overall overlap of 72% in the food plant species of captive elephants and gaur in Bandhavgarh Tiger Reserve. A certain amount of stall feeding is carried out for the captive elephants and they are also let loose in the night for feeding into the forest. Bamboo leaves and grass species like *Saccharum* and *Vetiveria* which are important gaur food plants also form a major food source of the captive elephants in Bandhavgarh. Since at present the gaur population is low in Bandhavgarh Tiger Reserve (n=72) and the availability of major food items like bamboo leaves and grasses is considerably high throughout the year it is highly unlikely that presently there is any competition for food resources between gaur and the captive elephants. However, as the gaur population increases over a time period, competition for the available food plants may arise between the two mega-herbivore species in Bandhavgarh Tiger Reserve. For a better understanding of this aspect there is a need for a long-term study of the food habits of the captive elephants and gaur in Bandhavgarh Tiger Reserve.

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Appendix

Appendix I: The season-wise hours of observation and scan records for each age and sex class of gaur in Bandhavgarh Tiger Reserve (March 2012-February 2014).

Season	Total hours of observation	Scan records for different age & sex classes of gaur						
		Adult cow	Sub-adult cow	Yearling	Calf	Sub-adult bull	Brown bull	Black bull
Summer 2012	40.1 hrs	667	302	264	98	269	48	70
Monsoon 2012	58.4 hrs	772	862	158	224	318	56	83
Winter 2012-13	50 hrs	657	510	153	240	167	75	75
Summer 2013	87.2 hrs	2011	935	373	933	357	249	356
Monsoon 2013	58.2 hrs	1324	890	102	593	194	133	101
Winter 2013-14	57 hrs	1093	485	380	484	29	132	108
Total	**350.9 hrs**	**6524**	**3984**	**1430**	**2572**	**1334**	**693**	**793**

Publication

Research Article

Home range, habitat use and food habits of re-introduced gaur (*Bos gaurus gaurus*) in Bandhavgarh Tiger Reserve, Central India.

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Abstract:

Gaur, which became locally extinct before 1995 in Bandhavgarh Tiger Reserve (BTR), Central India, is an endangered animal per Schedule – I of the Indian Wildlife Protection Act (1972). A re-introduction program was therefore created to rebuild the gaur population in BTR, both to enhance the long-term survival of the species and to restore natural biodiversity. After re-introduction, the home range, habitat use and food habits of gaur (*Bos gaurus gaurus*) were studied in BTR, India, from January 2011 to January 2012. Nineteen gaurs (five males - three radio-collared and 14 females - nine radio-collared) were re-introduced from Kanha Tiger Reserve to Bandhavgarh Tiger Reserve in January 2011. The reintroduced gaurs were monitored periodically through ground tracking and satellite GPS fixes. The mean annual group size of gaur was estimated at 7.3 ± 0.76 (SE). The overall estimated summer, monsoon and winter home ranges of gaur were 290 km^2, 137 km^2 and 155 km^2 (Minimum Convex Polygon) respectively. The overall individual male home ranges varied from 135 to 142 km^2, and overall individual female home ranges varied from 32 to 169 km^2. Radio collared locations were plotted on a classified (LISS III) habitat map of Bandhavgarh Tiger Reserve to evaluate the habitat use and availability in each season. Habitat preference was computed using Bonferroni confidence interval method, compositional analysis and Ivlev's index. In summer, gaur largely preferred grassland (P<0.0001), whereas in monsoon and winter, gaur preferred bamboo mixed forest (P<0.0001). Gaur avoided open mixed forest (P<0.0001) and agricultural land in all three seasons. Data on food habits were collected through opportunistic sightings. In total, gaur fed on 68 plant species. The present study has reported first-time information on ranging patterns of reintroduced gaur and their degree of preferences for different vegetation and terrain types across seasons, which will be very useful to the park administration for future conservation of this endangered species and for habitat intervention.

Key words: Reintroduction, gaur *(Bos gaurus gaurus),* home range, habitat use, food habits, Bandhavgarh Tiger Reserve.

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Introduction

Gaur (*Bos gaurus gaurus*), family Bovidae, is one of the large wild ungulates of Asian jungles. Gaur is an endangered animal per Schedule – I of the Indian Wildlife Protection Act (1972). It is included in Appendix I of the Conservation on International trade in Endangered Species of Wild Fauna and Flora (CITES) and categorized as Vulnerable by the International Union for Conservation of Nature and Natural Resources (IUCN). Gaur is the tallest living ox [1], and one of the four heaviest land mammals (elephant, rhino and wild buffalo are the other three). Adult gaur bulls weigh 600-940 kg and stand 1.6 to 1.9 m at shoulder [2]. The adult cows are about 10 cm shorter in height [3] and weigh about one fourth less than the adult males [4]. Formerly gaur were distributed throughout the forested tracts of India and South Nepal, east to Vietnam and south to Malaya [5]. According to Ranjitsinh [6] the estimated population of gaur in India is between 12,000 and 21,000. Sankar et al. [7] estimated the gaur population in India to be approximately 23,500. Presently gaur occur in 101 existing and 27 proposed Protected Areas (PA's) of India covering 15 states. Tropical Moist Deciduous and Tropical Dry Deciduous forests are the dominant vegetation types within the present distribution limits of gaur [7].

The gaur population in India co-occurs with elephants (*Elephas maximus*) throughout its present distributional range, except in the Central Indian highlands, where elephants have become extinct [8]. Presently gaur are distributed in more or less isolated pockets, largely corresponding to the major mountain systems of the Western Ghats, the Central Indian highlands and the North-Eastern Himalayas, including the hills south of Brahmaputra. As ecosystem landscapers, gaur play an important role in the moist and dry deciduous forests in India, as they have a major impact on the physical structure of habitats, rates of ecosystem processes and the diversity of communities [9]. Also, mega-herbivores like gaur are important modifiers of ecosystem structure and function because they can trigger trophic cascades [10-11], increase spatial heterogeneity, accelerate successional processes [12] and influence nutrient cycling and primary productivity [13].

The last small population of gaur (30 to 32 individuals) migrated out of the Bandhavgarh Tiger Reserve (BTR) in 1995. This population was considered to be the only population north of the Narmada River, in Central India. The local extinction of gaur from the park also resulted in loss of biodiversity and decline in tourist numbers in the park [14]. Since BTR also has a considerable population of tigers (n~50), it was important to have gaur in the park as a prey species of tiger [14].

For the last two decades, captive breeding, reintroduction and translocation programs have become increasingly important conservation tools [15-16], although there are two important obstacles to re-establishing species: first, understanding the fundamental ecological requirements and life histories of species of concern [17], and second, identifying appropriate areas for reintroduction or restoration, given that degradation or modification can render native habitats unsuitable [18-19]. A study [20] showed that young rhino males do not adapt quickly to a new environment and hence are susceptible to high mortality, whereas adult and near adult males and females adapt faster. Another factor in the success of reintroductions is whether animals remain where they are released [21]. There are few reintroductions of mega-herbivores and herbivores reported, *viz.,* reintroduction of bison (*Bison bison*) into the rocky mountain parks of Canada [22], elk (*Cervus canadensis*) in America [23], reindeer (*Rangifer tarandus*) in Finland [24], white rhinoceros (*Ceratotherium simum*) in Botswana [25] and Asiatic One-horned Rhinoceros (*Rhinoceros unicornis*) in Dudhwa Tiger Reserve, Uttar Pradesh [26].

The re-introduction program to re-build the gaur population in Bandhavgarh Tiger Reserve (BTR) translocated and reintroduced an initial population of 20 animals, with subsequent supplementation of 30 more animals; the sex ratio was 60% females and 40% males. The simulations of gaur population viability analysis (PVA) showed that the probability of survival of reintroduced gaur in BTR is 0.9400

(0.023 SE). This program is the first successful mass trans-location of gaur in its entire distributional range. Following re-introduction of gaur in BTR, the present study was conducted from January 2011 to January 2012 with the following objectives: a) to estimate the home ranges of gaur in different seasons, b) to understand the habitat use and habitat preference of gaur in different seasons and c) to estimate the food habits of gaur.

Methods

Study area

Bandhavgarh Tiger Reserve lies on the extreme north-eastern border of the Madhya Pradesh state and the northern flanks of the eastern Satpura Mountain range (23°30' 08" to 23°47'05" N and 80°11'43" to 80°47'05" E). BTR consists of two conservation units: Bandhavgarh National Park (442.842 km^2) and the Panpatha Wildlife Sanctuary (245.842 km^2). The altitude of the park varies between 410 m and 811 m. The terrain is of rocky hills rising sharply from the swampy and densely forested valley in the low land. BTR lies within the tropical zone, having three distinct seasons. The area is characterized by well-defined winter (November-February), summer (March- June) and monsoon-post monsoon (July- October). During the study period, the lowest temperature reported was 2.2 °C in winter, and the highest was 44 °C in summer. Average rainfall is 1,173 mm, most of which occurs during the monsoon [27].

Vegetation of BTR falls under five categories [28]: moist peninsular low level sal (*Shorea robusta*) forest ($3C/C_{2e}$), northern dry mixed deciduous forest ($5B/C_2$), dry deciduous scrub (DS_1), dry grassland ($5/DS_4$) and West Gangetic moist mixed deciduous forest ($3C/C_{3a}$). Wild herbivores found are chital (*Axis axis)*, sambar (*Rusa unicolor)*, barking deer (*Muntiacus muntjak)*, nilgai *(Boselaphus tragocamelus)* and chinkara (*Gazella bennettii)*; large carnivores are tiger *(Panthera tigris)* leopard *(Panthera pardus*) and dhole (*Cuon alpinus*). The scavengers/ omnivores consist of striped hyena *(Hyaena hyaena)*, golden jackal (*Canis aureus*), wild pig *(Sus scrofa)* and sloth bear *(Melursus ursinus)*. Other small carnivores such as jungle cat (*Felis chaus*), rattle (*Mellivora capensis*), common mongoose *(Herpestes edwardsi*), ruddy mongoose (*H. smithi*), palm civet (*Paradoxurus hermaphroditus*) and small Indian civet (*Viverricula indica*) are also found. Primates such as common langur *(Semnopithecus entellus)* and rhesus monkey *(Macaca mulatta)*, and rodents/lagomorphs such as porcupine (*Hystrix indica)* and rufous-tailed hare *(Lepus nigricollis ruficaudatus)* occur in the park.

There are 15 villages (with human population of 6160 and livestock population of 11042) located inside the Tiger Reserve, of which seven are located in National Park and are due for relocation. Large numbers of domestic buffaloes (*Bubalus bubalis*) and a few domestic brahmini cattle (*Bos indicus*) are kept in the villages.

Capture and translocation of gaur

The action plan was prepared by the Madhya Pradesh Forest Department which envisaged capture and reintroduction of 20 gaur (15 adult females and 5 adult males) from KTR to BTR, Madhya Pradesh. It was proposed that after careful monitoring of the initial reintroduced stock, reintroduction of 30 more gaur to Bandhavgarh would be undertaken within two years to maintain a viable population of approximately 50+ animals [14].

Nineteen gaur, five males (three sub adults, two adults) and 14 females (one yearling, six sub adults, seven adults) were captured from KTR between 21st January and 27th January 2011 and re-introduced into BTR. Of these, 12 animals were fitted with radio collars: two adult males with GPS/satellite collars

and 10 individuals with VHF collars (one male and nine females). A holding Boma (enclosure for large herbivores; *Swahili* term, Mozambique) was designed at KTR where the immobilized animal would be released before eventually being loaded in the transport truck. The Boma was constructed of steel sections 2.5 m high by 3 m long made out of 50 mm x 75 mm x 3 mm rectangular hollow tubes. The Boma had three sliding gates 1.5 m wide and 2.5 m high sliding on a 3 m rail. The Boma had a loading ramp, which was a 3 m section made of solid pressed steel at 2.5 m height. The steel sections of the Boma beyond the sliding gate were covered with agri-mesh all the way up to the entrance of the truck. Since gaur are forest dwelling animals, this was done to give them a sense of having a space to hide in. Branches with foliage were hung on the wires running across the Boma. The Boma was divided into two compartments using bamboo mats and sliding gate, providing food, water and salt in the last compartment. Transport trucks and containers were designed according to the animals' needs. A stretcher was specially designed for carrying immobilized animals from the site of capture to the vehicle. A suitable site with good vegetation, cover and water was selected for the soft release of gaur at the borders of Tala and Magdhi ranges at BTR. The reintroduced gaur were released in a power-fenced 50 hectare plot in BTR. On 20th March 2011 the reintroduced gaur were released into the wild.

Home range

The radio-collared gaurs were monitored periodically through ground tracking, using "homing in" and "triangulation" techniques [29-31]. The satellite data up-link in both the satellite collars ceased functioning, one in August 2011 and the other in October 2011. Thereafter the gaur were tracked by VHF signals (ground tracking). The Minimum Convex Polygon (MCP) technique was used to determine the home-ranges of the gaur [32-34]. The interpretation and comparison of home-range size were measured by 100% MCP. The use of MCP was justified because of the sample size in a one year study period, and the temporally clustered nature of fixes that resulted in autocorrelation of results [35]. Accurate analyses using Fixed Kernel methods would not be suitable with this data set because they generally require larger samples with a more even distribution of the locations to maintain accuracy [36]. Minimum Convex Polygon (MCP) technique is one of the oldest techniques for home range estimation, comparable among species globally, and its inclusion as one or more methods of range calculation is therefore valuable [32-34]. Program CALHOME [37] and ArcGIS 9.2 (ESRI 2006) were used to estimate the home ranges of gaur. Home ranges of each individual in different seasons were estimated in the present study. Since gaur is a group living animal, the home ranges were also grouped by males and females to understand their overall seasonal home ranges.

Habitat use

All the radio telemetry locations from 12 radio-collared gaur were analyzed to evaluate the habitat use patterns. Season-wise gaur locations were plotted on the classified Landsat ETM+ imagery of BTR. On each collared location, the major vegetation and terrain type were recorded. Seven vegetation types were classified from Landsat ETM+ imagery: sal (*Shorea robusta*) forest, bamboo forest, open mixed forest, mixed forest, riparian forest, grassland and agriculture land [38]. Three major terrain types were categorised in the study area, *viz.,* flat, gentle slope and steep slope. Habitat use by gaur was estimated as the percent of locations found in each vegetation and terrain type. The 100% MCP home range represents the total area within which an animal has the opportunity to choose different vegetation types. Therefore, the availability of different vegetation types (percentage area) to a gaur was computed within its 100% MCP home range in a GIS domain [39]. Subsequently, habitat use (vegetation and terrain) of gaur in each season was computed using Bonferroni simultaneous confidence intervals and

Chi-square test [40], and the result was further validated by the preference rank of different vegetation types through compositional analysis [38] and Ivlev's electivity Index [41]. The analytical methods (Bonferroni simultaneous confidence intervals and compositional analysis) were conducted using the program RSW (Resource Selection Analysis Software for Windows) [42]. Each gaur was considered as a sample for statistical analysis [43].

Food habits

Data on food habits of gaur were collected by opportunistic sightings in all seasons whenever the animals were located using radio-telemetry. After direct observation through binoculars (8 X 40), on-site inspections were made to identify the food plants and parts eaten by gaur in the field. Total time spent for recording food habits data was 146 hrs in summer, 139 hrs in monsoon and 161 hrs in winter.

Results

Group size and composition

The group size of gaur varied from 1 to 19 individuals. The two gaur bulls (GM3 and GM5) were found solitary on many occasions (n=138) in all seasons (summer, monsoon and winter) and would join the family groups for a span of 10-15 days. The mean annual group size of gaur was estimated as 7.3 ± 0.8 (SE). The mean group size of gaur in summer was 9.5 ± 0.8 (SE), in monsoon 7.6 ± 1.4 (SE) and in winter 5.3 ± 1.2 (SE).

Home range of gaur

In total, 3972 locations of radio collared gaur were obtained, of which 1579 locations were males and 2393 locations were females (March 2011 to January 2012). The number of radio collared locations obtained and home ranges of individual gaur are given in Appendix 1. The month-wise utilized area (in km^2) by the gaur is given in Fig. 1.

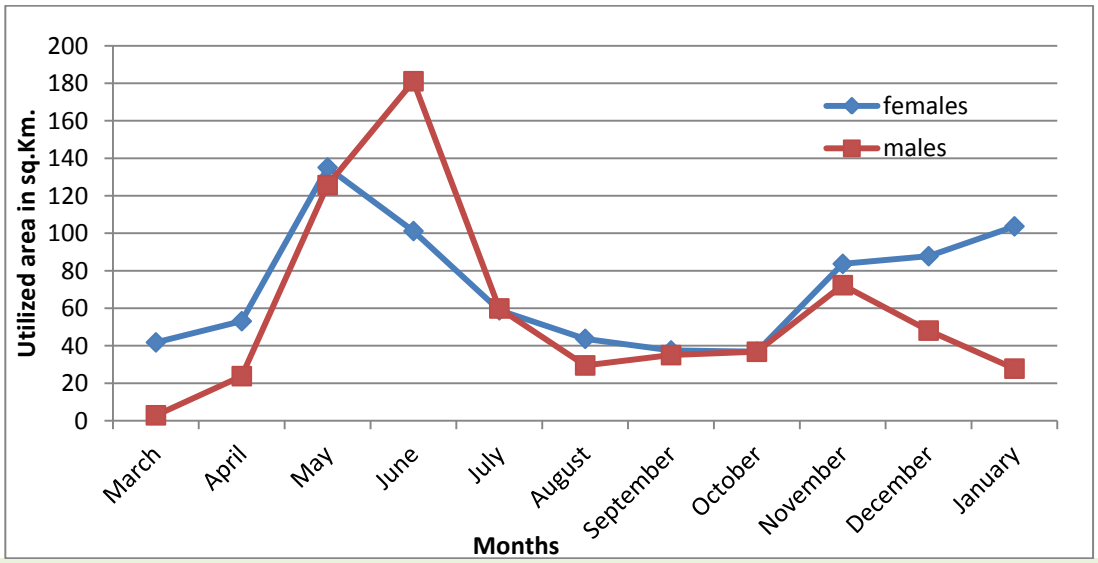

Fig. 1. Month-wise area of utilization of gaur in Bandhavgarh Tiger Reserve (March 2011- January 2012).

The estimated summer, monsoon and winter home ranges of the gaur were 290 km^2, 137.1 km^2 and 155 km^2 respectively. The overall home ranges of the males and females during the study period (March 2011 to January 2012) were 255 km^2 and 200 km^2, respectively, and the home-range overlap was 186 km^2 (Fig. 2). The summer (March 2011-June 2011) home ranges for males (n= 559) and females (n= 1338) were 231 km^2 and 161 km^2, respectively. In monsoon and post-monsoon (July 2011 to October 2011) the home ranges of males (n= 607) and females (n= 828) were 111 km^2 and 136 km^2 respectively. In winter (November 2011 to January 2012) the home ranges of males (n= 227) and females (n= 413) were 98 $km^2$and 152 km^2 respectively (Fig. 3). The overall individual male home ranges varied from 135 to 142 km^2 and overall individual female home ranges varied from 32 to 169 km^2.

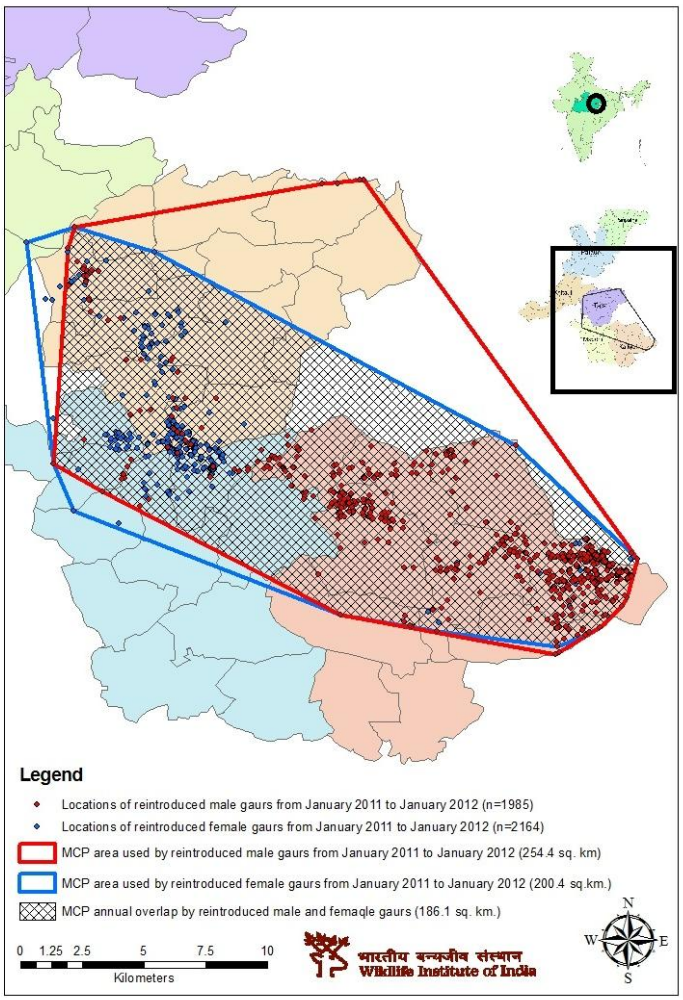

Fig.2. Overall home range of male and female gaur and their area of overlap in Bandhavgarh Tiger Reserve (March 2011- January 2012).

Natality and Mortality

There were four births during the study period, of which three calves survived. In total four animals died, of which two were collared females that died naturally. A sub-adult female was killed by a tiger on 4th June 2011. An un-collared female went missing from the park on 27th March 2011.

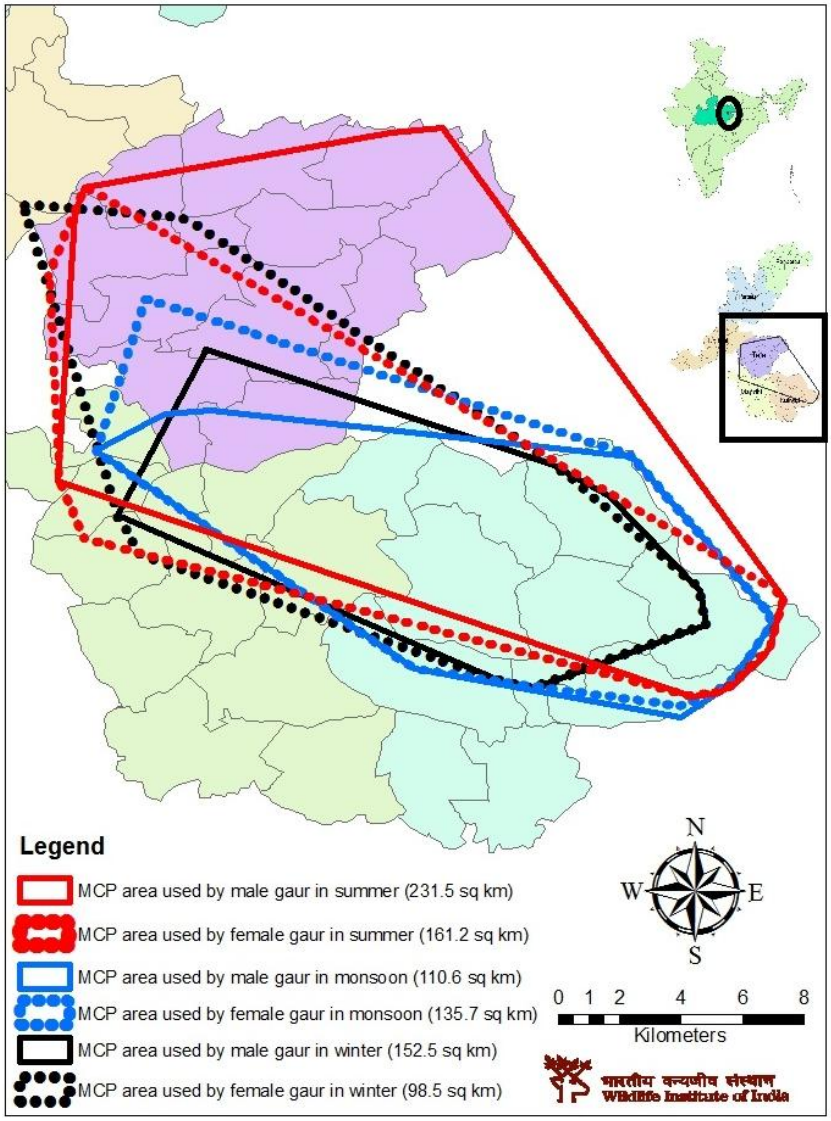

Fig. 3. Locations and home range of gaur season-wise (summer, monsoon and winter) in Bandhavgarh Tiger Reserve.

Habitat use by gaur

In summer, gaur used grassland ($P<0.001$) and sal forest ($P<0.001$) habitats more than their is availability; mixed forest ($P<0.001$), open mixed forest ($P<0.001$) and agricultural land ($P<0.001$) were less used than their availability; bamboo forest and riverine forest were used in proportion to their availability ($X^2=62.6731$, df= 6, $P<0.0001$, $\lambda= 0.0054$; Bonferroni simultaneous confidence intervals and Chi-square test) (Appendix 2). The summer habitat preference of gaur was in the following order: grassland> sal forest> bamboo forest> riparian forest> mixed forest> agricultural land> open mixed forest. In monsoon, gaur used bamboo forest ($P<0.001$) more than its availability; mixed forest ($P<0.001$), open mixed forest

(P<0.001) and agricultural (P<0.001) land less than their availability; grassland, sal forest and riparian forest were used in proportion to their availability (X^2=54.2351, df= 6, P<0.0001, λ= 0.028; Bonferroni simultaneous confidence intervals and Chi-square test) (Appendix 2). The monsoon habitat preference of the gaur was in the following order: bamboo forest >grassland> sal forest> mixed forest> riparian forest> open mixed forest> agricultural land. In winter, gaur used bamboo forest (P<0.001) more than its availability; grassland (P<0.001), sal forest (P<0.001), open mixed forest (P<0.001) and agricultural land less than their availability; mixed forest and riparian forest were used in proportion to their availability (X^2=33.0898, df= 6, P<0.0001, λ= 0.016; Bonferroni simultaneous confidence intervals and Chi-square test) (Appendix 2). The winter habitat preference of gaur was in the following order: bamboo forest> mixed forest> riparian forest> sal forest> grassland> open mixed forest> agricultural land. Ivlev's electivity Index provided identical results as compositional analysis for ranking of preference of different habitats by gaur in BTR (Appendix 3).

Gaur mostly used flat terrain (65%) compared to gentle slope (28%) and steep slope (7%). The use of undulating terrain by gaur increased in monsoon and winter compared to summer. The use of terrain with a gentle slope went up from 25% in summer to 45% in winter. Gaur used flat terrain mostly in summer (71%) followed by monsoon (63%) and winter (51%). The steep slope was used by gaur mostly in monsoon (12%) followed by winter (4%) and summer (4%).

Food habits

In total 68 plant species were consumed by gaur (Appendix 4). Among the food plants eaten the number of tree species were maximum (n=28) followed by grass (n=21), herbs (n=10), shrubs (n=6) and climbers (n=3). The number of tree species in the diet of gaur was considerably higher in summer (n=22) than in monsoon (n=11) and winter (n=9). On the other hand, the number of grass species consumed by gaur was higher in monsoon (n=14) than in summer (n=10) and winter (n=9). Five incidences of de-barking of sal (*Shorea robusta*) and three incidences of de-barking of mahuwa (*Madhuca indica*) by the gaur were recorded in peak summer.

Discussion

The group size of gaur may range from 1 to 16 animals [1, 7, 44-46] and occasionally up to 40 individuals [47-48]. In Pench Tiger Reserve the observed mean group size of gaur was highest in winter (5.6 ± 0.42), followed by monsoon (4.6 ± 0.29) and summer (3.9 ± 0.14), and significant differences in the group sizes between summer and monsoon were reported [7]. In Mudumalai Tiger Reserve, the overall mean group size of gaur was 9.8 ± 7.6, while in dry season it was 8.7 ± 6.2 and in wet season it was 10.2 ± 7.9 [49]. In Parambikulam Wildlife Sanctuary the mean group size of gaur was 6.0 [50]. In the present study there was no significant difference observed in the gaur group size in different seasons. Hence, it can be assumed that different seasons played a negligible role in determining group size of gaur in BTR.

It was observed that the relocated gaur initially (March 2011 to June 2011) utilized an area of 290 km^2 after their reintroduction, and subsequently their ranges were reduced to 160 km^2 after exploration of new areas. In Pench Tiger Reserve, the home range of male gaur was 12.6 km^2 and 7.6 km^2 in summer and monsoon respectively, while in the present study, the home ranges of male gaur were much larger. The home ranges of female gaur in Pench Tiger Reserve were 7.2 km^2 and 13.8 km^2 in summer and monsoon respectively, while in the present study, the home ranges of female gaurs were much higher. The observed smaller home ranges of gaur males and females in all seasons in Pench Tiger Reserve may be attributed to the availability of food resources and water through the year [7]. In BTR, gaur were found to utilize grasslands more during summer and bamboo forest more in monsoon and winter. Gaur

is a generalist feeder but prefers to browse in dry season and predominantly graze in monsoon [49]. Riparian forest was used by the gaur according to its availability in all the seasons, because a number of perennial streams and artificial waterholes are found in riparian forests which serve as the major source of water in the Park. Open mixed forest was avoided by gaur in all seasons, as it lacks food resources and water. Agricultural land was avoided by gaur in all seasons because of anthropogenic disturbance. In Kanha Tiger Reserve gaur frequently used the meadows and low-lying areas during most part of the year except monsoon, when the animals moved up and dispersed into the hills [47]. In Bandhavgarh also the gaur used areas with steep slope more in monsoon than in summer and winter.

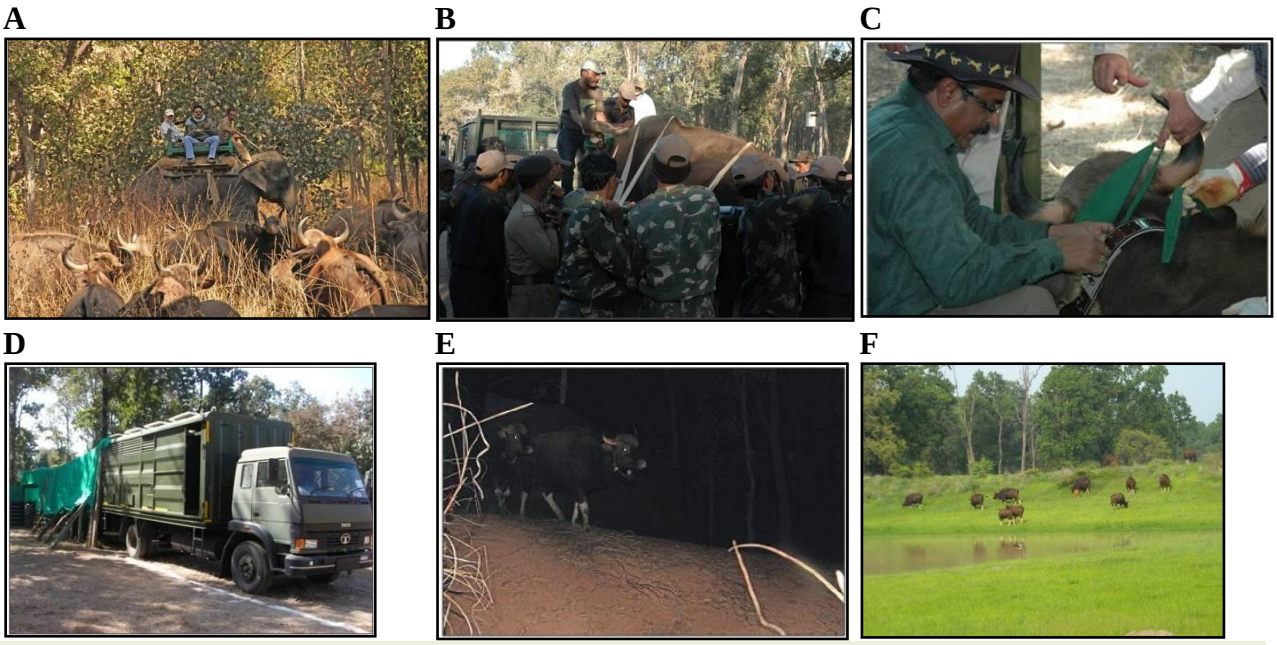

Fig. 4. A: Gaur Capture in Kanha Tiger Reserve; B: Gaur shifting into a small truck in Kanha Tiger Reserve; C: Fitting of radio-collar on gaur at Kanha Tiger Reserve.; D: Truck used to transport gaur from Kanha TR to Bandhavgarh TR.; E: Gaur released in an enclosure at Bandhavgarh Tiger Reserve; F: A herd of free ranging gaur in Bandhavgarh TR. PHOTO CREDITS – By Authors

Gaur have been reported to feed on the bark of trees such as *Adina cordifolia* and *Tectona grandis* in many areas throughout central India [47, 51]. In dry seasons, a high fibrous diet increases digestive efficiency by increasing the retention time of food in the gut [52] and also by increasing the turnover rate of the rumen content [53]. Incidences of de-barking of trees by gaur were rare in BTR, perhaps because even in summer considerable green foliage (trees/shrubs/bamboo) is available in the park.

Village relocation plays a major role in reducing the anthropogenic pressures on the forest area and is highly beneficial to wild animals [54]. In BTR there are 15 villages with large livestock populations located inside the National Park. Two villages in Kallwah range (Kallwah and Kumuruwah) from the National Park were successfully relocated in June 2011, which can set an example to expedite relocation of the remaining villages. Since August 2011, gaurs have been observed using these relocated village sites and hence creation of more such vacated habitats is vital for conservation of this species. Gaur are highly susceptible to transmission of infections from domestic livestock, and there are many records of populations of gaur succumbing to epidemics of foot and mouth disease (FMD), rinderpest and anthrax

in various parts of its distributional range [55]. There is a need to implement a wide vaccination program for the domestic livestock in and around BTR, to prevent the transmission of livestock diseases to gaur.

Implications for Conservation

The known extinction of gaur from three protected areas in India (Thattakad Wildlife Sanctuary, Kerala; Bhandhavgarh Tiger Reserve and Kanger Valley National Park, Madhya Pradesh) in the last two decades shows that this species is losing ground very fast and urgent measures are required to stem the process. Therefore, conservation requires active programs like reintroduction and reestablishment of important species in the areas where they have been recently lost, with or without habitat related interventions. Hence, the gaur reintroduction program in Bandhavgarh Tiger Reserve is an important attempt to re-establish a gaur population in an area that was once part of its historical range, from which it was locally extirpated in the recent past (Fig. 4). The present study takes a successful step towards the conservation of this large bovid, providing first-time information on ranging patterns of gaur and their degree of preferences for different vegetation and terrain types in different seasons. Such information will be very useful to the park administration for conservation of this endangered species and for habitat intervention, if needed. Per the proposed supplementation plan, 31 more gaur (nine males and 22 females) were reintroduced in BTR during March 2012 to establish a viable population of 50 animals.

A long-term study on ecological aspects such as ranging pattern, habitat use, food habits and predation of the reintroduced gaur in BTR will be crucial for the conservation and management of this endangered bovid. Also, the protocol prepared for gaur capture, chemical immobilization and transportation [14] will be highly useful for managers and conservationists in planning and execution of similar reintroduction program of mega-herbivores in their entire distributional range.

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Appendix 1. Home ranges of individual gaur in different seasons (summer, monsoon and winter) in Bandhavgarh Tiger Reserve.

Gaur ID	Summer	Monsoon	Winter			
	Home range (km^2)	Number of locations	Home range (km^2)	Number of locations	Home range (km^2)	Number of locations
GF1	44.5	196	108.7	207	83.4	81
GF3	44.5	194	108.7	207	95.9	81
GF5	33.1	119	xx	-	-	-
GF6	110.4	106	^^	-	45.8	86
GF7	106.5	106	xx	-	-	-
GF8	106.5	164	108.7	207	95.9	81
GF9	110.6	139	^^	-	^^	-
GF10	44.5	178	108.7	207	95.9	84
GF14	123.6	136	^^	-	^^	-
GM1	44.5	196	108.7	207	95.9	81
GM3	45.2	196	108.7	207	87.7	79
GM5	231.5	167	110.6	193	95.3	67

Note: GF= Gaur female; GM= Gaur male; 'xx'= animal dead; '^^'= animal was kept inside enclosure.

Appendix 2. Preference of different vegetation types by gaur in Bandhavgarh Tiger Reserve as shown by Bonferroni simultaneous confidence interval analysis.

Habitat types	Proportion use		Proportion available	Preference	Significance
	Lower limit	Upper limit			
Summer					
Agriculture land	0.0000	0.0112	0.0148	Used less than availability	
Bamboo forest	0.1412	0.1996	0.1862	Used in proportion to availability	
Grassland	0.3573	0.4332	0.0935	Used more than availability	P < 0.0001
Mixed forest	0.1406	0.1989	0.4535	Used less than availability	P < 0.0001
Open mixed forest	0.0087	0.0301	0.0659	Used less than availability	P < 0.0001
Riparian forest	0.0079	0.0287	0.0278	Used in proportion to availability	
Sal forest	0.1893	0.2537	0.1582	Used more than availability	P < 0.0001
Monsoon					
Agriculture land	0.0000	0.0000	0.0134	Used less than availability	
Bamboo forest	0.3525	0.4523	0.1758	Used more than availability	P < 0.0001
Grassland	0.0757	0.1386	0.0942	Used in proportion to availability	

Mixed forest	0.2556	0.3490	0.4745	Used less than availability	P < 0.0001
Open mixed forest	0.0000	0.0000	0.0557	Used less than availability	P < 0.0001
Riparian forest	0.0087	0.0401	0.0398	Used in proportion to availability	
Sal forest	0.1261	0.2014	0.1466	Used in proportion to availability	
Winter					
Agriculture land	0.0000	0.0000	0.0142	Used less than availability	
Bamboo forest	0.3201	0.4117	0.2035	Used more than availability	P < 0.0001
Grassland	0.0094	0.0386	0.0976	Used less than availability	P < 0.0001
Mixed forest	0.4248	0.5198	0.4314	Used in proportion to availability	
Open mixed forest	0.0000	0.0000	0.0494	Avoided	P < 0.0001
Riparian forest	0.0062	0.0323	0.0245	Used in proportion to availability	
Sal forest	0.0878	0.1493	0.1795	Avoided	P < 0.05