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HABITAT UTILIZATION OF ANIMALS IN PARAMBIKULAM WILDLIFE SANCTUARY WITH SPECIAL REFERENCE TO GAUR

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Summary

Gaur, *Bos gaurus gaurus* is a threatened species confined to Western Ghats, Central Indian highlands and foothills of Himalayas. In Western Ghats, they occur mostly in the hilly forest areas of Karnataka, Tamil Nadu and Kerala. Populations in these tracts are adversely affected due to habitat loss or degradation and epidemics. Gaur, the second largest animal in its range is also the least studied one. Information available on the species are from casual observations and short term studies.

The present study was carried out in Parambikulam Wildlife Sanctuary, Palakkad district, Kerala during 1993-1996. The Sanctuary with an area of about 285 km^2 is a part of the vast stretch of forests comprising Anamalais, Nelliampathis, High Ranges and Palani Hills. The area has southern tropical wet evergreen, southern tropical moist deciduous and southern tropical dry deciduous forests and grasslands. Plantations of teak and eucalypts are also met within the area. These forest types are interspersed and hence the overall vegetation is mosaic. The area is rich in fauna with the representation of all Peninsular Indian mammals. The region comprising Parambikulam has the second largest density of Gaur in Kerala.

Information on group size, composition and structure of Gaur were collected through direct observations. The individuals were classified into different age-sex categories based on morphological characters. Adult females formed a major share of populations (44.79%) followed by adult males (17.97%). The adult male to female sex ratio was 1:2.49. The basic unit of group is formed by adult females in combination with sub adults and juveniles. Mean group size was 6.0398 and groups of 3, 5 and 7 were frequented. About 21% of the populations were solitary bulls. The seasonal influence on group size is explained mostly by the variations in availability of grass. Most of the births

occurred between the two peak rainfall periods. However, this was highest after the south west monsoon.

One hundred and fifty one species of food plants were identified through direct observation and examination of fresh feeding sites. Plant species belonging to Poaceae and Cyperaceae combinedly formed the major food items. The principal grass, herb and shrub food species showed a seasonal and habitat difference in number and rank. Food preference index estimated through feeding quadrat method also showed seasonal and habitat difference. Gaur in Parambikulam was observed to be a grazer (78.3%). There were seasonal and between age-sex category variations. The males were observed to spend comparatively higher time for browsing throughout.

The data on activity pattern and time budget were collected through instantaneous scan sampling. Activities were classified into different major categories. Activity pattern of gaur was of polyphase where feeding was interspersed with resting and walking. Gaur showed a bimodal diurnal pattern in feeding with peaks in the morning and evening hours. There was a gradual increase in the resting period during noon hours. Walking was more or less uniform throughout. There were seasonal differences in the pattern with a marked reduction in dry season. There were differences between age-sex categories and seasonal differences within the category.

Feeding dominated the activity time budget followed by resting and walking. There were significant seasonal variations. Feeding was considerably low in dry season where as percentage time in walking and resting were higher. The difference in the budget between age-sex categories and seasonal difference within age-sex categories were significant.

Information on density distribution in different habitats and zones were collected through dung density estimates from transects laid in proportion to habitat size. The zones were identified based on natural features and dominant vegetation types. Food availability in different habitats and zones were estimated through clip and weigh method. Grasslands were used by gaur at a higher proportion in all seasons. The zones with moist deciduous vegetation interspersed with grasslands were used more and seasonal differences were significant. Food availability influenced the habitat and zone selection.

Effect of fire on vegetation was studied by establishing permanent experimental plots in different habitat types. These plots were subjected to summer and cold burning and were monitored for changes in species composition and biomass. The results indicate that the impact of fire on vegetation differed according to habitat type and season. An increase in number and biomass of grass species were observed in both summer and cold burn in moist deciduous. However, there was a decrease in plantation in summer burnt areas in the beginning and then increased subsequently. Though the number of herb food species recorded an increase in burnt areas, there was a decrease in biomass in both food and non food herb species in deciduous. The number of food and non food species decreased in plantations.

There was a change in the composition of shrub species in the burnt areas. But the change in the biomass of non food shrubs in moist deciduous was highly significant.

Chapter 1

Introduction

Bovinae are phylogenetically relatively young group compared to other mammals. The oldest fossil comes from the beginning of the Upper Lignite era. Asia is the original habitat of the wild oxen and most of the present day species are distributed in this continent. Wild oxen of Europe and North America were almost completely destroyed in historical times and a few survivors are confined to the Zoological Parks and Protected Areas. The four genera (Asiatic buffaloes, African buffaloes, true cattle and bisons) have seven sub genera, nine species and twenty one sub species.

The genus *Bos*, in addition to the domestic cattle (*Bos taurus* and *Bos indicus*) and the yak (*Bos grunneus*) contains several other species of wild cattle, all confined to the Oriental Region (Schaller, 1967). Kouprey (*B. sauveli*) of Cambodia, Banteng (*B. banteng*) of Java, Borneo, Malaya and parts of Indochina, gaur (*Bos gaurus*) of India, Malaya and Indochina and the gayal (*B. frontalis*) of Assam and Burma are the wild cattle found in this part of the world. Three sub species of gaur are recognised: *Bos gaurus gaurus*, occurring in India and Nepal; *Bos gaurus readei*, in Burma and Indochina and *Bos gaurus hubbacki* in Malaysia. Srikosamatara and Suteethorn (1995) suggested from morphometric data that the Thailand and Indochina's *Bos gaurus readei* Lydekkear 1903 and Malaysia's *Bos gaurus hubbacki* Lydekkear 1907 are the same and may be called *Bos gaurus laosiensis* Heude 1901.

1.1 Status and distribution in India

Schaller (1967) gave a detailed account on the distribution of gaur in India mainly from information collected from various sources. Gaur is an animal of the hills and is confined to Western Ghats, Central Indian high lands and the foot hills of Himalayas, including the hills south of Brahmaputhra river. The population in each area are further fragmented and live in isolation. The widely centered population occurs principally along the Eastern Ghats of Orissa, Mahadeo Hills and the Maikal Range of Madhya Pradesh. A few herds are also seen in the Northern Andhra Pradesh, Bastar districts of Madhya Pradesh and adjoining Chanda district of Maharashtra and in Palmau and Singhbhum districts of Bihar. Kanha National Park supports a good population of the animal. A few gaur were reported from Northern Bengal (Rao, 1961).

The true home of gaur in India is the chain of undulating hills in the Western Ghats (Krishnan, 1972). He described the area as "a fine ground stamping place for gaur in the world". The highest number of gaur are presently confined to the South of Peninsula than the north (Krishnan, 1972) The Anamalai hills, the Nilgiris, Wayanad, Coorg, the Bababooden hills and the Mahabaleshwar hills are all favourite haunts of this animal. North of this, it occurs in the forests on the Taptee river and adjacent areas. On the Eastern side of the Peninsula, it is found in the Palani and Dindigal hills, the Shandamangalam ranges, the Shervaroys and some of the hill ranges near Vellore and the border of Karnataka. North of this, it does not occur till the Krishna and Godavery rivers and thence all along the range of Eastern Ghats, to near Cuttack and Midnapore. Then it extends west far into Central India, and northwards towards the edge of the great plateau which terminates south of the Gangetic Valley (Jerdon, 1984).

In Western Ghats, they are reported from Karnataka, Tamil Nadu and Kerala where a sizeable population is occurring mostly in the hilly forest areas. Elimination of habitat and epidemics of rinderpest and foot and mouth disease have adversely affected the population in the Central and Southern India (Stewart, 1928; Ali, 1927; Baker, 1890; Bansal and Joshi, 1980). Krishnan (1972) described the alteration in the distribution of gaur and decimation from earlier locations. According to him, indiscriminate shooting of gaur for sports has been one of the major reasons for the decline in the population. Hunting the gaur, the "noble game among the oxen", as Oscar Kauffmann has called, has always been considered as a special challenge and ultimately lead to decimation of the largest of all contemporary wild oxen.

1.2 Status and distribution in Kerala

Gaur which was once found throughout Kerala are presently confined to isolated patches due to habitat fragmentation and their number is dwindling in most of its ranges while some populations are on the increase. Gaur in Kerala is fairly widespread and are reported from most of the Forest Divisions (Anonymous, 1993). The population in the State was estimated in the Wildlife Census conducted in 1993 and 1997 jointly by Kerala Forest Department and Kerala Forest Research Institute. Gaur density in the State from the Wildlife Census in 1997 is 0.4522/km^2 from the line transect sampling and the population in the State is estimated as 4151 and the 95% of confidence interval is 2527-5775 (Wildlife Census, 1997 - unpublished data). Parambikulam Wildlife Sanctuary has an estimated density of 1.4356 (30.96 %CV) from the block count. The dung density estimates for different Forest Divisions indicate that Parambikulam Wildlife Sanctuary stands second for whole of Kerala with an estimated density of 549.840 with a %CV of 17.23.

1.3 Review of Literature

Gaur, the second largest animal in Peninsular India has been one of the least studied in all respects throughout its ranges. Most of the information on the species are limited to the observations published as short notes (Cameron, 1929; Brander, 1935; Blackburn, 1935; Morris, 1937, 1938a, 1938b, 1948a, 1948b, 1952, 1954a & 1954b; Biddulph, 1936; Mustill, 1938; Russel 1938 & 1940; Rynjah, 1950; Hutton, 1951). A few of the published notes dealt with observations on the morphology of gaur (Cameron, 1929; Morris 1930 & 1947; Biddulph, 1936; Robinson, 1942; Hundley, 1951; Pillai 1951). Piezy (1940) reported the distinction between Indian and Malayan gaur. Notes on white bison were published by Brander (1935) and Davidar (1970). Morris (1948b) and Kurt (1974) briefly mentioned the disease aspects of gaur. The outbreak of rinderpest in Periyar Tiger Reserve was reported by Bansal and Joshi (1980).

Published works on the status of gaur in many of its ranges in India are rather scanty. Coe (1980) estimated about 550-600 animals in Kanha National Park. Karanth (1986) reported a population of about 1000 in Rajiv Gandhi National Park and Bhadra Wildlife Sanctuary in Karnataka. Bandipur Tiger Reserve in Karnataka has an estimated population of about 464 (Basappanavar, 1985) and Dijapur Wildlife Sanctuary about 200-300 (Samant, 1990). Melghat in Maharashtra (Rodgers, 1991) and Manas in Assam (Debroy, 1991) harbour an estimated population of about 1581 and 1200-1500 respectively.

Two short-term studies, by Moorthy (1989) in Kodaikanal Hills on the activity pattern and feeding behaviour and by Prabhakar (1992) in Indira Gandhi National Park on feeding and activity pattern are probably the only studies conducted on the species. Observations of Dwivedi and Shukla (1988) on habitat of Pench bison and of Belsare *et al.,* (1984) in Kanha National Park brought out some information on the group composition and behaviour of the species. Still, Schaller (1967) and Krishnan (1972) remain the most often quoted authentic works on the species.

Schaller (1967) mentioned the lack of adequate information on the species due to absence of serious long-term and systematic studies on the wild relatives of the genus *Bos.*

The review of literature clearly indicates lack of information on any aspects of gaur based on long-term studies. **Hence, the present study was conducted in Parambikulam Wildlife Sanctuary, Kerala to collect information on 1. group composition and size, 2. food and feeding, 3. activity pattern and time budget and 4. density distribution and habitat use.**

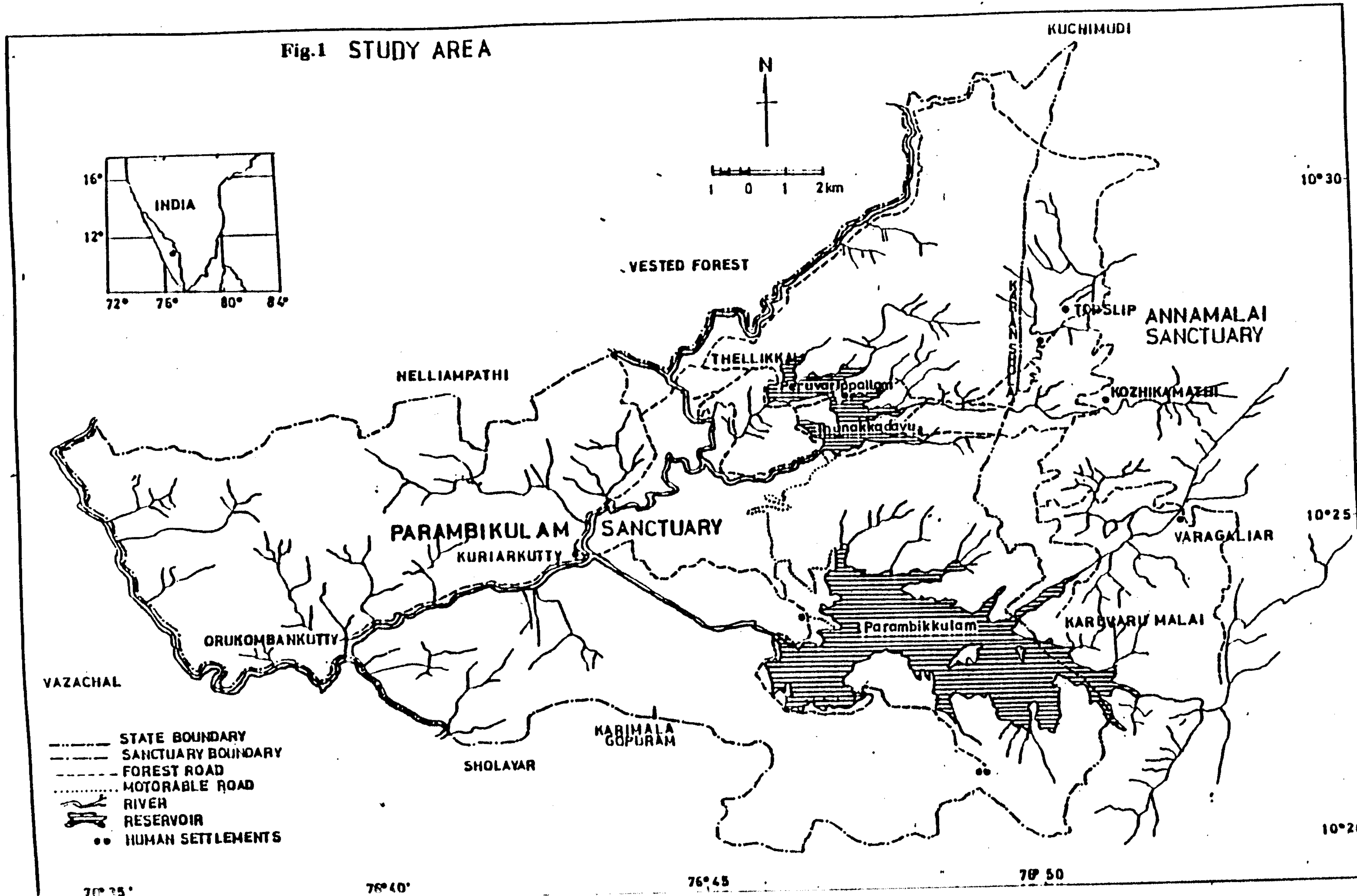
Chapter 2

Study Area

Parambikulam Wildlife Sanctuary is situated in Palghat district, Kerala state, India (between 76^0 35’ and 76^0 50 ’ E and between 10^0 20’ and 10^0 26’ N) (Fig. 1). The Sanctuary is bordered by the west flowing Karapara river in the west and the same river flowing easterly in part of the south. The Sanctuary is contiguous with the natural forests of Sholayar and Vazhachal. The boundary on the east is purely an administrative one with the forest clearance running throughout the area bordered by Indira Gandhi Wildlife Sanctuary (Anamalai WLS) of Tamil Nadu. The northern side is bordered by the southwest flowing Thekkady ar up to the central part of the area and the remaining portion by the forest clearance along the waterdivide between the northerly and southerly flowing streamlets. The Sanctuary is part of the contiguous larger area of forest comprising Anamalai’s, Nelliampathis, Sholayar, High ranges and Palani hills. Easa (1989), Uniyal and Easa (1990) and Uniyal (Undated) has given a detailed description of the Sanctuary.

The major interception in the Western Ghats ridges is the Palghat gap which lies just north of this area. The area in general has a slope towards west with the highest peak of Karimalagopuram (1438 m) and the lowest, the bank of Chalakkudy ar (439.5 m). The Sanctuary forms whole or part of the catchment of Chalakkudy river. A number of streams originate from the hills within the area running through the valley and converging at Orukombankutty forming the Chalakkudy river. The Sanctuary includes the hilly terrain with undulated plateau. The Nelliampathy hills in the north and west constitute the westerly extension of Anamalais. The Kuchimudi (1169.7 m) is the northeastern mark of the Sanctuary. The hills drop steeply down to Thekkady - Keerapadi in the southwest and raises precipitously up to Pandaravara malai. The hills slope down gently towards the

Fig.1 STUDY AREA



south to Thunacadavu valley of Sungam Range and the valley is fairly large ascending southwards to Vengolimalai (1224.2 m). The Nelliampathy hills in the north- west gradually descend and open up in Thuthampara, Thellickal and Parambikulam valley forming widest valley areas in the Sanctuary. The valley ends up in Poopara and Karimala peaks forming the southern boundary of the Sanctuary. The mountain slopes in the area are non-symmetric and non-uniform spreading throughout in different directions. The main geological formations in the area are hornblende-biotite-gneisses, garnetiferus-biotite-gneissess, Charnockites included by Granitic-ortho-gneisses and Plagio Clasceporphyry-dykes. Quartz, Biotite, Orthoclase, Plagioclase and Feldspar are the major constituents of the rocks.

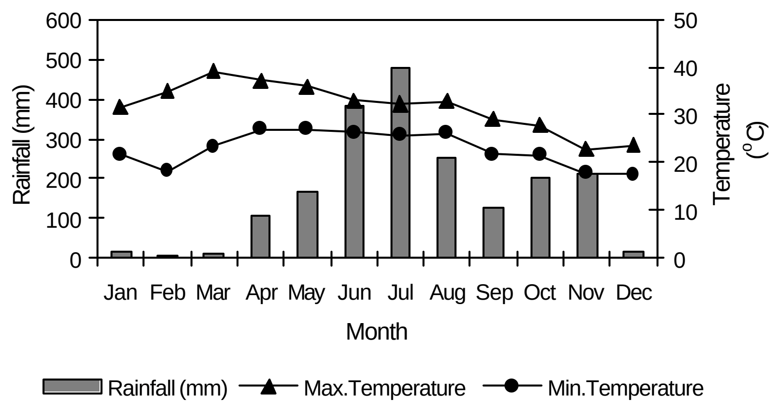
The area is drained by Thekkady ar, Parambikulam ar, Kuriarkutti ar, Thunacadavu ar, Thellickal ar, Karappara ar, Bagapallam ar, Vetti ar and Pulikkal ar. Of these, Thekkady ar, Thellickal ar and Bagapallam ar get dried up with stagnant pools during the summer season. There are three reservoirs of Parambikulam Aliyar project within the area.: Parambikulam, Thunacadavu and Peruvarippalam. These three have a water spread area of about 28 km^2.

The monthly distribution of rainfall and temperature in the area is given in the Figure 2. Two sets of rainy seasons from both South-west and North-east monsoons were observed. However, South-west monsoon is the more active one in this region. The first peak of rains occur between June and July and the second during October and November. Based on this rainfall pattern three seasons could be differentiated. Dry season (from Feb. to May), first wet season (from June to Sep.) and second Wet season (from Oct. to Jan.).

2.1 Flora

Natural vegetation of the Sanctuary is a combination of Malabar and Deccan elements (Sebastian and Ramamoorthy, 1966) and both natural and man-made vegetation types are met within the area. Menon (1991) gave a detailed description of the vegetation types of Parambikulam. Following Champion and Seth (1968), the natural forests can be broadly classified into the Westcoast tropical Evergreen, Westcoast Semi Evergreen, Southern Moist Mixed Deciduous and Southern Dry Mixed Deciduous forests.

Fig.2 Monthly distribution of rainfall and temperature in Parambikulam Wildlife Sanctuary



Source: Parambikulam Aliyar Project, Tamil Nadu

2.1.1 Westcoast tropical evergreen forests are distributed in higher slopes bordering Nelliampathy and Anamalai ranges. Small patches are also seen in depressions within moist deciduous forest localities such as, Thuthampara, Pulikkal, Orukomban, Kariyanshola, Vengolimala and Karimalagopuram. Tree species like, *Palaquium ellipticum, Calophyllum polyanthum, Mesua ferrea, Cullenia exarillata, Dipterocarpus indicus, Artocarpus hirsutus, Hopea parviflora, Vateria indica, Dysoxylum malabaricum, Myristica malabarica, Polyalthia fragrans, Canarium strictum,* etc. form the top storey of these type of forests. The lower storey is mainly of *Aporusa lindleyana, Vitex altissima, Elaeocarpus serratus, Cinnamomum verum, Evodia lunu-ankenda, Holigarna arnottiana,* etc. *Calamus spp., Dendrocnide sinuata, Nilgirianthus sp., Elettaria cardamomum* etc. form the ground vegetation. The evergreen forests are also rich in epiphytic orchids and ferns.

2.1.2 Westcoast semi evergreen forests are transitional between evergreen and moist deciduous forests and are distributed unevenly throughout. They possess a mixture of both evergreen and deciduous elements.

2.1.3 Southern moist mixed deciduous forests are found along the ridges and lower slopes covering an area of about 60 km^2 . This type of forest is distributed as large patches in Anapady, Elathodu, Poopara and Vengoli. They are also seen in small patches adjacent to teak plantations. Tree species observed in the area include *Haldina cordifolia, Albizia procera, Dalbergia sissoides, D. latifolia, Pterocarpus marsupium, Bauhinia racemosa, Tectona grandis, Dillenia pentagyna, Cassia fistula, Xylia xylocarpa, Pongamia pinnata, Careya arborea, Bombax ceiba, Terminalia paniculata, , T. bellirica, T. alata, Phyllanthus emblica, Grewia tiliifolia, Lagerstroemia microcarpa*. Most of the deciduous forests of the Sanctuary have been converted into teak plantations. The forests have thick regenerative ratio of bamboos as evident from areas such as Elathodu and Thellickal.

2.1.4 The southern dry mixed deciduous forests are confined to low rainfall areas around Thekkady and Keerapady and occupy about 15 km^2. The dry deciduous forests are dominated by *Anogeissus latifolia* along with other species of the moist deciduous forests. Extensive natural regeneration of *Bambusa arundinacea* are also found in the dry deciduous forests.

2.1.5 Grasslands and swamps (vayals), extending over an area of about 2 km^2 in a highly fragmented distributional pattern is one of the major characteristics of Parambikulam Wildlife Sanctuary. These vayals range from 5 ha. to 20 ha. in extent and are interspersed with plantations and natural forests at more than 30 locations. These have profuse growth of grasses and sedges and a few have extensive natural regeneration of *Bambusa arundinacea*. The vayals at Kannimara, Thellickal, Anakkal, Kothala and Poopara are the largest of these occupying contiguous area.

2.1.6 Teak plantations constitute about 90 km^2 and the eucalypts plantations near the northeast boundary about 3 km^2. The teak plantations of the area are of different age categories, since the plantation works were initiated in a phased manner. The area at present has plantations raised in 1916 to the recently regenerated 1982. Most of these plantations have a belt of natural forests and also a good undergrowth of shrub, herb and grass species. Natural regeneration of species such as *Cassia fistula, Dalbergia sissoides, Dillenia pentagyna, Xylia xylocarpa,* etc. is the characteristic phenomenon of most of the plantations in the Sanctuary.

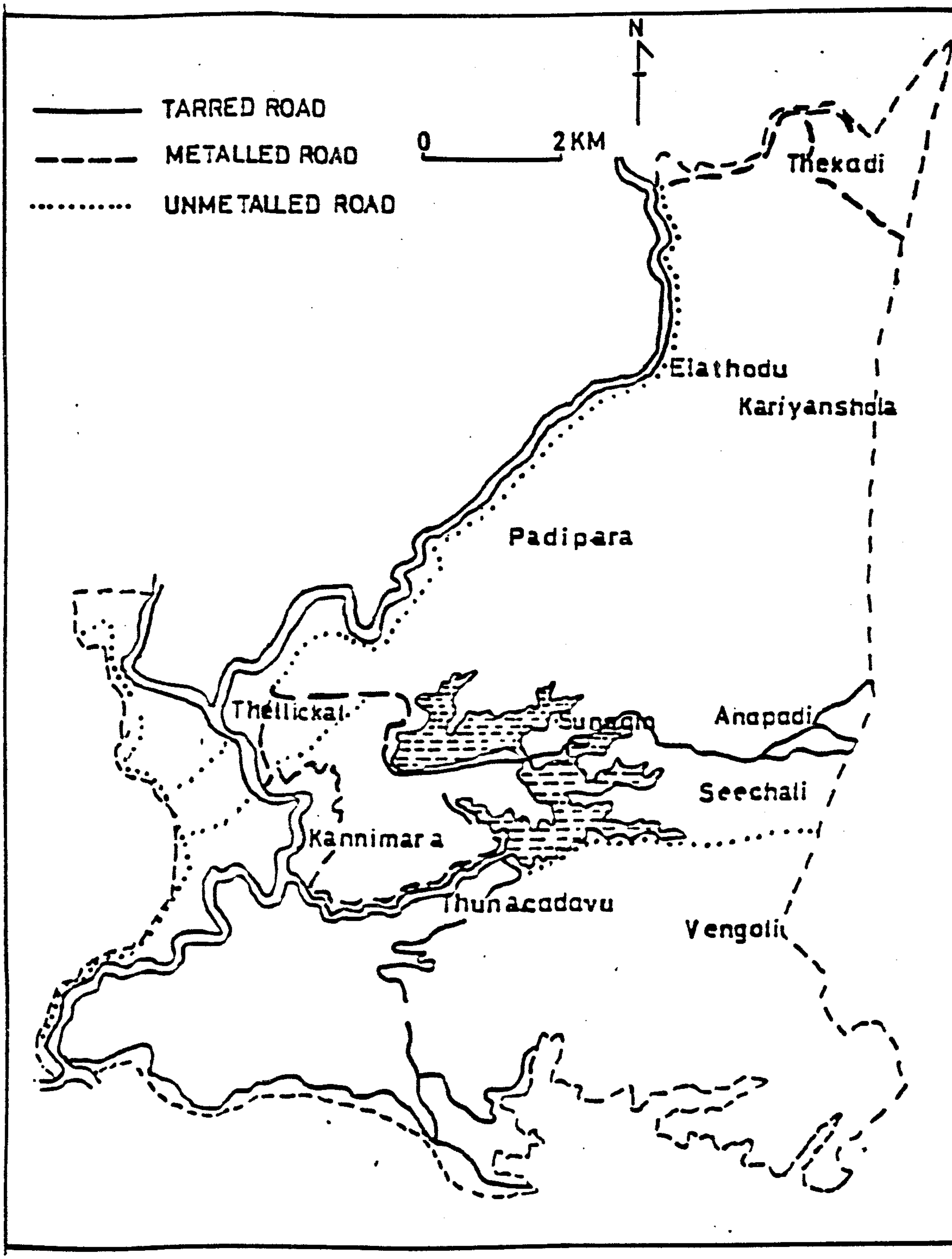
Three tribal communities in the Sanctuary are located at Sungam (Malasar), Parambikulam and Kuriarkutty (Kadars) and Muduva colony (Muduvar).

The diverse habitats and strategic locations of Parambikulam make it one of the faunistically richest areas in Kerala. Easa and Balakrishnan (1990) and Balakrishnan and Easa (1986) have described the mammals of Parambikulam Wildlife Sanctuary. The area has a good population of elephants (*Elephas maximus*), gaur (*Bos gaurus*), wild boar (*Sus scrofa*), sambar deer (*Cervus unicolor*), spotted deer (*Axis axis*) and mouse deer (*Tragulus meminna*). The rodents include the Malabar giant squirrel (*Ratufa indica*) and porcupine (*Hystrix indica*) in addition to a number of smaller ones like rats and mice. All the four species of primates reported from the Western Ghats, *viz,* lion tailed macaque (*Macaca silenus*), bonnet macaque (*Macaca radiata*), Nilgiri langur (*Presbytis johni*) and common langur (*Presbytis entellus*) are seen in the area. Carnivores such as tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*) and wild dog (*Cuon alpinus*) are frequently sighted. Pangolin (*Manis crassicaudata*) is of rare occurrence. Ruddy mangoose (*Herpestes smithi*), common mangoose (*Herpestes edwardsi*) and stripe-necked mangoose (*Herpestes* *vitticolis*), Nilgiri marten (*Martes gwatkinsi*) and bats are seen in the area. The lesser cats such as jungle cat (*Felis chaus*) and viverrids such as small Indian civet (*Viverricula indica*) and toddy cat (*Paradoxurus hermaphroditus*) are also common. Nilgiri tahr (*Hemitragus hylocrius*) is found in isolated places at Vengoli and Karimalagopuram. Otter is found in the reservoirs.

A number of studies on various aspects of wildlife have been conducted in Parambikulam Wildlife Sanctuary. Vijayan (1979) and Sugathan (1981) listed the birds of the area. Uniyal (Undated) gives a list of 168 species of birds. Balakrishnan and Easa (1986) reported their findings on habitat preference of larger mammals. Easa (1988) published his findings on factors governing the movement pattern of elephants in the Sanctuary. Ramachandran (1988) reported the ecology and behaviour of Malabar giant squirrel. Easa (1989) studied the ecology and behaviour of elephants. Nair and Jayson (1990) reported the habitat utilization of mammals in the area. Easa and Balakrishnan (1990) dealt with the population ecology and management problems of larger mammals in Parambikulam. Uniyal and Easa (1990) discussed the options for management of elephants. Radhakrishnan (1996) listed the reptiles of the area. The foregoing discussions on the studies indicate absence of studies on any aspect of gaur, the second largest mammal in Parambikulam.

For the present study, an intensive study area (Fig.3) was selected based on natural features such as rivers and streams. This area has all the vegetation types represented and could be considered as a representative sample of Parambikulam Wildlife Sanctuary.

Fig.3. Map of intensive study area



Chapter 3

Group composition and size

3.1 Introduction

Knowledge of animal population, their structure and the trend are of paramount importance for wildlife management. This is especially true of an animal contributing a larger proportion of biomass to the population of an area even in small numbers. Herbivores normally tend to live in groups which may vary widely within and between species (Eisenberg, 1966; Crook *et al*., 1976; McBride 1976; Rodman, 1981; Johnson, 1983). The pattern in group size is considered to be influenced by environmental conditions prevalent in the area (Leuthold and Leuthold, 1975; Southwell, 1984). Barrette (1991) discussed the significance of studies on group composition, size and structure. Further, studies on group composition could yield very useful information on population characteristics and trend (Mc Cullough, 1993 & 1994).

Very few studies have been reported on the trend in population of gaur based on long-term and systematic monitoring. Most of the available information on the number of gaur in different areas have been from population estimation exercise by Forest Department in different States. Such an exercise in Kerala reported the status and distribution of gaur in different parts of its ranges (Anonymous, 1993). Brander (1923), Schaller (1967) and Krishnan (1975) recorded their observations from different parts of the country. Belsare *et al*. (1984) dealt with the group composition and behaviour in Kanha National Park and Dwivedi and Shukla (1988) in Pench Bison Wildlife Sanctuary. In Kerala, ecological studies in Periyar Tiger Reserve (Vijayan *et al*., 1979; Nair *et al*., 1985) have made preliminary observations on gaur population.

3.2 Methods

The Sanctuary area was covered every month on foot from March 1993 to February 1996. Size, composition and structure of gaur groups sighted were recorded, taking care to spend time in all habitat types in proportion to their size. Individuals in the group were classified into different age and sex classes based on the criteria mentioned below following Schaller (1967) and Krishnan (1972) with appropriate modifications.

1. Adult Male :- Sooty black in colour, enlarged dewlap, well diverged and fully converged tip of horn, prominent dorsal ridge and rotary movement of hump while walking.
2. Adult Female :- Dark brown and closer to black in colour, non-prominent dewlap, less diverged but fully converged tip of horn, less prominent dorsal ridge.
3. Sub-adult Male :- Black or brownish black in colour, prominent dewlap, the diverged horn about to converge.
4. Sub-adult female:- Brownish black in colour (more black in thoracic portion and more brownish colour in the rump portion), dewlap absent and less diverged but not converged horn.
5. Juveniles :- Brownish in colour with dagger like spike horn (approximately 20 to 25 cm in length in both sexes).
6. Calf :- Golden brownish in colour and can pass through between the legs of its mother (less than three months old and approximately 1 m in height) in both sexes. Lack of conspicuous white stockings.

Only the completely classified groups had been considered for composition analyses. Proportion of different age and sex classes in the population was derived on the basis of all sightings during the study period. The solitaries were not considered for calculating mean group size. The data upto February 1996 were considered for the analyses on changes in the mean group size over time.

The number of calves present in the group and their percentage contribution to the population in different months were considered to know the calving season. The calf and adult female ratio were also estimated.

Food species of gaur were identified through direct observations. Food availability was measured in terms of biomass (dry weight) through clip and weigh method (Wiegert, 1962). A number of quadrates of 1m x 1m size for grasses and herbs, and 5m x 5m for shrubs were laid using stratified random sampling procedure. All food species within the plot were clipped and weighed in the field for wet weight and sub-samples were oven dried at 60°C constant temperature till the samples reached constant weight. Biomass of each individual food species was estimated. For the present analyses, food species were grouped into grass, herb and shrub. The total of these three groups were taken as total food available. Data on food availability were collected for six seasons during 1994 and 1995 (three seasons for each year).

Analyses

3.2.1 Effect of age-sex categories on group size.

In simple terms, group size is just a sum of the number of individuals in the different component classes. However, group size need not respond in a simple manner to the changes in the number of individuals in the component classes because of the complex association possible among the classes.

The effect of age-sex categories on group size was studied through regression analysis taking group size as dependent variable and number of individuals in each age-sex category as independent variable. The regression functions included each category one at a time. In such cases, the regression functions fitted were of the following form,

$$GS=\beta_0+\beta_1 N \qquad (1)$$

where GS = group size

N = number of individuals in a particular age-sex category

β_0, β_1 = parameters to be estimated

The parameter estimates were obtained through weighted least squares. The weights were inversely proportional to different powers of the corresponding regressors. The herd size was subjected to squareroot transformation as the variance in the herd size was found related to the mean. The value of the index of power for each equation was obtained through a grid search utilizing the procedure WLS of SPSS/PC+ (Anonymous, 1987).

In order to study the combined effect of the different categories on group size, a multiple linear regression equation was fitted including all the categories except the unsexed class in the model. The prominent components affecting group size were identified through step-wise regression.

Association among the different age-sex categories was studied by working out Pearson's product moment correlation coefficient. Because of the possible inter-correlation among the groups, changes in number of individuals in any category may have indirect effect on the group size through other categories, apart from the direct effects. Path coefficient analysis (Wright, 1921) were carried out for studying such effects.

3.2.2 Changes in the mean group size over time

The data consisted of monthly observations on group size for 36 months starting from March 1993. The mean group size for each month was computed and changes in the mean group size over time were analysed using the following general model.

$$y_t = \mu + \alpha t + \in_t \tag{2}$$

where $\mathbf{y}_t$ = mean group size at time t, μ = intercept, t = time in years

α = coefficient of the trend variable, $\in_t$ = error at time t

The effect due to months was superimposed on the above model as:

$$\mathbf{y}_{t(i)} = \mu + \alpha t + \beta_i + \in_{t(i)} \tag{3}$$

where $\mathbf{y}_{t(i)}$ = mean group size at time *t* belonging to *i* th month.

β_i = effect due to *i* th month. $\in_{t(i)}$ = residual at time *t* belonging to the *i* th month.

μ, α, t = as defined earlier.

Model (3) assumes a continuous change in the mean group size over time with seasonal fluctuations superimposed. The additivity of the monthly effects was examined using the mean range plot. The coefficients of the model were estimated first through ordinary least squares (OLS). The auto-correlation coefficient for the residual was nonsignificant as shown by Durbin-Watson statistic. However, a plot of residuals against the months showed heteroscedasticity. Observations in the wet seasons were less variant compared to those of other months. Hence, the coefficients of the model were re-estimated through weighted regression. The weights were roughly proportional to the reciprocal of the variance of residuals for each month. The weights (W) were

W = $^{-\delta}$

where

= standard deviation of the residuals for each month

δ = index of power

The optimal value of δ came to 2.2 through a grid search from 1 to 2.6 using the WLS procedure of SPSS/PC+.

3.2.3 Changes in distribution of group size over time

Analysis in the previous section dealt with only changes in the mean group size over time. In practice, there was considerable variation in group size around the mean and the pattern of this variation itself could change from time to time. A χ^2 test was carried out to see whether significant differences existed in the group size distribution over different seasons and years. For this analysis, the months were grouped into dry (February - May), and first wet (June - September) and second wet (October - January) seasons. It was found that most of the cells had expected frequency below 5 which made the test ineffective. Hence the analysis was done through log linear models (Haberman, 1978). Solitary animals were excluded from the data and also groups of size 11 and above were put in a single class.

The following model was used for studying the changes in the herd size distribution over different seasons and years.

$$\ln f_{ijk} = \mu + \lambda_i^{G} + \lambda_j^{S} + \lambda_k^{Y} + \lambda_{ij}^{GS} + \lambda_{ik}^{GY} + \lambda_{jk}^{SY} + \lambda_{ijk}^{GSY} \tag{4}$$

where f_{ijk} = the frequency in the multiway contingency table, corresponding to the i th group size, jth season, k th year. ln = indicates natural logarithm. λ's = are the parameters corresponding to the main effects and interactions due to factors viz. group size (G), season (S), and years (Y).

The above is a saturated model with full set of parameters in a three way set up. The nonsignificant parameters were eliminated through backward elimination using HILOGLINEAR procedure of SPSS/PC+.

3.2.4 Mean group size in relation to food availability

The relation between mean group size and food availability was worked out by fitting a multiple regression equation with mean group size as dependent variable and components of food availability (grass, herb and shrub) as independent variables. The model was as follows

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 \tag{5}$$

where y = Mean group size, x_1= Grass food, x_2= Herb food

x_3= Shrub food, a, b_1, b_2 and b_3 are fitted constants

A linear regression equation was also fitted to find whether there is any significant relation between mean group size and total food availability inclusive of grass, herb and shrub.

3.3 Results

3.3.1 Group composition

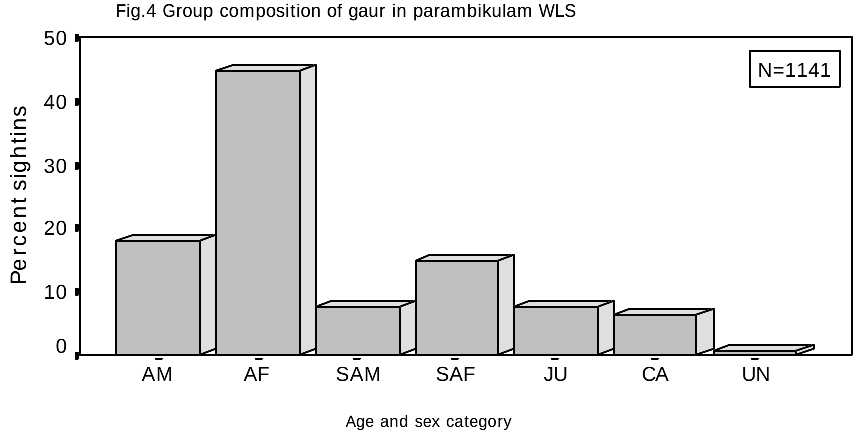
A total of 241 sightings consisting of 1141 individuals were considered for age and sex classification, out of which 62 sightings were of loners. About 82% of the loners were males. The proportion of age and sex classes of gaur calculated for the entire period of study are given in Table 1.

Table 1. Proportion of different age and sex classes of gaur in Parambikulam WLS.

Age and sex class	Proportion	Percentage
Adult Males (AM)	0.1797	17.97
Adult Females (AF)	0.4479	44.79
Sub-adult Males (SAM)	0.0771	7.71
Sub-adult Females (SAF)	0.1481	14.81
Juveniles (JUV)	0.0771	7.71
Calves (CA)	0.0631	6.31
Unsexed	0.0070	0.7

Adult females formed the major share of the population (44.79%). This was followed by adult males (17.97 %), sub-adult females (14.81 %) and sub-adult males (7.71%). The juveniles and calves contributed 7.71 % and 6.31 % respectively. About one percent of the total number of individuals could not be sexed (Fig. 4). The Adult male to female sex ratio was calculated as 1:2.49.

Fig.4 Group composition of gaur in parambikulam WLS



AM-Adult male, AF-Adult female, SAM-Sub adult male, SAF-Sub adult female
JU-Juvenile, CA-Calf, UN-Unsexed

The maximum percentage contribution of calves to the population was observed in the month of September (10.71%) and minimum was observed in February (3.7%) (Table 2). The overall calf - adult female ratio observed was 1:7.1. The high ratio between calf and adult female was also observed during the month of September (1:4.33) followed by October (1:4.6) and April (1:4.6) (Fig. 5).

Fig.5 Monthly calf - adult female ratio

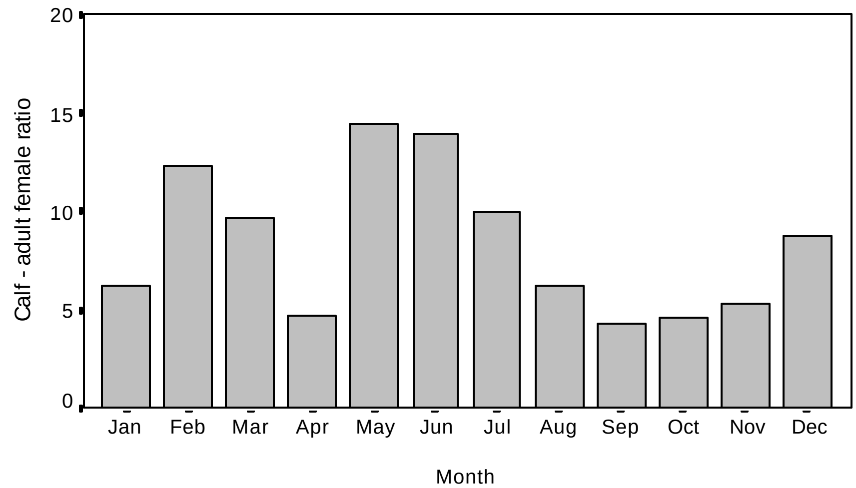


Table 2. Monthly percentage of calves in the population and calf-adult female ratio.

Month	Percentage of calves	Calf-adult female ratio
JAN	7.69	1: 6.29
FEB	3.70	1:12.33
MAR	4.76	1: 9.67
APR	7.59	1: 4.67
MAY	3.67	1:14.50
JUN	3.85	1:14.00
JUL	5.00	1:10.00
AUG	6.99	1: 6.20
SEP	10.71	1: 4.33
OCT	7.94	1: 4.60
NOV	7.78	1: 5.29
DEC	4.95	1: 8.80

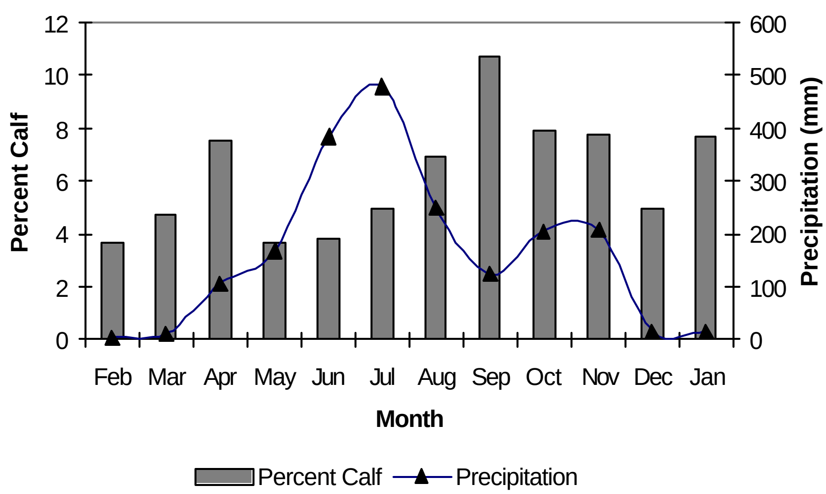
Seasonal percentage contribution of calves and its ratio with adult female are given in Table 3. The wet-2 season has a higher value compared to other seasons.

Table 3. Seasonal percentage of calves in the population and calf-adult female ratio.

Season	Percent contribution	Calf-adult female ratio
Dry	5.35	1:8.18
Wet-1	6.75	1:7.04
Wet-2	6.96	1:6.17
Overall	6.31	1:7.10

A comparison of month wise percentage of calves in the population with the mean precipitation (obtained from five years) indicate an increase in the number of calves before and after the first peak of precipitation and a decrease after the second peak (Fig. 6).

Fig.6 Relation of mean monthly precipitation and percentage of calves



The relation between mean monthly temperature and percentage of calves in the population (Fig. 7) and the difference in the monthly mean temperature (Fig. 8) show that higher temperature and temperature differences have a negative correlation with the number of calves.

Fig.7 Relation between mean monthly temperature and percentage of calves

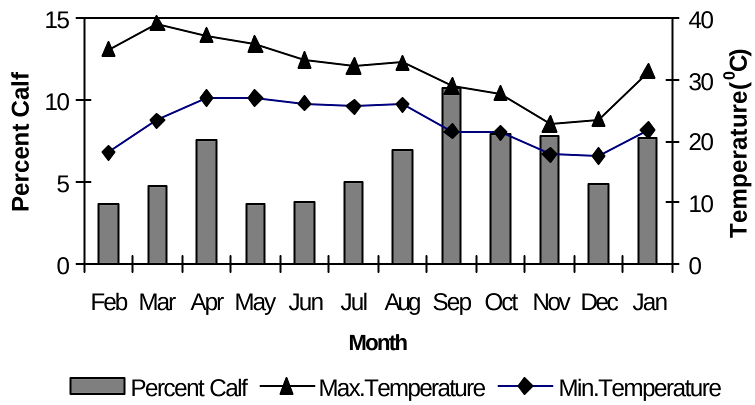
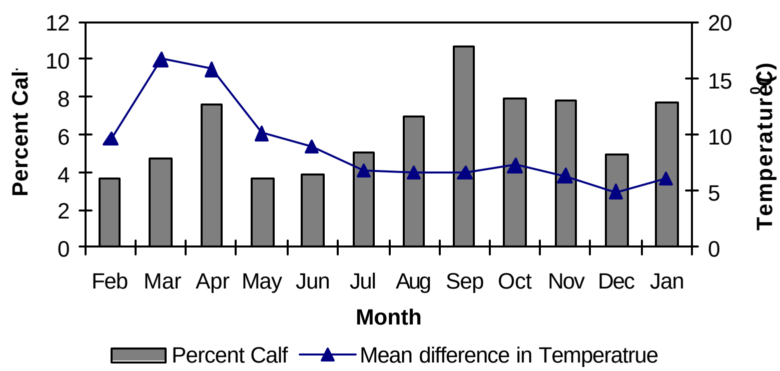


Fig.8 Relation of mean temperature difference and percentage of calves



3.3.2 Age-sex categories and group size

The results of simple linear regression between group size and different age-sex categories are presented in Table 4. Individually, the number of adult female had the largest Adj. R^2 value showing that a substantial part of variation in group size is accountable by the adult females in the group. The corresponding regression coefficient (β_1) was 1.7582 indicating that with addition of every adult female, at least one more additional individual is added to the group. The sub-adult males accounted for 47 % of the variation in group size individually. The high value for regression coefficient indicates that sub-adult males generally occur in large groups.

Table 4. Regression coefficient associated with simple linear regression of group size on age-sex categories of gaur.

Age-sex class	b_0	SE (b_0)	b_1	SE(b_1)	Adj. R^2	Value of d used for transformation
AM	3.2392	0.9309	2.7523	0.7982	0.0894	1.25
AF	1.0711	0.2931	1.7582	0.1085	0.6043	0.75
SAM	1.0411	1.1176	8.5206	1.0243	0.4701	0.50
SAF	3.8407	0.6183	2.2849	0.3805	0.2520	0.25
JUV	4.5447	1.0953	2.6660	0.8112	0.1406	0.25
CA	4.1051	1.0573	2.8224	0.8464	0.1708	0.75

SE = standard error.

The results of stepwise regression analysis confirmed the above findings showing that adult female combined with sub-adult males explained about 80 % of the variation in group size (Table 5).

Table 5. Stepwise regression analysis - Cumulative effect of various age-sex categories on group size.

Age-sex class	Cumulative value of R^2	Partial regression coefficients of the final model(b)	SE(b)
AF	0.6635	0.9713	0.0215
SAM	0.7909	1.0725	0.0573
AM	0.8733	1.0035	0.0377
SAF	0.9079	1.0215	0.0321
JUV	0.9526	1.0006	0.0392
CA	0.9900	1.0058	0.0397
Constant		0.0642	0.0595

The coefficient of correlation between group size and different individual age-sex categories and between age-sex categories are presented in Table 6. Group size was highly correlated positively with adult female, sub-adult male and sub-adult female. The adult female was associated with all the categories except adult male. It showed high association with sub-adult male (0.524) and sub-adult female (0.446). The sub-adult female showed more or less equal extent of association with adult female

(0.446) and sub adult male (0.437). The juvenile and calf categories were more attached to sub adult male (0.400,0.301) compared to other categories. The basic unit of a group seems to be formed by adult females in combination with sub-adult males, sub-adult females and juveniles.

Table 6 . Correlation matrix of different age-sex categories and group size (GS).

	AM	AF	SAM	SAF	JUV	CA	GS
AM	1.000	**0.171**	**0.184**	**0.274****	**0.172**	**0.095**	**0.460****
AF	0.171	1.000	**0.524****	**0.446****	**0.298****	**0.254****	**0.815****
SAM	0.184	0.524**	1.000	**0.436****	**0.400****	**0.301****	**0.731****
SAF	0.274**	0.446**	0.437**	1.000	**0.120**	**0.012**	**0.656****
JUV	0.172	0.298**	0.400**	0.120	1.000	**0.226***	**0.540****
CA	0.095	0.254**	0.301**	0.012	0.226*	1.000	**0.448****

Two-tailed Significance. * - significant at P=0.01, ** - significant at P=0.001

Results of path-coefficient analysis are presented in Table 7. The estimate of residual variation was 0.01, thus only a negligible part of the total variation is left unexplained. The adult females had the maximum positive direct effect on group size (0.4305) followed by sub-adult females (0.2948). No age sex class had a negative effect.

Adult females were found to have high indirect effect on the size through sub-adult females indicating that variation in these categories are mostly simultaneous in a group. Similarly, sub-adult males, juveniles and calves also had high indirect effect on the group size through adult females. The adult males were mostly a stand alone group with high indirect effects on the group size through sub-adult females and adult females implying the possible attractions between the groups.

Table 7. Path - coefficient analyses - Direct and indirect effects of different age-sex categories on group size

	AM	AF	SAM	SAF	JUV	CA
AM	<u>0.2140</u>	0.0736	0.0344	0.0808	0.0373	0.0197
AF	0.0366	<u>0.4305</u>	0.0981	0.1315	0.0647	0.0531
SAM	0.0393	0.2254	<u>0.1873</u>	0.1287	0.0870	0.0628
SAF	0.0586	0.1921	0.0818	<u>0.2948</u>	0.0260	0.0026
JUV	0.0367	0.1283	0.0750	0.0352	<u>0.2173</u>	0.0472
CA	0.0202	0.1095	0.0563	0.0036	0.0491	<u>0.2089</u>

Note: Direct effects are in main diagonal with underline; off diagonal elements are indirect effects.

3.3.3 Mean group size (MGS)

The loners were not considered for calculating MGS. The overall mean group size for three year observation was 6.0398. There was not much deviation in the year wise MGS from the overall MGS (Table 8).

Table 8 . Year wise mean group size

Year	Mean Group Size
1993	5.4706
1994	6.3281
1995	6.2281
1996	6.0000
Over All	6.0398

Seasonal MGS is given in Table 9. The second wet season had the highest of 6.9167. One-way ANOVA for yearwise variation turned out to be non-significant. However, the seasonal difference was significant (F= 2.7607, α= 0.1).

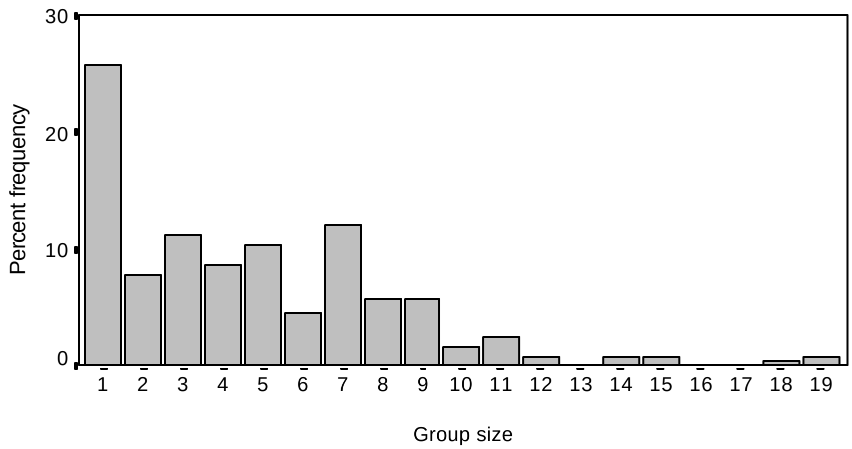
Table 9. Seasonal mean group size

Season	Mean Group Size
Dry season	5.4769
First wet season	5.9524
Second wet season	6.9167

3.3.4 Changes in distribution of group size over time

Group size was found to range from 1 to 19 during the study period with a positively skewed distribution (Fig. 9). Out of 241 sightings, 25.73% were solitaries (mostly bulls). Most frequently observed group size was seven (12.0%). Group size of 3 and 5 were observed in 11.2% and 10.4% of total sightings respectively. Group size of 2 and 4 formed only 7.9% and 8.7% respectively. Largest group observed was of 19 individuals.

Fig. 9 Percentage frequency distribution of group size of gaur



The results of χ^2 test for seasonal difference in group size ineffective as large number of cells had expected frequency less than 5. Hence a solution was sought through a log-linear model, results of which are summarised in Table 10.

There were three factors involved in the multi-way contingency table viz., group size (G), season(S) and year(Y). Results (Table 10) show that two way and three way interactions were nonsignificant. The only factor which came out significant through the likelihood-ratio χ^2 was herd size, indicating that the herd size distribution *ie* , the pattern of variation around the mean did not undergo changes with the seasons or years.

Table 10. Results of analysis through loglinear models.

Factors	**Df**	**Likelihood ratio χ^2**	**Probability of χ^2 value**
G,S,Y(combined)	13	38.269	0.0003
GS,GY,SY (combined)	40	43.018	0.3433
GSY	36	32.663	0.6281
Y	2	1.611	0.4469
S	2	3.042	0.2185
G (Group size)	9	33.616	0.0001

Although there were differences in the mean group size between seasons, the two way and three way interactions did not show significant differences in group size distribution around the mean in relation to seasons or years. The non significance of interaction between group size and season indicates that the group size distribution was not changing over the seasons. Similar was the case with group size x year interaction. The non significance of three-way interaction (GSY) indicates that there was no change in the interaction between group size and season with change in years. However, the percentage of solitaries in dry season (36.45%) was more compared to the first wet (13.70%) and second wet (21.31%) seasons.

3.3.5 Changes in the mean group size over time

The estimates of parameters in model (3) are given in Table 11. The coefficient of adjusted multiple determination for the model was 0.8571. There was a slightly increasing trend for the mean group size during the period of observation. The increase was of the order of 0.2132 per year. While estimating the effects of months, the month of December was kept as a reference with no deviation from the trend line. The mean group size showed significant decrease in the months of March, June and July.

Table 11. Parameter estimates for the different effects in the model.

Effect	**Coefficient(C)**	**SE(C)**	**t value**	**Prob. Of t value**
Constant	7.3524	1.0251	7.172	<0.0001 *

Trend	0.2132	0.0637	3.349	0.0028 *
Jan	-1.5444	1.0258	-1.506	0.1458 ns
Feb	-1.6112	2.1239	-0.759	0.4555 ns
Mar	-2.9167	1.1880	-2.455	0.0221 *
Apr	-0.7478	1.4473	-0.517	0.6103 ns
May	-2.2489	1.9079	-1.179	0.2506 ns
Jun	-3.0467	1.0211	-2.934	0.0066 *
Jul	-2.4778	1.0307	-2.404	0.0247 *
Aug	-0.1455	1.1856	-0.123	0.9033 ns
Sep	-0.9134	1.4419	-0.633	0.5327 ns
Oct	-1.3978	1.0381	-1.347	0.1913 ns
Nov	-0.7009	1.6053	-0.442	0.6629 ns

* - significant at P=0.05, ns - nonsignificant.

3.3.6 Mean group size in relation to food availability

Multiple regression analyses showed that the relation between mean group size and availability of individual food items (grass, herb and shrub) as individual variables were significant. The model of multiple regression equation fitted using stepwise regression was as follows

$$MGS = \underset{(0.3611)}{3.1063} + \underset{(0.0202)}{0.1435}(Grass) - \underset{(0.0211)}{0.0789}(Shrub) \qquad Adj.R^2=0.9456 \qquad (5)$$

The results of stepwise regression revealed that the variable herb was excluded from the equation. This is because, the variation in mean group size explained by herb food item was not significant. Additional results of combined regression of mean group size using food items is given in Table 12. Variation in mean group size was highly explained (69.28% variation) by grass showing that mean group size was very much dependent on availability of grass. Grass and shrub combinedly explained 94.56% of variation in the mean group size. The results of linear regression analysis showed that the relation between mean group size and total food availability was not significant ($Adj.R^2=0.1695$).

Table 12 .Results of combined regression of mean group size using food items

Food items	Co-efficient	SE of Co-efficient	Cumulative R^2
Intercept	3.1063	0.3611	--------
Grass	0.1435	0.0202	0.6928
Shrub	-0.0789	0.0211	0.9456

3.4 Discussion

Gaur is a gregarious animal and the group is centered around the adult females. Wroblewski (1927) defines the bison herd as a family group. Family links exert an important influence on formation and shaping of different groups (Krasinski, 1978). Basic unit, as found from the present study consists of adult females, sub-adult males and females and juveniles. Adult females had maximum influence on the group size followed by sub-adult females. The adult males in gaur are found to influence the group only through adult and sub-adult females. This follows the same pattern as in the case of American (Shult, 1972; Meagher, 1973) and European (Krasinski, 1967) bisons where the bulls neither dominate nor lead the group even during the rutting period. Larter and Gates (1994) observed similar pattern in the case of wood bison groups. This observation was supported by others (McHugh, 1958; Fuller, 1960; Larter, 1988).

The solitary bulls in Parambikulam constituted 21.45% of the total sightings and all of them were healthy adults. The early conclusion that the solitaries were older bulls in the case of American (Soper, 1941; Fuller, 1960) and European (Bojanus, 1827) bisons were later refuted (Krasinski, 1978). The tendency of bulls to be solitaries is considered to be a property of males of the genus *Bison* in both America and Europe (Krasinski, 1978). The present observations in Parambikulam also indicate presence of solitaries throughout the year though the proportion is low compared to those in American and

European bisons. However, occurrence of females forming about 18% of the observed solitaries need further observations for a satisfactory explanation. Unlike the *Bison* sp. (Krasinska and Krasinski, 1995), there was no bull groups observed in Parambikulam. Proportion of adult males within the group was almost constant and explains the nonsignificant influence of adult males on group size. However, there were differences in the proportion of solitaries in different seasons. The solitary bulls of American and European bisons are reported to wander a lot from group to group ensuring exchange of genes (McHugh, 1972). Similar observations have been made in the present study area also.

A distorted sex ratio favouring females of gaur is observed in Parambikulam. Similar observation was also reported by Schaller (1967). Klein (1970) attributed the alteration of the age ratios in North American deer to decreased fawn survival associated with limitations in quality and quantity of available food among several other factors. There is no information available on the sex ratio of gaur at birth. However, assuming an equal sex ratio at birth, the distorted sex ratio could be due to differential sex mortality. Evidences on such differential sex mortality among mule deer have been reviewed by Robinette *et al.* (1957). Krasinski (1978) reported a male mortality of about 69% in Eurpean bison. About 23% of the total mortality were of calves of less than one year. Mortality due to poor nutrition on males, particularly during the first year of life was greatly accentuated. Similar observations have also been made on black-tailed deer (Taber and Dasmann, 1954; Longhurst and Douglas, 1953). According to Klein (1970) male appears to be more susceptible when food becomes limiting and this could be due to their higher metabolic rate resulting from a greater rate of growth, activity, curiosity and independance than the females. Such factors could also be responsible for the distorted sex ratio among gaur in Parambikulam.

The mean group size of 6.0398 and the most frequented group size of 3, 5 and 7 observed in Parambikulam agrees with the findings of Dwivedi and Shukla (1988) in

Pench, Schaller (1967) and Belsare *et al*. (1984) in Kanha National Park. However, the large groups reported by Belsare *et al*. (1984) in Kanha and Nair *et al*. (1985) in Periyar could be aggregations of smaller units probably due to the environmental factors in these areas. Further, Shackleton (1968) has drawn the attention to the relation between habitat conditions and group size. The mosaic nature of habitat with very few large open areas could be the reason for large number of smaller groups of gaur in Parambikulam. Dwivedi and Shukla (1988) have also indicated the possibility of casual assemblages of individuals forming larger groups in Pench. Similar aggregations were observed by Krasinski (1978) in European bison during winter due to constant supply of supplementary food.

Group size is an optimal response to the environment. Ecological factors appear to influence mean group size in a number of primates (Denham, 1971; Crook, 1972), and in the African antelopes (Jarman, 1974). Mean group size of gaur in Parambikulam was found to be influenced by season indicating the direct relation with food availability and also the proportion of calves. The second wet season had maximum food availability and also the highest proportion of calves in the population. However, variation in mean group size is mostly explained by the combination of grass and shrubs and is highly influenced by the availability of grass alone. The higher proportion of calves during the second wet season causes the gaur to form large sized groups but with less cohesion.

The general objective strategy of ungulates is to drop their fawns near the beginning of the time most favourable for ultimate survival, or after any particular unfavourable condition. In the tropics, warm temperature prevails year round at lower elevation and the animals are subjected to different selective regimes. Local monsoons or droughts become very important factors limiting the survival of new born. The present findings of maximum number of births between the two peak rainfall months in Parambikulam indicate the strategy of gaur to ensure successful calf birth and survival.

Tropical mammals have a very small range of temperature tolerance. Metabolic rate also increases with the fall in temperature below a critical minimum (Scholander *et al*., 1950). Most of the births in tropics have been observed to be during a period of optimum fawn survival possibility (Duplessis, 1972; Skinner *et al*., 1973; Estes, 1976; Eltringham, 1979; Delany and Happold, 1979). However, a few births have also been reported through out the year. The present observation of calves in the month of April in Parambikulam and the sudden fall in the percentage of calves in the subsequent months of May, June and July explains the low survival rate of calves born during the month of April. These could be due to the adverse effect of higher temperature and maximum daily fluctuation. This is especially true while considering the poorly developed homeothermic mechanism in new born mammals (Brody, 1945).

Considering the additional nutritional requirement of pregnant and lactating females (Sadlier, 1969), chances of survival of new born calves during the second wet season starting from August to January are maximum because of higher food availability. Further, the new born calves were observed to spend more time in resting (sleeping) under the bushes for the first few days. Similar observations on deer producing maximum number of fawns in spring when food is more abundant have also been reported from temperate ranges (Linsdale and Tomich, 1953; Southern, 1964; Sadlier, 1969; Mitchel *et al*., 1977). Klein (1970) observed decreased production and survival of deer fawns in situations where food quality deteriorate due to various reasons. In tropical climate, the foraging production and the breeding cycle among most ungulates are closely associated with the annual cycle of rain fall (Phillipson, 1975; Eltringham, 1979).

Parturition was considerably less synchronized and the length of birth of season did not fit the pattern typical of ungulates exhibiting a follower strategy of mother-young spatial relations. Gaur, like *Bison sp*. (Green and Rothstein, 1993) seems to differ from typical follower species and the calf concealed itself in hiding places for a short period before moving with the group continuously. This short period of concealment enables to reduce calf mortality to a certain extent as the golden brown coloured calf would be highly conspicuous in the company of dark coloured adults and thus would be highly prone to predation.

Brander (1923) reported that breeding season of gaur varied considerably in different areas (districts) and was not confined to one period. Majority of the breeding, according to him was during the cold weather of December and January. In Central India, the calves are reported to be born mostly in the month of August and September. Stebbing (1911) and Sanderson (1912) have also made similar observations with maximum number of calves in April, May and June. The present observations on calving in Parambikulam confirm these findings and indicate the survival strategy of the species.

Estes (1974) has discussed social organization of the African bovids in detail. According to him, gregariousness is an essential adaptation for life in the open. Further, Eisenberg (1966) has observed that adaptations to open habitats favours group formation. Grouping tendencies are shown by many solitary bovids when attracted into the open onto neutral ground. Eisenberg (1966) argued that small size, solitary habits and concealment behaviour are inter related elements in an anti-predator strategy. Estes (1974) found that several large bovids live in cover. However, in gaur, the disadvantages of being conspicuous due to large size is compensated by the groups substituting cover.

Two of the three social classes universal in gregarious bovids (Estes, 1974), the females with/without young and solitary adults are apparent in gaur. The bachelor (all-male) groups were not observed. Considering the preference for open grasslands surrounded by forest, grazing feeding habits, less conspicuous sexual dimorphism, well developed horns in females as well, precocial young, group defence and the small to medium sized groups gaur exhibits the major features of bovine social organization as mentioned by Estes (1974).

Chapter 4

Food and Feeding

4.1 Introduction

Large herbivores are not evenly distributed across a region while foraging, but rather favour certain habitat types over others (McNaughton and Georgiadis, 1986). Preference for a given habitat type is largely determined by the available vegetation within the area, providing food, water, minerals, shelter from climatic extremes and cover from predators (Jarman & Sinclair, 1979). Food resources, however, not only vary between different habitat types, but also show marked seasonal variations within a given habitat, in response to changes in rainfall patterns (Philipson, 1975; Sinclair, 1975). Changes in plant distribution and phenology also affect ungulate food habits, energy budgets, movements and seasonal distribution (Dinerstein, 1979). Survival of a herbivore depends on the success in searching and finding the usable food which varies in time and space. There has been a lot of difference in these, from species to species and between individuals of a species.

Riney (1982) has discussed the relevance of food habit studies in making management decisions. According to him, a wealth of knowledge could be generated through food habit studies. The studies could consist of composition of the diet, its seasonal variation and the parts utilized. Riney (1982) has also reviewed the various techniques available for food habit studies and has mentioned the limitations of each such technique. It is also important to identify the principal foods of an animal population which form the largest percentage of food items in its diet and also the food preference which is the extent to which a food is consumed in relation to its availability.

The seasonal and spatial differences between plant communities in species composition, production, food quality and quantity and food-items' dispersion all have a bearing on how an individual ungulate sets about feeding (Jarman & Sinclair, 1979). Herbivores respond to the changes in the distribution of food species by choosing the best site and the nutritionally rich abundant species. A feeding pattern established for one area need not be the same to another (Sukumar, 1989a). A knowledge on feeding preferences and nutritive requirements is essential in planning habitat management.

Gaur has been described basically a grazer (Brander, 1923; Schaller, 1967; Krishnan, 1972). The North American bison (*Bison bison bison*) and the Wood bison (*Bison bison athabascae*) are also primarily grazers and browzers secondarily (Reynolds *et.al* . 1982). Krishnan (1972) reported grass as a major component of gaur diet in Mudumalai Wildlife Sanctuary, Tamil Nadu. Similar observations were also made by Moorthy (1989) and Prabhakar (1992) from their short term study. But for these, there was no detailed study on the food and feeding habits of gaur, the *Bos gaurus gaurus*. The present observations aimed at collecting information on food and feeding habits including the principal and preferred food in Parambikulam Wildlife Sanctuary.

4.2 Methods

4.2.1 Food species: Information on the food plants were collected through direct observation of animals. The feeding sites were also examined, after the animal left the location, for fresh feeding signs and identification of plants fed by the animal. A herbarium of the food plants were made for confirmation of species identity.

4.2.2 Principal and preferred food: Food preference was estimated through feeding quadrat method (Grobler, 1981 & 1983). The plots were selected at random using ball throwing method and the number of plots varied depending on the size of the area used by the animal at the time of observation. Plots of 1x1m (for grass and herbs) and 5x5m (for shrubs) were laid at fresh feeding sites located while observing. All the food plants species within the plots were listed. The number of food species (grass, herb and shrub), the total number of each species and the phenology of available and utilized species were recorded. Each species was also categorised into young, mature and with dry leaves and flowers for recording phenology. In the case of grass, percentage cover of each species was estimated instead of total number of each species. Observations were made proportionately for the above information in all habitat types and zones.

Table 13. Seasonal distribution of feeding quadrats in different habitats

Habitat	Grass	Herb	Shrub
Dry season			
Evergreen	20	20	20
Moist deciduous	197	196	203
Plantation	118	118	118
Grassland	121	121	111
Riverine	5	5	5
First wet season			
Evergreen	0	0	0
Moist deciduous	138	133	138
Plantation	93	93	87
Grassland	63	63	59
Riverine	0	0	0
Second wet season			
Evergreen	0	0	0
Moist deciduous	76	76	76
Plantation	70	70	70
Grassland	88	88	88
Riverine	11	11	11
Total	1000	994	986

The details of number of feeding quadrats laid in each zone and habitat are given in Tables 13 and 14 respectively. The principal food have been worked out for grass, herb and shrub separately since method of quantification varied for each group, the aerial cover for grass and number of plants for others. Principal food in each group in different habitats has also been worked out. The major habitat types identified for the purpose were evergreen, moist deciduous, plantation, grassland (vayal) and riverine.

Table 14. Seasonal distribution of feeding quadrats in different zones

Zone	Grass	Herb	Shrub
Dry season			
Kariyanshola	5	5	5
Elathodu	11	11	11
Seechali	138	138	136
Sungam	53	53	52
Thellickal	62	62	62
Kannimara	179	179	179
First wet season			
Kariyanshola	0	0	0
Elathodu	48	48	48
Seechali	51	51	48
Sungam	88	83	83
Thellickal	31	31	30
Kannimara	76	76	75
Second wet season			
Kariyanshola	0	0	0
Elathodu	20	20	20
Seechali	58	58	58
Sungam	58	58	58
Thellickal	30	30	30
Kannimara	47	47	47

Analyses

Chi-square (3 x 6 contingency table) test was performed using SPSS/PC+ CROSSTAB procedure to test the variation in frequency distribution of grazing and browsing between different age and sex categories and between seasons within categories.

Food preference index was calculated as suggested by Riney (1982).

$$\text{Food preference index} = \frac{\text{\% food species present in diet}}{\text{\% food species available in environment}}$$

where

$$\text{\% food species present in diet (Principal food)} = \frac{\text{\% cover/number used of a species}}{\text{\% cover/number used of all species}}$$

$$\text{\% food species available in environment} = \frac{\text{\% cover/number available of a species}}{\text{\% cover/number available of all species}}$$

4.3 Results

4.3.1 Food species

Table 15 gives the list of plant species fed by gaur in Parambikulam Wildlife sanctuary. It was observed to feed on 151 species of plants belonging to 37 families and only one species, *Lygodium scandens* of the group Pteridophyta. More than 50 % of the food species were of the family Poaceae (43 species), Cyperaceae (17 species), Papilionaceae (15 species) and Malvaceae (10 species). Plants from the families of Poaceae and Cyperaceae combinedly formed the major food item of gaur in the area.

Table 15. Food species of gaur in Parambikulam Wildlife Sanctuary

Ranunculaceae
Naravelia zeylanica
Malvaceae
Hibiscus furcatus
Hibiscus hispidissimus
Hibiscus lobatus
Sida acuta
Sida beddomei
Sida cordifolia
Sida mysorensis
Sida rhombifolia
Thespesia lampas
Urena lobata
Sterculiaceae
Helicteres isora
Melochia corchorifolia

Tiliaceae
Triumfetta rhomboidea
Oxalidaceae
Biophytum reinwardtii
Rhamnaceae
Ziziphusoenoplia
Ziziphusxylopyrus
Sapindaceae
Cardiospermum helicacabum
Papilionaceae
Alysicarpus glumaceous
Alysicarpus monilifer
Centrosema pubescens
Desmodium gangeticum
Desmodium heterophyllum
Desmodium laxiflorum
Desmodium pulchellum
Desmodium triangulare
Desmodium triquetrum
Flemingia strobilifera
Indigofera hirsuta
Indigofera spicata
Pseudarthria viscida
Smithia geminiflora
Uraria hamosa
Caesalpiniaceae
Acacia intsia
Cassia occidentalis
Mimosaceae
Mimosa pudica
Lythraceae
Ammannia baccifera
Nesaea lanceolata
Onagraceae
Ludwigia hyssopifolia
Aizoaceae
Mollugo pentaphylla
Umbelliferae
Centella asiatica
Rubiaceae
Mitracarpus vertcillatus
Oldenlandia nitida
Asteraceae
Ageratum conyzoides
Bidens pilosa
Crassocephalum crepidioides
Eclipta alba
Elephantopus scaber
Spilanthes radicans
Synedrella nodiflora
Campanulaceae
Lobelia alsinoides
Plumbaginaceae
Plumbago zeylanica
Apocynaceae
Catheranthus pusillus
Ichnocarpus frutescens
Asclepiadaceae
Hemidesmus indicus
Hydrophyllaceae
Hydrolea zeylanica
Convolvulaceae
Ipomoea deccana
Ipomoea hederifolia
Merremia umbellata
Quamoclit phoenicea
Scrophulariaceae
Lindernia pusilla
Acanthaceae
Dipteracanthus prostrata
Justicia trinervia
Micranthus oppositifolius
Rungia sp.
Staurogyne zeylanica
Thunbergia fragrans
Verbenaceae
Lantana camara
Labiatae
Acrocephalus hispidus
Leucas aspera

Ocimum gratissimum
Amaranthaceae
Achyranthes aspera
Alternanthera pungens
Alternanthera sessilis
Chenopodiaceae
Chenopodium ambrosioides
Polygonaceae
Polygonum barbatum

Piperaceae
Peperomia pellucida
Euphorbiaceae
Acalypha racemosa
Phyllanthus urinaria
Urticaceae
Laportea interrupta
Pouzolzia indica
Orchidaceae
Habenaria affinis
Peristylus goodyeroides
Zingiberaceae
Curcuma vamana
Globba marantina
Zingiber officinale
Hypoxidaceae
Curculigo orchioides
Commelinaceae
Aneilema sp.
Commelina benghalensis
Commelina clavata
Cyperaceae
Cyperus compressus
Cyperus distans
Cyperus exaltatus
Cyperus haspan
Cyperus iria
Cyperus kurzii
Cyperus pilosus
Cyperus zollingeri
Fimbristylis dichotoma
Fimbristylis littoralis
Kyllinga monocephala
Kyllinga triceps
Mariscus pictus
Murdannia japonica
Pycreus odoratus
Scleria stipularis
Scleria elata
Poaceae
Alloteropsis cimicina
Apluda mutica
Arundinella mesophylla
Axonopus compressus
Bambusa arundinacea
Brachiaria ramosa
Centotheca lappacea
Cymbopogon flexuosus
Cynodon dactylon
Cyrtococcum decurrens
Dactyloctenium aegyptium
Digitaria bicornis
Digitaria ciliaris
Digitaria griffithii
Digitaria ornithopoda
Digitaria setigera
Digitaria wallichiana
Echinochloa colona
Eleusine indica
Eragrostis tenella
Eragrostis tenuifolia
Eragrostis unioloides
Garnotia tenella
Heteropogon contortus
Imperata cylindrica
Ischaemum indicum
Ischaemum rangacharianum
Leersia hexandra
Oplismenus compositus
Oryza granulata

Oryza rufipogon	*Paspalum scrobiculatum*
Ottochloa nodosa	*Setaria pallida-fusca*
Panicum indicum	*Setaria pumila*
Panicum notatum	*Setaria verticillata*
Panicum psilopodium	*Sporobolus indicus*
Paspalidium flavidum	*Themeda triandra*
Paspalum conjugatum	*Tripogon ananthaswamianus*

All the parts except woody part of the plants of Malvaceae, Tiliaceae and Papilionaceae were fed. All the parts of Poaceae species were utilised in all seasons except those of *Digitaria spp., Heteropogon contortus*, *Setaria spp*., *Sporobolus indicus*. The animal was observed to feed more on Cyperaceae during first wet season before it flowered. *Helicteres isora* was the most preferred among Sterculiaceae members and feeding was confined to young leaves and rarely on mature leaves. *Desmodium spp*. and *Pseudarthria viscida* were more utilized compared to other species of Papilionaceae family. *Desmodium laxiflorum* was the most preferred among the *Desmodium* species. Feeding on young leaves of *Acacia intsia* was observed only on few occasions and was restricted to plants below 1 m height. Feeding on *Mimosa pudica* was observed only during first wet season. *Ammannia baccifera* of family Lythraceae and *Alternanthera* species of Amaranthaceae family were fed during first and second wet seasons. Feeding on species of Asteraceae were observed more in first wet season before flowering. The *Ageratum conyzoides* and *Synedrella nodiflora* were used extensively wherever available with limited use while in flower. *Micranthes oppositifolius* and the climber *Thunbergia fragrans* were more fed among the species of Acanthaceae. Among the Hypoxidaceae, *Curculigo orchioides* were fed frequently. *Kyllinga monocephala* and *K. triceps* were the highly utilised among the Cyperaceae. *Cyperus compressus* and *Fimbristylis littoralis* were often fed whenever encountered. Only the young leaves of *Scleria spp*. and *Cyperus distans* and *C. exaltatus* were fed and hence was confined to growing season.

4.3.2 Principal food

4.3.2.1 Grass

The principal food is defined as the percentage composition of the food items contributing maximum to the animals diet. Those contributing below one percent to diet are excluded. Nineteen species formed the principal grass food of gaur in Parambikulam with about seven species contributing more the 50 % (Table 16). The seasonal ranking of principal grass food for dry, first wet and second wet seasons are given in Table 17. *Axonopus compressus* forms the major percentage of the diet throughout the year and different seasons except in first wet where it contributes only 3.83 %. *Paspalum scrobiculatum* which formed 11.59 % of the overall diet figures in the ranking in all seasons. *Eleusine indica* (9.38 % in overall), has fourth, second and third ranking in the dry, first wet and second wet seasons. In dry seasons five species contributed more than 50 % to the diet compared to six species in first and second wet seasons.

Table 16. Over all principal grass food of gaur in Parambikulam (irrespective of season)

Species	% in Diet
Axonopus compressus	12.23
Paspalum scrobiculatum	11.59
Eleusine indica	9.38
Kyllinga monocephala	8.52
Themeda triandra	8.47
Brachiaria ramosa	6.71
Paspalidium flavidum	5.14
Oplismenus compositus	3.41
Paspalum conjugatum	3.32
Ottochloa nodosa	3.27
Ischaemum indicum	2.68
Commelina benghalensis	2.59
Ischaemum rangacharianum	2.43

Sporobolus indicus	2.31
Leersia indica	2.14
Cyrtococcum decurrens	1.95
Eragrostis unioloides	1.54
Digitaria setigera	1.20
Eragrostis tenella	1.16

Table 17. Seasonal principal grass food of gaur in Parambikulam

Season					
Dry		First wet		Second wet	
Species	% in Diet	Species	% in Diet	Species	% in Diet
Paspalum scrobiculatum	19.11	*Kyllinga monocephala*	17.95	*Axonopus compressus*	13.19
Axonopus compressus	18.97	*Eleusine indica*	10.71	*Themeda triandra*	12.36
Themeda triandra	12.03	*Brachiaria ramosa*	8.98	*Eleusine indica*	8.50
Eleusine indica	8.72	*Paspalidium flavidum*	6.88	*Ischaemum rangacharianum*	7.47
Brachiaria ramosa	5.31	*Paspalum scrobiculatum*	6.11	*Paspalum scrobiculatum*	6.54
Ischaemum indicum	3.95	*Paspalum conjugatum*	4.85	*Paspalidium flavidum*	5.96
Paspalum conjugatum	3.69	*Axonopus compressus*	3.83	*Brachiaria ramosa*	5.70
Oplismenus compositus	3.48	*Sporobolus indicus*	3.83	*Ottochloa nodosa*	4.96
Paspalidium flavidum	3.19	*Eragrostis unioloides*	3.48	*Leersia hexandra*	4.81
Kyllinga monocephala	2.81	*Ottochloa nodosa*	3.30	*Kyllinga monocephala*	4.05
Commelina benghalensis	2.54	*Oplismenus compositus*	3.07	*Oplismenus compositus*	3.81
Ottochloa nodosa	2.32	*Digitaria setigera*	2.60	*Commelina benghalensis*	3.64
Cyrtococcum decurrens	1.76	*Oryza rufipogon*	2.45	*Sporobolus indicus*	3.28
Panicum psilopodium	1.60	*Leersia hexandra*	2.10	*Cyrtococcum decurrens*	2.95
Ischaemum rangacharianum	1.30	*Commelina benghalensis*	1.97	*Ischaemum indicum*	1.70
		Themeda triandra	1.88	*Alloteropsis cimicina*	1.46
		Ischaemum indicum	1.82	*Oryza granulata*	1.05
		Eragrostis tenella	1.79		
		Cyrtococcum decurrens	1.55		
		Echinochloa colona	1.28		
		Panicum notatum	1.08		
		Digitaria ciliaris	1.08		

4.3.2.2 Herb

About seven species of herbs dominated the overall diet (Table 18) with four species in dry, five species in first wet and four species in second wet seasons (Table 19). There was not much variation in the number of principal food throughout the year and in different seasons. However, the composition of the species in the diet varied in different seasons.

Table 18. Over all principal herb food of gaur in Parambikulam (irrespective of season)

Species	% in Diet
Desmodium heterophyllum	15.49
Alternanthera pungens	10.79
Micranthus oppositifolius	9.77
Centella asiatica	8.42
Ageratum conyzoides	7.50
Synedrella nodiflora	6.33
Mimosa pudica	5.75
Justicia trinervia	4.86
Sida beddomei	3.50
Curculigo orchiodes	3.26
Centrosema pubescens	3.17
Peperomia pellucida	3.13
Lobelia alsinoides	2.00
Achyranthes aspera	1.72
Ipomoea decana	1.44
Smithia geminiflora	1.41
Thunbergia fragrans	1.38
Uraria hamosa	1.29
Spilanthes radicans	1.04

Table 19. Seasonal principal herb food of gaur in Parambikulam

Season					
Dry		First wet		Second wet	
Species	% in	Species	% in	Species	% in Diet

	Diet		Diet		
Alternanthera pungens	20.13	*Ageratum conyzoides*	16.76	*Desmodium heterophyllum*	19.33
Desmodium heterophyllum	17.62	*Desmodium heterophyllum*	10.96	*Micranthus oppositifolius*	12.11
Centella asiatica	9.70	*Synedrella nodiflora*	9.83	*Centella asiatica*	11.98
Micranthus oppositifolius	9.46	*Micranthus oppositifolius*	8.62	*Alternanthera pungens*	10.31
Mimosa pudica	5.82	*Peperomia pellucida*	7.33	*Synedrella nodiflora*	6.70
Centrosema pubescens	3.48	*Justicia trinervia*	5.96	*Mimosa pudica*	6.19
Justicia trinervia	3.23	*Mimosa pudica*	5.40	*Justicia trinervia*	5.67
Synedrella nodiflora	2.59	*Centella asiatica*	4.92	*Ipomoea decana*	4.25
Lobelia alsinoides	2.59	*Sida beddomei*	4.35	*Sida beddomei*	3.87
Sida beddomei	2.43	*Curculigo orchioides*	4.03	*Curculigo orchioides*	3.74
Ammannia baccifera	2.34	*Centrosema pubescens*	3.14	*Centrosema pubescens*	2.71
Curculigo orchioides	2.18	*Uraria hamosa*	2.66	*Achyranthes aspera*	2.45
Thunbergia fragrans	2.02	*Smithia geminiflora*	2.42	*Ageratum conyzoides*	1.93
Synedrella nodiflora	1.70	*Lobelia alsinoides*	2.01	*Thunbergia fragrans*	1.42
Ageratum conyzoides	1.70	*Alternanthera pungens*	1.77	*Hibiscus lobatus*	1.42
Achyranthes aspera	1.54	*Achyranthes aspera*	1.45	*Spilanthes radicans*	1.16
Hemidesmus indicus	1.46	*Spilanthes radicans*	1.29	*Lobelia alsinoides*	1.03
Smithia geminiflora	1.29	*Phyllanthus urinaria*	1.05	*Hemidesmus indicus*	1.03

4.3.2.3 Shrub

Twelve species of shrubs contributed much to the diet of gaur with *Sida rhombifolia* sharing a major portion in the overall (Table 20) and in different seasons (Table 21). Six species viz. *Sida rhombifolia*, *Triumfetta rhomboidea*, *Bambusa arundinacea*, *Urena lobata*, *Pseudarthria viscida* and *Desmodium laxiflorum* contributed about 80 % of the diet.

Table 20. Over all principal shrub food of gaur in Parambikulam (irrespective of season)

Species	% in Diet
Sida rhombifolia	22.34
Triumfetta rhomboidea	17.13
Bambusa arundinacea	14.41
Urena lobata	12.43
Desmodium laxiflorum	8.75
Pseudarthria viscida	7.14
Helicteres isora	4.71
Hibiscus furcatus	3.18

Desmodium triangulare	1.69
Desmodium gangeticum	1.61
Lantana camara	1.20
Sida cordifolia	1.07

Table 21. Seasonal principal shrub food of gaur in Parambikulam

Season					
Dry		**First wet**		**Second wet**	
Species	**% in Diet**	**Species**	**% in Diet**	**Species**	**% in Diet**
Bambusa arundinacea	27.47	*Sida rhombifolia*	26.57	*Triumfetta rhomboidea*	19.91
Sida rhombifolia	19.47	*Triumfetta rhomboidea*	21.67	*Sida rhombifolia*	18.81
Urena lobata	13.79	*Desmodium laxiflorum*	11.37	*Pseudarthria viscida*	14.16
Triumfetta rhomboidea	10.95	*Urena lobata*	10.49	*Urena lobata*	13.94
Helicteres isora	7.79	*Pseudarthria viscida*	6.47	*Desmodium laxiflorum*	10.18
Desmodium laxiflorum	5.26	*Bambusa arundinacea*	5.59	*Bambusa arundinacea*	6.86
Pseudarthria viscida	4.53	*Lantana camara*	2.84	*Hibiscus furcatus*	4.87
Hibiscus furcatus	3.58	*Helicteres isora*	2.35	*Helicteres isora*	3.54
Desmodium triangulare	2.42	*Hibiscus furcatus*	2.06	*Ziziphusoenoplia*	2.65
Sida cordifolia	1.26	*Desmodium gangeticum*	1.76	*Desmodium gangeticum*	2.21
Ziziphusoenoplia	1.26	*Desmodium pulchellum*	1.47	*Sida cordifolia*	1.11
Desmodium gangeticum	1.16				

4.3.3 Principal food in different habitats

The results of overall analysis for principal grass food species in different habitats are given in Table 22. Food species viz. *Paspalum scrobiculatum, Paspalum conjugatum, Axonopus compressus* and *Eleusine indica* contributed most to the diet. *Panicum psilopodium* dominated in the evergreen where as the number of species contributing to much of the diet in other types of habitat were more than five.

Table 22. Principal grass food of gaur in different habitats

Species	**% in diet**
Evergreen	
Panicum psilopodium	59.30
Oplismenus compositus	12.79
Commelina benghalensis	10.47
Panicum notatum	10.47
Ottochloa nodosa	4.65
Cyperus kurzii	2.33
Moist deciduous	
Brachiaria ramosa	11.65
Axonopus compressus	10.21
Paspalidium flavidum	8.28
Eleusine indica	8.11
Kyllinga monocephala	7.57
Oplismenus compositus	5.29

Ottochloa nodosa	5.23
Paspalum scrobiculatum	4.89
Themeda triandra	4.43
Ischaemum indicum	2.72
Oryza rufipogon	2.51
Cyrtococcum decurrens	2.48
Commelina benghalensis	2.01
Digitaria setigera	1.84
Sporobolus indicus	1.80
Eragrostis tenella	1.55
Paspalum conjugatum	1.41
Ischaemum rangacharianum	1.28
Digitaria ciliaris	1.28
Mariscus pictus	1.23
Panicum notatum	1.23
Alloteropsis cimicina	1.16
Species	**% in diet**
Echinochloa colona	1.16
Oryza granulata	1.12
Arundinella mesophylla	1.02
Plantation	
Paspalum scrobiculatum	10.93
Kyllinga monocephala	10.41
Axonopus compressus	10.12
Brachiaria ramosa	9.23
Eleusine indica	6.58
Oplismenus compositus	6.32
Sporobolus indicus	6.23
Ottochloa nodosa	5.80
Paspalidium flavidum	4.01
Cyrtococcum decurrens	3.92
Themeda triandra	3.87
Commelina benghalensis	3.40
Digitaria setigera	2.68
Eragrostis tenella	2.19
Ischaemum rangacharianum	2.08
Eragrostis unioloides	1.70
Leersia hexandra	1.62
Panicum notatum	1.18
Grassland	
Paspalum scrobiculatum	16.53
Axonopus compressus	14.66
Themeda triandra	14.07
Eleusine indica	11.38
Kyllinga monocephala	8.88
Paspalum conjugatum	5.23
Ischaemum indicum	3.79
Species	**% in diet**
Leersia hexandra	3.77
Ischaemum rangacharianum	3.62
Paspalidium flavidum	3.31
Commelina benghalensis	2.41
Brachiaria ramosa	2.37
Eragrostis unioloides	2.14
Sporobolus indicus	1.20
Riverine	
Paspalum scrobiculatum	25.45
Species	**% in diet**
Paspalum conjugatum	21.12
Axonopus compressus	17.56
Eleusine indica	16.79
Paspalidium flavidum	6.11
Commelina benghalensis	4.58
Kyllinga monocephala	2.80
Ottochloa nodosa	2.29
Cyrtococcum decurrens	2.04
Oplismenus compositus	1.02

In the case of herbs, the number of species contributing to the diet were comparatively few in the evergreen, grassland and riverine habitats (Table 23).

Table 23. Principal herb food of gaur in different habitats

Species	**% in diet**
Evergreen	
Curculigo orchioides	30.30
Ageratum conyzoides	24.24
Micranthus oppositifolius	18.18
Synedrella nodiflora	12.12
Zingiber officinale	6.06
Achyranthes aspera	6.06
Ichnocarpus frutescens	3.03
Moist deciduous	
Ageratum conyzoides	12.10
Micranthus oppositifolius	10.84
Synedrella nodiflora	9.08
Peperomia pellucida	8.57
Alternanthera pungens	7.31
Mimosa pudica	6.89
Justicia trinervia	6.22
Sida beddomei	5.46
Curculigo orchioides	4.37
Centrosema pubescens	4.12
Desmodium heterophyllum	3.87
Uraria hamosa	2.52
Achyranthes aspera	2.18
Thunbergia fragrans	2.10
Ammannia baccifera	2.10
Spilanthes radicans	1.68
Hemidesmus indicus	1.60
Species	**% in diet**
Lobelia alsinoides	1.26
Plantation	
Micranthus oppositifolius	16.57
Alternanthera pungens	12.79
Justicia trinervia	9.45
Synedrella nodiflora	7.56
Centrosema pubescens	6.83
Sida beddomei	6.40
Curculigo orchioides	6.10
Desmodium heterophyllum	5.67
Mimosa pudica	5.52
Achyranthes aspera	2.91
Ageratum conyzoides	2.62
Thunbergia fragrans	2.33
Hibiscus lobatus	2.03
Uraria hamosa	1.74
Phyllanthus urinaria	1.60
Lobelia alsinoides	1.60
Ipomoea decana	1.45
Hemidesmus indicus	1.31
Spilanthes radicans	1.16
Grassland	
Desmodium heterophyllum	29.79
Centella asiatica	21.50
Alternanthera pungens	12.56
Ageratum conyzoides	5.80
Species	**% in diet**
Mimosa pudica	5.15
Micranthus oppositifolius	4.43
Smithia geminiflora	3.22
Synedrella nodiflora	3.14
Lobelia alsinoides	3.14
Ipomoea decana	2.98
Alternanthera sessilis	1.69
Justicia trinervia	1.53
Species	**% in diet**
Riverine	
Desmodium heterophyllum	48.51
Alternanthera pungens	19.80
Micranthus oppositifolius	13.86
Achyranthes aspera	4.95
Synedrella nodiflora	2.97
Mimosa pudica	2.97
Ageratum conyzoides	1.98
Sida beddomei	1.98
Thunbergia fragrans	1.98

Number of shrub species forming the principal food were few in all habitat types (Table 24). *Sida rhombifolia, Triumfetta rhomboidea* and *Urena lobata* were the major food species in evergreen, plantation and grassland. However, *Bambusa arundinacea* contributed considerably to the diet in moist deciduous, grassland and riverine types.

Table 24. Principal shrub food of gaur in different habitats

Species	% in diet
Evergreen	
Sida rhombifolia	63.64
Triumfetta rhomboidea	18.18
Urena lobata	9.09
Pseudarthria viscida	9.09
Moist deciduous	
Sida rhombifolia	21.22
Bambusa arundinacea	16.91
Triumfetta rhomboidea	14.39
Urena lobata	11.87
Desmodium laxiflorum	8.71
Pseudarthria viscida	7.55
Helicteres isora	4.17
Hibiscus furcatus	2.59
Desmodium gangeticum	2.23
Desmodium triangulare	2.09
Lantana camara	2.09
Ziziphusoenoplia	1.65

Species	% in diet
Plantation	
Triumfetta rhomboidea	22.16
Sida rhombifolia	21.64
Urena lobata	13.30
Desmodium laxiflorum	10.69
Pseudarthria viscida	8.34
Bambusa arundinacea	7.56
Helicteres isora	7.04
Hibiscus furcatus	3.00
Desmodium triangulare	1.56
Sida cordifolia	1.04
Ziziphusoenoplia	1.04
Grassland	
Sida rhombifolia	28.18
Bambusa arundinacea	24.09
Triumfetta rhomboidea	16.82
Urena lobata	13.64
Hibiscus furcatus	5.45

Species	% in diet
Desmodium laxiflorum	4.09
Cassia occidentalis	2.73
Sida cordifolia	2.27
Staurogyne zeylanica	1.82
Riverine	
Hibiscus furcatus	26.09

Species	% in diet
Sida rhombifolia	17.39
Triumfetta rhomboidea	17.39
Bambusa arundinacea	13.04
Urena lobata	8.70
Helicteres isora	8.70
Desmodium triquetrum	4.35
Pseudarthria viscida	4.35

4.3.4 Food preferences

4.3.4.1 Grass

The results of analyses for preference index of grass food species for the over all study period (irrespective of seasons) are given in Table 25. Gaur was observed to have a high preference for *Cyperus haspan, Kyllinga triceps, Fimbristylis littoralis* and *Dactyloctenium aegyptium.* But the occurrence of these species in the feeding sites were very few. *Paspalum scrobiculatum*, *Axonopus compressus* and *Eleusine indica* were observed to have a high index value with a comparatively better occurrence in the sites.

Table 25. Grass food preference index of gaur (irrespective of season)

Species	No. of occurrence	Index
Cyperus haspan	1	2.99
Kyllinga triceps	4	2.59
Fimbristylis littoralis	1	1.80
Dactyloctenium aegyptium	3	1.74
Cyperus pilosus	4	1.71
Oryza rufipogon	7	1.62
Apluda mutica	5	1.56
Paspalum scrobiculatum	115	1.48
Axonopus compressus	136	1.44
Eleusine indica	131	1.36
Digitaria griffithii	11	1.34
Paspalum conjugatum	33	1.32
Themeda triandra	90	1.32
Leersia hexandra	36	1.28
Paspalidium flavidum	94	1.28
Digitaria ornithopoda	5	1.20
Arundinella mesophylla	14	1.12
Ischaemum rangacharianum	44	1.09
Cynodon dactylon	25	1.07
Ischaemum indicum	56	1.06
Oryza granulata	27	1.05
Brachiaria ramosa	193	1.04

Alloteropsis cimicina	17	1.03
Panicum psilopodium	34	1.03
Kyllinga monocephala	273	1.01
Sporobolus indicus	72	1.01
Eragrostis unioloides	50	0.96
Heteropogon contortus	2	0.95
Panicum indicum	3	0.94
Cymbopogon flexuosus	1	0.90
Eragrostis tenella	43	0.90
Setaria verticillata	8	0.89
Tripogon anathaswamianus	4	0.84
Echinochloa colona	36	0.83
Cyperus kurzii	22	0.80
Panicum notatum	29	0.77
Cyrtococcum decurrens	80	0.74
Commelina benghalensis	210	0.67
Cyperus compressus	11	0.64
Centotheca lappacea	2	0.60
Garnotia tenella	1	0.60
Mariscus pictus	35	0.60
Digitaria ciliaris	30	0.58
Commelina clavata	17	0.52
Digitaria bicornis	21	0.52
Eragrostis tenuifolia	18	0.48
Ottochloa nodosa	227	0.48
Fimbristylis dichotoma	12	0.46
Digitaria setigera	88	0.43
Imperata cylindrica	18	0.42
Oplismenus compositus	292	0.42
Cyperus distans	11	0.37
Cyperus iria	33	0.29
Aneilema sp.	8	0.25
Murdannia japonica	6	0.21
Scleria stipularis	5	0.07

Eragrostis tenuifolia, *Ottochloa nodosa*, *Fimbristylis dichotoma*, *Digitaria setigera*, *Imperata cylindrica*, *Oplismenus compositus*, *Cyperus distans*, *Cyperus iria*, *Aneilema sp.*, *Murdannia japonica* and *Scleria stipularis* were the least preferred (less than 0.5). *Cyperus exaltatus*, *C. Zollingeri*, *Pycreus odoratus*, *Scleria elata* and *Setaria pumila* were seen to be totally avoided by the animal.

4.3.4.2 Herb

In the case of herb, *Chenopodium ambrosioides*, *Cardiospermum helicacabum*, *Elephantopus scaber*, *Lygodium scandens*, *Zingiber officinale* and *Nesaea lanceolata* were the most preferred though occurred only few times in feeding quadrats (Table 26). *Thunbergia fragrans*, *Synedrella nodiflora*, *Sida beddomei*, *Ageratum conyzoides*, *Centrosema pubescens*, *Curculigo orchioides*, *Lobelia alsinoides* and *Centella asiatica* were moderately preferred and occurred in high numbers in the sites. A few viz. *Alysicarpus glumaceous*, *Acalypha racemosa*, *Eclipta alba*, *Naravelia zeylanica* and *Polygonum barbatum* which were totally avoided.

Table 26. Herb food preference index of gaur (irrespective of season)

Species	No. of occurrance	Index
Cardiospermum helicacabum	2	2.96
Chenopodium ambrosioides	4	2.96
Elephantopus scaber	1	2.96
Lygodium scandens	2	2.96
Zingiber officinale	2	2.96
Nesaea lanceolata	3	2.37
Peperomia pellucida	17	2.31
Thunbergia fragrans	47	2.08
Quamoclit phoenicea	8	1.98
Lindernia pusilla	3	1.78
Synedrella nodiflora	96	1.74
Sida beddomei	81	1.72
Ageratum conyzoides	78	1.66
Centrosema pubescens	122	1.50
Acrocephalus hispidus	2	1.48
Bidens pilosa	3	1.48

Biophytum reinwardtii	1	1.48
Sida cordifolia	5	1.48
Curculigo orchioides	98	1.40
Lobelia alsinoides	33	1.37
Hibiscus hispidissimus	5	1.32
Centella asiatica	51	1.27
Merremia umbellata	5	1.27
Ammannia baccifera	7	1.23
Justicia trinervia	139	1.19
Achyranthes aspera	56	1.17
Micranthus oppositifolius	241	1.16
Alternanthera pungens	58	1.10
Spilanthes radicans	38	1.02
Ipomoea decana	19	1.01
Alysicarpus monilifer	6	0.99
Catheranthus pusillus	1	0.99
Hydrolea zeylanica	2	0.99
Oldenlandia nitida	9	0.94
Uraria hamosa	46	0.94
Mollugo pentaphylla	12	0.93
Desmodium heterophyllum	119	0.91
Ichnocarpus frutescens	30	0.85
Smithia geminiflora	11	0.84
Hibiscus lobatus	38	0.82
Phyllanthus urinaria	47	0.72
Alternanthera sessilis	9	0.59
Hemidesmus indicus	84	0.59
Pouzolzia indica	12	0.56
Mitracarpus vertcillatus	26	0.49
Rungia sp.	8	0.47
Habenaria affinis	2	0.42
Dipteracanthus prostrata	19	0.36
Ludwigia hyssopifolia	5	0.33
Mimosa pudica	490	0.32
Laportea interrupta	18	0.25
Globba marantina	17	0.11
Peristylus goodyeroides	10	0.10

4.3.4.3 Shrub

The preference index for different shrubs is given in Table 27. Though *Desmodium pulchellum* had highest preference index values, it occurred only occasionally in the feeding sites. *Triumfetta rhomboidea*, *Hibiscus furcatus*, *Desmodium triangulare, D. laxiflorum* and *Pseudarthria viscida* were having higher index values with frequent occurrence in feeding quadrats. *Flemingia strobilifera* and *Ipomoea hederifolia* were fully avoided. *Sida mysorensis*, *Helicteres isora*, *Acacia intsia* and *Cassia occidentalis* were least preferred among the shrub species.

Table 27. Shrub food preference index of gaur (irrespective of season)

Species	No. of occurrence	Index
Desmodium pulchellum	12	1.66
Triumfetta rhomboidea	207	1.58
Hibiscus furcatus	52	1.55
Desmodium triangulare	28	1.49
Desmodium laxiflorum	131	1.37
Desmodium gangeticum	46	1.31
Pseudarthria viscida	113	1.29
Desmodium triquetrum	11	1.25
Urena lobata	196	1.23
Sida rhombifolia	339	1.22
Crassocephalum crepidioides	4	1.11
Bambusa arundinacea	246	0.97
Thespesia lampas	11	0.83
Indigofera hirsuta	9	0.81
Staurogyne zeylanica	8	0.79
Plumbago zeylanica	7	0.66
Sida cordifolia	47	0.65
Ocimum gratissimum	8	0.62
Sida mysorensis	10	0.49
Helicteres isora	195	0.47
Acacia intsia	14	0.42
Lantana camara	41	0.29
Cassia occidentalis	16	0.25

Ziziphusoenoplia	188	0.14

4.3.5 Seasonal preferences in food species

4.3.5.1 Grass

Results of seasonal food preference for grass species showed (Tables 28, 29 and 30). *Paspalum scrobiculatum*, *Paspalidium flavidum*, *Axonopus compressus* and *Eleusine indica* were almost equally preferred in all the seasons. *Paspalum conjugatum* and *Panicum psilopodium* were mostly preferred in dry season compared to first and second wet seasons. *Cyperus compressus* were observed only during first wet season. An increase in preference index values of *Kyllinga monocephala* and *Digitaria bicornis* were observed in first wet season. Feeding on *Cyperus iria* and *Digitaria ciliaris* were found only during dry and first wet seasons. *Imperata cylindrica* was preferred more in second wet season. Preference on *Themeda triandra* was high during dry and second wet seasons.

Table 28. Grass food preference index of gaur (Dry season)

Species	No. of occurrance	Index
Cyperus haspan	1	3.02
Kyllinga triceps	3	3.02
Paspalum scrobiculatum	74	1.55
Axonopus compressus	84	1.51
Paspalum conjugatum	15	1.46
Themeda triandra	45	1.45
Eleusine indica	55	1.36
Panicum notatum	7	1.36
Panicum psilopodium	17	1.36
Leersia hexandra	7	1.16
Ischaemum rangacharianum	14	1.15
Cynodon dactylon	15	1.08
Paspalidium flavidum	41	1.07
Ischaemum indicum	29	1.05

Setaria verticillata	5	1.05
Cyperus kurzii	7	1.03
Mariscus pictus	9	0.91
Brachiaria ramosa	88	0.90
Cyrtococcum decurrens	23	0.90
Centotheca lappacea	1	0.90
Alloteropsis cimicina	1	0.89
Oryza granulata	20	0.88
Tripogon ananthaswamianus	4	0.84
Digitaria griffithii	6	0.80
Arundinella mesophylla	5	0.78
Digitaria ornithopoda	2	0.75
Commelina benghalensis	93	0.68
Eragrostis tenuifolia	13	0.60
Echinochloa colona	17	0.58
Sporobolus indicus	16	0.57
Digitaria bicornis	5	0.49
Eragrostis unioloides	16	0.49
Fimbristylis dichotoma	9	0.47
Eragrostis tenella	29	0.46
Digitaria ciliaris	12	0.44
Kyllinga monocephala	99	0.43
Oplismenus compositus	122	0.43
Cyperus distans	10	0.41
Ottochloa nodosa	102	0.40
Imperata cylindrica	3	0.33
Cyperus iria	11	0.28
Murdannia japonica	5	0.13
Digitaria setigera	40	0.06

Table 29. Grass food preference index of gaur (First wet season)

Species	**No. of occurrance**	**Index**
Cyperus pilosus	2	2.00
Dactyloctenium aegyptium	1	1.96
Kyllinga monocephala	103	1.75
Digitaria griffithii	4	1.72
Fimbristylis littoralis	1	1.56
Eragrostis tenella	8	1.51

Oryza rufipogon	7	1.41
Apluda mutica	5	1.36
Paspalidium flavidum	31	1.33
Arundinella mesophylla	5	1.32
Axonopus compressus	14	1.29
Eleusine indica	47	1.29
Mariscus pictus	6	1.26
Paspalum scrobiculatum	22	1.20
Digitaria ornithopoda	2	1.17
Sporobolus indicus	26	1.15
Eragrostis unioloides	21	1.14
Brachiaria ramosa	65	1.09
Paspalum conjugatum	17	1.08
Alloteropsis cimicina	5	1.04
Cynodon dactylon	2	1.04
Echinochloa colona	15	1.02
Leersia hexandra	15	0.98
Ischaemum indicum	21	0.91
Setaria verticillata	1	0.91
Cyrtococcum decurrens	21	0.90
Themeda triandra	10	0.88
Heteropogon contortus	1	0.87
Cyperus kurzii	10	0.85
Digitaria bicornis	10	0.85
Cymbopogon flexuosus	1	0.78
Ischaemum rangacharianum	7	0.78
Panicum psilopodium	7	0.78
Digitaria setigera	29	0.75
Commelina clavata	5	0.72
Cyperus compressus	9	0.65
Panicum notatum	16	0.62
Digitaria ciliaris	16	0.59
Commelina benghalensis	67	0.53
Garnotia tenella	1	0.52
Ottochloa nodosa	63	0.45
Oplismenus compositus	100	0.35
Cyperus iria	20	0.33
Imperata cylindrica	6	0.30
Scleria stipularis	4	0.07

Table 30. Grass food preference index of gaur (Second wet season)

Species	No. of occurrance	Index
Digitaria griffithii	1	2.38
Leersia hexandra	14	1.73
Paspalum scrobiculatum	19	1.65
Oryza granulata	7	1.57
Axonopus compressus	38	1.54
Themeda triandra	35	1.47
Dactyloctenium aegyptium	1	1.43
Murdannia japonica	1	1.43
Eleusine indica	29	1.42
Ischaemum indicum	6	1.41
Paspalidium flavidum	22	1.37
Eragrostis tenella	6	1.35
Ischaemum rangacharianum	23	1.31
Panicum indicum	2	1.31
Cynodon dactylon	8	1.27
Arundinella mesophylla	4	1.24
Paspalum conjugatum	1	1.19
Alloteropsis cimicina	11	1.17
Commelina clavata	7	1.10
Brachiaria ramosa	40	1.09
Heteropogon contortus	1	1.07
Kyllinga triceps	1	1.02
Sporobolus indicus	30	0.98
Commelina benghalensis	50	0.88
Aneilema sp.	2	0.71
Digitaria ornithopoda	1	0.71
Panicum psilopodium	10	0.69
Echinochloa colona	4	0.63
Ottochloa nodosa	62	0.63
Cyrtococcum decurrens	36	0.62
Imperata cylindrica	9	0.57
Panicum notatum	6	0.52
Fimbristylis dichotoma	3	0.51
Oplismenus compositus	70	0.51
Eragrostis unioloides	13	0.47
Kyllinga monocephala	71	0.43
Digitaria setigera	19	0.41
Mariscus pictus	20	0.41
Cyperus kurzii	5	0.40

Centotheca lappacea	1	0.36
Eragrostis tenuifolia	5	0.32

4.3.5.2 Herb

Seasonal analyses for food preference index for herb species show that *Thunbergia fragrans, Centrosema pubescens, Sida beddomei* and *Lobelia alsinoides* were preferred in all the seasons (Tables 31, 32 and 33). However, *Chenopodium ambrosioides* and *Merremia umbellata* were more preferred in dry season. *Zingiber officinale* and *Nasaea lanceolata* were observed only in dry season. Feeding on *Cardiospermum helicacabum* and *Elephantopus scaber* were observed only during first wet season. *Quamoclit phoenicea* was preferred only during first wet season. There was a seasonal difference in preference for *Ageratum conyzoides*. *Dipteracanthus prostrata* was fed only in the second wet season. *Curculigo orchioides* was observed to have a higher index value during first and second wet seasons compared to dry season. *Micranthus oppositifolius* were more or less equally preferred in all the seasons.

Table 31. Herb food preference index of gaur (Dry season)

Species	No. of occurrance	Index
Nesaea lanceolata	2	3.32
Chenopodium ambrosioides	2	3.32
Zingiber officinale	2	3.32
Lygodium scandens	2	3.32
Merremia umbellata	2	3.32
Thunbergia fragrans	26	2.52
Phyllanthus urinaria	7	2.49
Ipomoea deccana	8	2.37
Centrosema pubescens	50	1.99
Mollugo pentaphylla	7	1.74
Sida beddomei	22	1.69
Oldenlandia nitida	1	1.66
Acrocephalus hispidus	2	1.66
Hibiscus hispidissimus	3	1.66

Bidens pilosa	3	1.66
Sida cordifolia	5	1.66
Ammannia baccifera	7	1.38
Lobelia alsinoides	20	1.30
Alternanthera sessilis	4	1.27
Synedrella nodiflora	16	1.27
Alternanthera pungens	40	1.26
Micranthus oppositifolius	92	1.25
Centella asiatica	23	1.24
Desmodium heterophyllum	46	1.20
Peperomia pellucida	7	1.11
Ichnocarpus frutescens	21	1.11
Justicia trinervia	42	1.06
Achyranthes aspera	25	1.04
Smithia geminiflora	6	0.84
Curculigo orchioides	37	0.81
Hemidesmus indicus	45	0.72
Hibiscus lobatus	9	0.57
Ageratum conyzoides	19	0.55
Rungia sp.	8	0.53
Spilanthes radicans	16	0.51
Uraria hamosa	12	0.47
Pouzolzia indica	3	0.37
Ludwigia hyssopifolia	5	0.37
Mimosa pudica	211	0.32
Mitracarpus vertcillatus	6	0.26
Laportea interrupta	16	0.22

Table 32. Herb food preference index of gaur (First wet season)

Species	No. of occurrance	Index
Thunbergia fragrans	7	2.43
Quamoclit phoenicea	6	2.43
Cardiospermum helicacabum	2	2.43
Chenopodium ambrosioides	2	2.43
Elephantopus scaber	1	2.43
Peperomia pellucida	7	2.40
Ageratum conyzoides	43	2.10
Achyranthes aspera	9	1.99

Synedrella nodiflora	49	1.72
Curculigo orchioides	35	1.69
Sida beddomei	36	1.51
Spilanthes radicans	14	1.49
Lindernia pusilla	3	1.46
Mitracarpus vertcillatus	9	1.42
Lobelia alsinoides	9	1.41
Biophytum reinwardtii	1	1.21
Justicia trinervia	57	1.09
Centrosema pubescens	49	1.08
Micranthus oppositifolius	81	1.05
Uraria hamosa	26	0.98
Centella asiatica	16	0.90
Habenaria affinis	1	0.81
Hibiscus hispidissimus	2	0.81
Hydrolea zeylanica	2	0.81
Smithia geminiflora	5	0.73
Alternanthera pungens	7	0.73
Oldenlandia nitida	8	0.71
Ipomoea deccana	5	0.69
Desmodium heterophyllum	38	0.65
Hibiscus lobatus	17	0.61
Phyllanthus urinaria	30	0.57
Pouzolzia indica	9	0.53
Ichnocarpus frutescens	4	0.40
Mimosa pudica	157	0.36
Peristylus goodyeroides	2	0.27
Hemidesmus indicus	25	0.25
Globba marantina	10	0.17

Table 33. Herb food preference index of gaur (Second wet season)

Species	**No. of occurrance**	**Index**
Dipteracanthus prostrata	6	2.32
Curculigo orchioides	26	2.30
Spilanthes radicans	8	2.09
Centella asiatica	12	1.93
Sida beddomei	23	1.91
Synedrella nodiflora	31	1.78
Thunbergia fragrans	14	1.63

Lobelia alsinoides	4	1.63
Laportea interrupta	1	1.63
Centrosema pubescens	23	1.59
Hibiscus lobatus	12	1.43
Justicia trinervia	40	1.38
Micranthus oppositifolius	68	1.21
Alternanthera pungens	11	1.21
Alysicarpus monilifer	5	1.16
Hemidesmus indicus	14	1.08
Catheranthus pusillus	1	1.08
Achyranthes aspera	22	1.05
Ipomoea deccana	6	0.97
Desmodium heterophyllum	35	0.92
Uraria hamosa	8	0.87
Ageratum conyzoides	16	0.71
Merremia umbellata	3	0.65
Ichnocarpus frutescens	5	0.54
Mimosa pudica	122	0.29
Phyllanthus urinaria	10	0.28
Mitracarpus vertcillatus	11	0.11

4.3.5.3 Shrub

Desmodium laxiflorum, D. triangulare, D. gangeticum and *Sida rhombifolia* were more or less equally preferred in all the seasons (Table 34, 35 and 36). *Triumfetta rhomboidea* was highly preferred in the first wet compared to dry and second wet seasons. There was a remarkably higher dry season preference for *Bambusa arundinacea* and *Hibiscus furcatus*. Higher preference for *Desmodium pulchellum* was observed in first wet than the dry season and it was not observed to be fed by the animal during second wet season. Feeding on *Lantana camara* was found only in the first wet season. *Ziziphusoenoplia* was the least preferred and there was a complete avoidance of *Ipomoea hederifolia* and *Cassia occidentalis* eventhough these were occurring in the feeding sites.

Table 34. Shrub food preference index of gaur (Dry season)

Species	No. of occurrance	Index
Hibiscus furcatus	18	1.84
Desmodium triangulare	17	1.75
Desmodium gangeticum	13	1.41
Bambusa arundinacea	131	1.39
Triumfetta rhomboidea	80	1.21
Desmodium laxiflorum	49	1.16
Urena lobata	94	1.10
Sida rhombifolia	153	1.02
Pseudarthria viscida	44	0.98
Thespesia lampas	4	0.91
Helicteres isora	88	0.79
Sida cordifolia	33	0.50
Cassia occidentalis	2	0.49
Desmodium triquetrum	3	0.49
Ocimum gratissimum	5	0.44
Staurogyne zeylanica	4	0.41
Acacia intsia	4	0.41
Ziziphusoenoplia	69	0.17

Table 35. Shrub food preference index of gaur (First wet season)

Species	No. of occurrance	Index
Desmodium pulchellum	7	2.63
Triumfetta rhomboidea	80	1.83
Desmodium laxiflorum	51	1.44
Desmodium triquetrum	6	1.44
Hibiscus furcatus	18	1.39
Urena lobata	59	1.37
Desmodium triangulare	8	1.36
Pseudarthria viscida	33	1.32
Sida rhombifolia	124	1.30
Desmodium gangeticum	24	1.02
Lantana camara	12	1.00
Crassocephalum crepidioides	4	0.96

Staurogyne zeylanica	4	0.96
Sida cordifolia	9	0.87
Indigofera hirsuta	5	0.83
Ocimum gratissimum	3	0.83
Plumbago zeylanica	7	0.58
Sida mysorensis	5	0.58
Bambusa arundinacea	70	0.45
Acacia intsia	10	0.39
Thespesia lampas	7	0.38
Helicteres isora	73	0.24
Cassia occidentalis	2	0.21
Ziziphusoenoplia	68	0.07

Table 36. Shrub food preference index of gaur (Second wet season)

Species	**No. of occurrance**	**Index**
Desmodium gangeticum	9	1.85
Pseudarthria viscida	36	1.62
Desmodium triquetrum	2	1.61
Triumfetta rhomboidea	47	1.55
Sida rhombifolia	62	1.49
Urena lobata	43	1.49
Hibiscus furcatus	16	1.47
Desmodium laxiflorum	31	1.35
Sida cordifolia	5	1.34
Bambusa arundinacea	45	0.73
Indigofera hirsuta	4	0.60
Desmodium triangulare	3	0.48
Helicteres isora	34	0.36
Sida mysorensis	5	0.30
Ziziphusoenoplia	51	0.22
Cassia occidentalis	12	0.21

4.3.6 Food species preferences in different habitats

4.3.6.1 Grass

Result of analyses of the data for food preference index for grass species in different habitats are given in Tables 37, 38, 39, 40 and 41. The number of preferred grass species in the evergreen habitats were comparatively low. The species along riverine habitats, though occuring in few numbers had comparatively maximum index values. The number of species with higher index values (>1.0) were comparatively more in moist deciduous habitats and plantation.

Table 37. Gaur food preference index for grass species in evergreen forests

Species	No. of occurrance	Index
Panicum psilopodium	10	1.47
Commelina benghalensis	4	1.36
Panicum notatum	4	1.36
Cyperus kurzii	2	1.21
Oplismenus compositus	8	0.60
Ottochloa nodosa	10	0.24

Table 38. Gaur food preference index for grass species in moist deciduous forests

Species	No. of occurrance	Index
Cyperus pilosus	2	2.60
Dactyloctenium aegyptium	2	2.32
Fimbristylis littoralis	1	1.96
Oryza rufipogon	5	1.83
Apluda mutica	5	1.70
Mariscus pictus	14	1.61
Paspalum scrobiculatum	19	1.52
Eleusine indica	43	1.51
Paspalidium flavidum	53	1.50
Axonopus compressus	42	1.49
Arundinella mesophylla	7	1.47
Leersia hexandra	3	1.46
Eragrostis unioloides	9	1.44
Oryza granulata	19	1.36

Themeda triandra	20	1.35
Digitaria ornithopoda	4	1.32
Kyllinga monocephala	84	1.28
Digitaria griffithii	8	1.27
Cynodon dactylon	9	1.23
Alloteropsis cimicina	12	1.22
Brachiaria ramosa	108	1.22
Paspalum conjugatum	6	1.21
Cyperus kurzii	4	1.19
Setaria verticillata	6	1.13
Ischaemum rangacharianum	12	1.09
Sporobolus indicus	16	1.08
Echinochloa colona	18	1.06
Panicum notatum	12	1.05
Panicum indicum	3	1.03
Cymbopogon flexuosus	1	0.98
Heteropogon contortus	1	0.98
Ischaemum indicum	27	0.98
Kyllinga triceps	1	0.93
Cyperus compressus	9	0.92
Cyrtococcum decurrens	32	0.86
Eragrostis tenella	26	0.83
Panicum psilopodium	12	0.82
Digitaria ciliaris	23	0.67
Digitaria ornithopoda	1	0.65
Garnotia tenella	1	0.65
Fimbristylis dichotoma	4	0.59
Cyperus iria	7	0.54
Commelina benghalensis	83	0.53
Commelina clavata	15	0.52
Ottochloa nodosa	132	0.49
Imperata cylindrica	4	0.47
Oplismenus compositus	151	0.43
Digitaria setigera	52	0.42
Digitaria bicornis	16	0.40

Table 39. Gaur food preference index for grass species in plantations

Species	**No. of occurrance**	**Index**
Digitaria griffithii	3	2.08

Paspalum scrobiculatum	18	1.71
Paspalidium flavidum	13	1.64
Axonopus compressus	23	1.62
Arundinella mesophylla	1	1.56
Ischaemum rangacharianum	6	1.49
Sporobolus indicus	29	1.47
Themeda triandra	9	1.47
Eleusine indica	26	1.42
Alloteropsis cimicina	2	1.40
Leersia hexandra	8	1.40
Digitaria bicornis	5	1.35
Cyperus kurzii	10	1.30
Paspalum conjugatum	1	1.20
Commelina clavata	2	1.17
Heteropogon contortus	1	1.17
Ischaemum indicum	3	1.17
Eragrostis unioloides	9	1.11
Brachiaria ramosa	58	1.08
Cyrtococcum decurrens	27	1.08
Kyllinga monocephala	75	1.04
Eragrostis tenella	14	1.02
Tripogon ananthaswamianus	4	0.98
Cynodon dactylon	8	0.97
Cyperus distans	3	0.94
Panicum psilopodium	8	0.88
Oryza granulata	8	0.78
Digitaria setigera	26	0.75
Commelina benghalensis	58	0.71
Aneilema sp.	2	0.70
Fimbristylis dichotoma	1	0.70
Digitaria ciliaris	5	0.59
Panicum notatum	13	0.58
Ottochloa nodosa	74	0.55
Cyperus iria	1	0.53
Oplismenus compositus	107	0.51
Echinochloa colona	4	0.44
Murdannia japonica	2	0.41
Centotheca lappacea	1	0.35
Mariscus pictus	13	0.11
Imperata cylindrica	7	0.04

Table 40. Gaur food preference index for grass species in grasslands

Species	No. of occurrance	Index
Kyllinga triceps	3	2.57
Eragrostis tenella	3	1.44
Axonopus compressus	68	1.31
Paspalum scrobiculatum	74	1.28
Eleusine indica	59	1.16
Themeda triandra	61	1.16
Paspalum conjugatum	23	1.12
Leersia hexandra	25	1.10
Cynodon dactylon	8	1.01
Ischaemum indicum	26	1.01
Ottochloa nodosa	7	1.00
Paspalidium flavidum	24	0.94
Ischaemum rangacharianum	26	0.93
Commelina benghalensis	56	0.86
Brachiaria ramosa	27	0.85
Kyllinga monocephala	111	0.85
Centotheca lappacea	1	0.77
Cyperus pilosus	2	0.77
Oryza rufipogon	2	0.77
Eragrostis unioloides	32	0.76
Eragrostis tenuifolia	6	0.71
Echinochloa colona	14	0.67
Arundinella mesophylla	6	0.65
Sporobolus indicus	27	0.62
Cyrtococcum decurrens	16	0.58
Imperata cylindrica	7	0.58
Panicum psilopodium	4	0.57
Mariscus pictus	8	0.51
Oplismenus compositus	22	0.36
Fimbristylis dichotoma	7	0.32
Cyperus kurzii	6	0.26
Cyperus iria	24	0.20
Digitaria setigera	10	0.16
Cyperus distans	8	0.10
Scleria stipularis	5	0.06

Table 41. Gaur food preference index for grass species in riverine forests

Species	No. of occurrance	Index
Cyperus haspan	1	2.99
Eleusine indica	3	2.01
Paspalum conjugatum	3	1.98
Paspalum scrobiculatum	4	1.81
Axonopus compressus	3	1.25
Paspalidium flavidum	4	1.05
Kyllinga monocephala	3	0.66
Commelina benghalensis	9	0.41
Ottochloa nodosa	4	0.32
Oplismenus compositus	4	0.27
Cyrtococcum decurrens	5	0.15

4.3.6.2 Herb

Food preference index for different herb food species indicate higher preference for more number of species in plantation followed by grasslands, moist deciduous and riverine habitats (Tables 42, 43, 44, 45 and 46).

Table 42. Gaur food preference index for herb species in evergreen forests

Species	No. of occurrance	Index
Curculigo orchioides	4	2.36
Zingiber officinale	2	2.36
Synedrella nodiflora	2	1.58
Achyranthes aspera	2	1.58
Micranthus oppositifolius	6	1.01
Ageratum conyzoides	2	0.95
Ichnocarpus frutescens	4	0.34

Table 43. Gaur food preference index for herb species in moist deciduous forests

Species	No.of occurrance	Index
Chenopodium ambrosioides	2	2.79
Cardiospermum helicacabum	2	2.79

Elephantopus scaber	1	2.79
Peperomia pellucida	17	2.18
Thunbergia fragrans	26	1.89
Quamoclit phoenicea	5	1.86
Ageratum conyzoides	34	1.85
Lobelia alsinoides	5	1.68
Lindernia pusilla	1	1.68
Sida beddomei	43	1.65
Curculigo orchioides	47	1.50
Synedrella nodiflora	51	1.49
Acrocephalus hispidus	2	1.40
Biophytum reinwardtii	1	1.40
Mitracarpus vertcillatus	12	1.40
Centrosema pubescens	65	1.28
Hibiscus hispidissimus	5	1.24
Ammannia baccifera	6	1.16
Micranthus oppositifolius	96	1.05
Hibiscus lobatus	12	1.00
Centella asiatica	2	0.98
Uraria hamosa	29	0.97
Ludwigia hyssopifolia	1	0.93
Achyranthes aspera	30	0.90
Alternanthera pungens	22	0.88
Justicia trinervia	84	0.86
Ichnocarpus frutescens	19	0.86
Smithia geminiflora	1	0.84
Desmodium heterophyllum	13	0.81
Spilanthes radicans	26	0.80
Hemidesmus indicus	39	0.76
Phyllanthus urinaria	24	0.58
Pouzolzia indica	12	0.52
Rungia sp.	7	0.42
Oldenlandia nitida	3	0.40
Dipteracanthus prostrata	17	0.36
Mimosa pudica	220	0.36
Laportea interrupta	13	0.34

Table 44. Gaur food preference index for herb species in plantations

Species	**No. of occurrance**	**Index**
Chenopodium ambrosioides	1	3.25

Lygodium scandens	2	3.25
Nesaea lanceolata	2	3.25
Ipomoea deccana	7	2.71
Merremia umbellata	3	2.44
Thunbergia fragrans	17	2.26
Sida cordifolia	4	2.17
Sida beddomei	32	2.04
Spilanthes radicans	6	2.00
Synedrella nodiflora	23	1.99
Achyranthes aspera	14	1.97
Lobelia alsinoides	5	1.88
Centrosema pubescens	49	1.86
Justicia trinervia	36	1.81
Phyllanthus urinaria	15	1.79
Curculigo orchioides	44	1.63
Bidens pilosa	2	1.39
Ammannia baccifera	1	1.30
Micranthus oppositifolius	88	1.15
Alternanthera pungens	15	1.13
Catheranthus pusillus	1	1.08
Ichnocarpus frutescens	7	1.08
Ageratum conyzoides	12	0.96
Uraria hamosa	17	0.85
Hibiscus lobatus	24	0.81
Rungia sp.	1	0.81
Desmodium heterophyllum	11	0.72
Habenaria affinis	2	0.46
Hemidesmus indicus	36	0.40
Mimosa pudica	132	0.23
Peristylus goodyeroides	7	0.18
Globba marantina	16	0.13

Table 45. Gaur food preference index for herb species in grasslands

Species	**No. of occurrance**	**Index**
Chenopodium ambrosioides	1	3.01
Quamoclit phoenicea	2	3.01
Thunbergia fragrans	2	3.01
Synedrella nodiflora	18	2.26

Lindernia pusilla	2	1.81
Bidens pilosa	1	1.81
Ageratum conyzoides	29	1.61
Justicia trinervia	19	1.55
Centrosema pubescens	8	1.51
Micranthus oppositifolius	43	1.51
Oldenlandia nitida	5	1.51
Hemidesmus indicus	5	1.51
Centella asiatica	49	1.29
Alternanthera pungens	19	1.24
Lobelia alsinoides	23	1.21
Spilanthes radicans	6	1.13
Alysicarpus monilifer	5	1.08
Hydrolea zeylanica	2	1.00
Mollugo pentaphylla	12	0.95
Desmodium heterophyllum	88	0.94
Achyranthes aspera	5	0.90
Ipomoea deccana	12	0.88
Smithia geminiflora	10	0.84
Sida cordifolia	1	0.75
Alternanthera sessilis	8	0.67
Sida beddomei	5	0.65
Mimosa pudica	127	0.39
Curculigo orchioides	3	0.18
Mitracarpus vertcillatus	13	0.08

Table 46. Gaur food preference index for herb species in riverine forests

Species	No. of occurrance	Index
Thunbergia fragrans	2	2.64
Sida beddomei	1	1.76
Micranthus oppositifolius	8	1.61
Alternanthera pungens	2	1.51
Synedrella nodiflora	2	1.32
Ageratum conyzoides	1	1.32
Desmodium heterophyllum	7	1.08
Hibiscus lobatus	1	0.88
Achyranthes aspera	5	0.88
Mimosa pudica	9	0.15

4.3.6.3 Shrub

Food preference index for shrubs in different habitats are given in Tables 47, 48, 49, 50 and 51. Number of shrub food species with higher index values were more in moist deciduous habitats followed by plantation, riverine habitats and grasslands.

Table 47. Gaur food preference index for shrub species in evergreen forests

Species	No. of occurrance	Index
Sida rhombifolia	8	1.41
Urena lobata	2	1.20
Pseudarthria viscida	2	0.80
Triumfetta rhomboidea	4	0.80

Table 48. Gaur food preference index for shrub species in moist deciduous forests

Species	No. of occurrance	Index
Desmodium pulchellum	8	2.35
Hibiscus furcatus	21	1.58
Desmodium triangulare	20	1.48
Pseudarthria viscida	58	1.47
Desmodium gangeticum	34	1.45
Desmodium laxiflorum	74	1.40
Triumfetta rhomboidea	109	1.34
Urena lobata	99	1.23
Sida rhombifolia	168	1.18
Crassocephalum crepidioides	4	1.10
Desmodium triquetrum	9	1.10
Sida mysorensis	2	1.10
Staurogyne zeylanica	1	1.10
Bambusa arundinacea	150	0.94
Thespesia lampas	8	0.88
Plumbago zeylanica	5	0.82
Indigofera hirsuta	7	0.73
Sida cordifolia	29	0.53
Helicteres isora	107	0.44
Lantana camara	21	0.44

Acacia intsia	14	0.41
Ocimum gratissimum	5	0.40
Ziziphusoenoplia	98	0.22

Table 49. Gaur food preference index for shrub species in plantations

Species	No. of occurrance	Index
Desmodium triquetrum	1	2.31
Triumfetta rhomboidea	64	2.14
Desmodium triangulare	8	1.54
Hibiscus furcatus	19	1.36
Desmodium laxiflorum	51	1.34
Sida rhombifolia	112	1.34
Indigofera hirsuta	2	1.16
Pseudarthria viscida	51	1.16
Urena lobata	78	1.16
Bambusa arundinacea	52	1.06
Ocimum gratissimum	3	0.99
Desmodium gangeticum	11	0.95
Thespesia lampas	3	0.88
Sida cordifolia	13	0.74
Helicteres isora	84	0.53
Sida mysorensis	6	0.53
Ziziphusoenoplia	83	0.07

Table 50. Gaur food preference index for shrub species in grasslands

Species	No. or occurrance	Index
Desmodium laxiflorum	6	1.67
Hibiscus furcatus	8	1.64
Urena lobata	16	1.61
Triumfetta rhomboidea	25	1.51
Sida cordifolia	5	1.14
Sida rhombifolia	48	1.13
Desmodium gangeticum	1	1.02
Bambusa arundinacea	40	0.94
Staurogyne zeylanica	7	0.68
Pseudarthria viscida	1	0.51

Cassia occidentalis	16	0.21

Table 51. Gaur food preference index for shrub species in riverine forests

Species	No. of occurrance	Index
Desmodium triquetrum	1	1.87
Hibiscus furcatus	4	1.87
Urena lobata	1	1.25
Helicteres isora	2	0.93
Sida rhombifolia	3	0.93
Triumfetta rhomboidea	5	0.93
Pseudarthria viscida	1	0.62
Bambusa arundinacea	4	0.56

4.3.7 Feeding behaviour

About 63% of the total 5696 observational scan records were on feeding (Grazing and browsing). The results of the analysis irrespective of season is given in Figure 10.Grazing accounted for 78.30% and browsing only 21.70%. Figures 11, 12, and 13 gives percentage of observation on grazing and browsing in dry, first wet and second wet seasons. Grazing dominated in all the seasons. However, there were considerable variations between seasons with second wet season (24.16%) recording higher percentage.

Fig. 10. Proportion of time spent in two categories of feeding by gaur in Parambikulam WLS

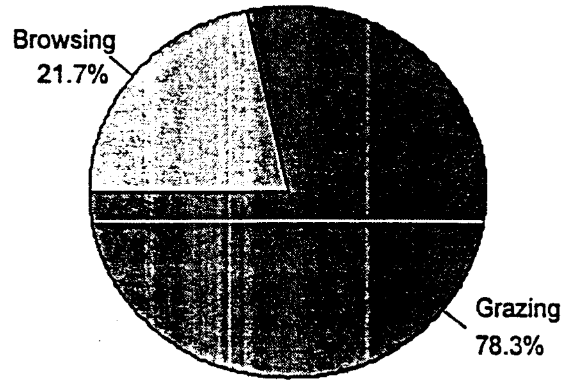


Fig. 11. Proportion of time spent in two categories of feeding by gaur in dry season in Parambikulam WLS

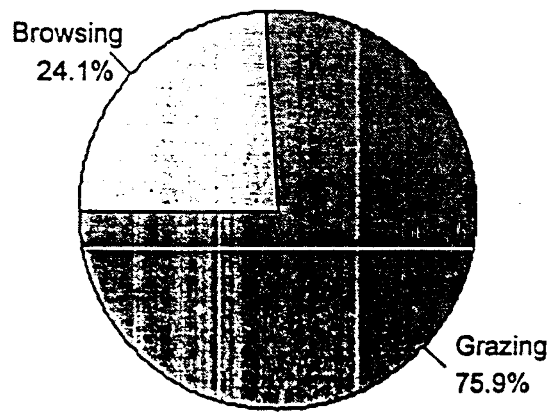


Fig. 12. Proportion of time spent in two categories of feeding by gaur in first wet season in Parambikulam WLS

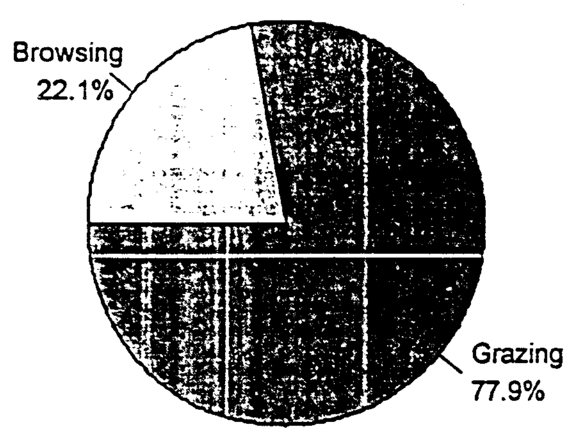
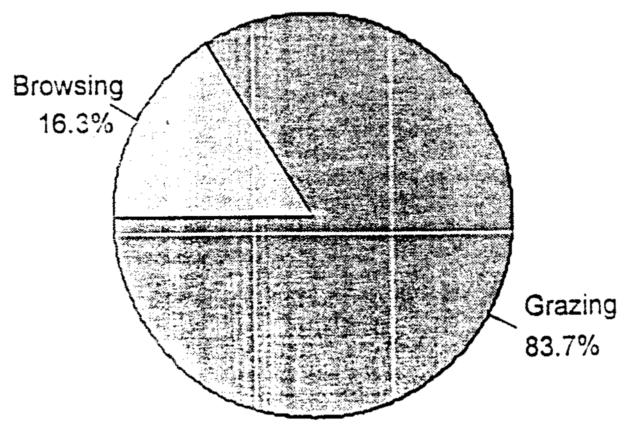


Fig.13. Proportion of time spent in two categories of feeding by gaur in second wet season in Parambikulam WLS



4.3.8.1 Adult male

Analyses of the overall (irrespective of seasons) data on adult male gaur shows that the time spent for grazing was slightly higher than browsing (Fig.14). There were seasonal differences in the time spent for grazing and browsing (Figs.15, 16 and 17). Percentage of time spent on browsing was higher in dry season.

Fig.14. Proportion of time spent in two categories of feeding by adult male gaur in Parambikulam WLS

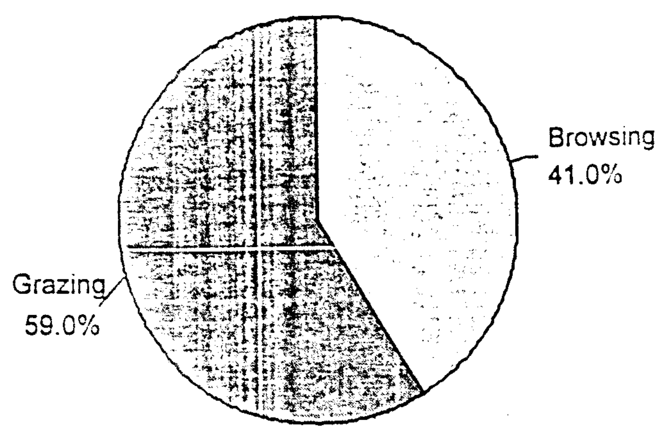


Fig.15. Proportion of time spent in two categories of feeding by adult male gaur in dry season in Parambikulam WLS

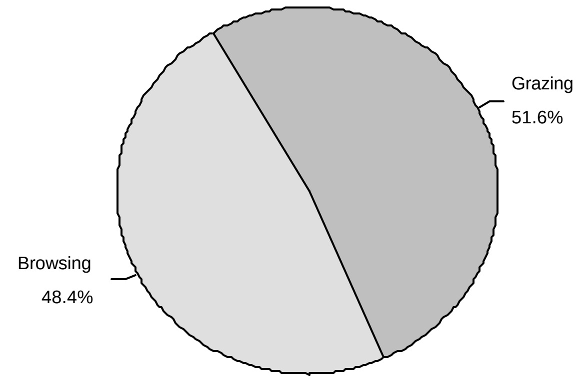


Fig.16. Proportion of time spent in two categories of feeding by adult male gaur in first wet season in Parambikulam WLS

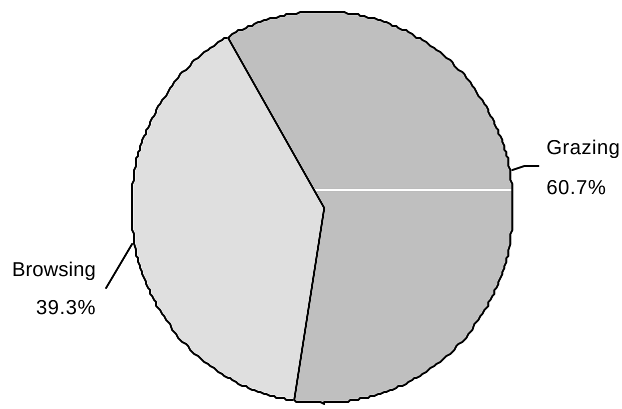
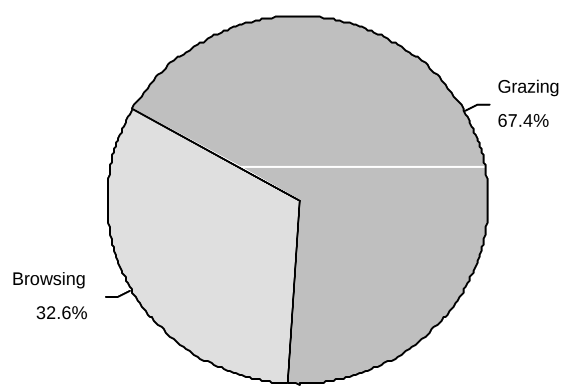


Fig.17. Proportion of time spent in two categories of feeding by adult male gaur in second wet season in Parambikulam WLS



4.3.8.2 Adult female

Time spent on grazing was higher than browsing in the overall (Fig.18) and in all the seasons (Figs.19, 20 and 21). About 90% of the time were spent for grazing in second wet season and was higher compared to dry and first wet seasons.

Fig.18. Proportion of time spent in two categories of feeding by adult female in Parambikulam WLS

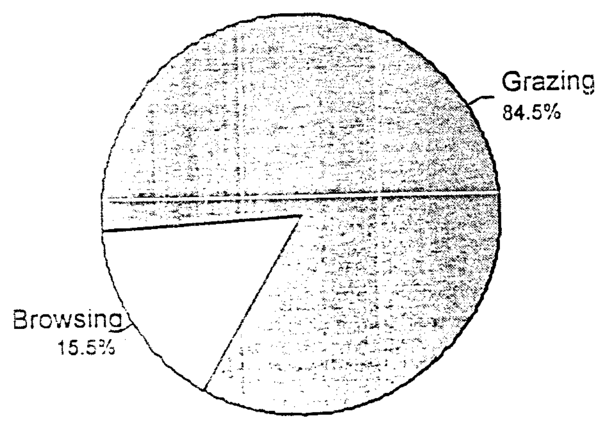


Fig.19. Proportion of time spent in two categories of feeding by adult female gaur in dry season in Parambikulam WLS

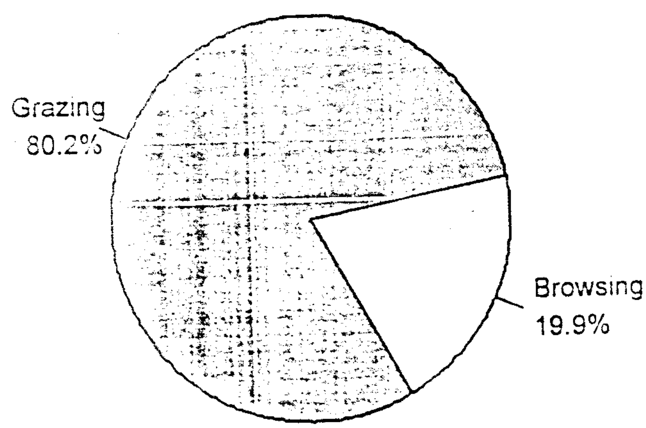


Fig.20. Proportion of time spent in two categories of feeding by adult female gaur in first wet season in Parambikulam WLS

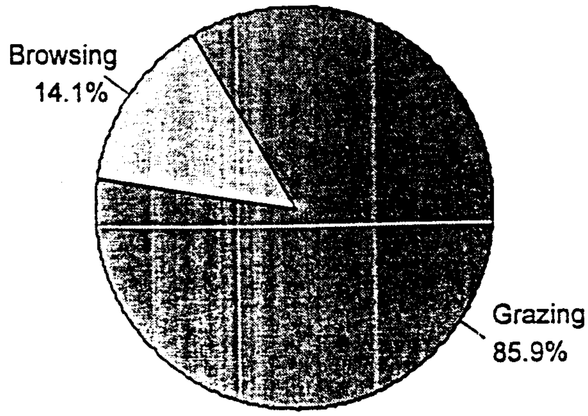
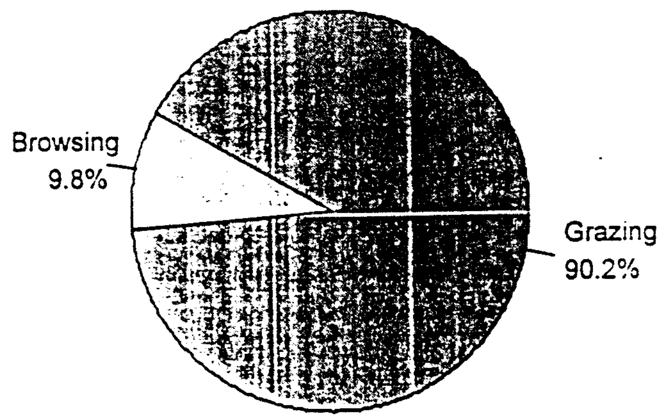


Fig.21. Proportion of time spent in two categories of feeding by adult female gaur in second wet season in Parambikulam WLS



4.3.8.3 Sub-adult male

Analyses, irrespective of seasons of sub-adult male gaur show that the time spent for grazing (57.36%) was higher compared to browsing (42.64%) (Fig. 22). More or less equal percentage of time was spent for grazing and browsing in dry and first wet seasons (Figs.23, 24 and 25). But the dry and second wet season, more time was spent for grazing.

Fig.22. Proportion of time spent in two categories of feeding by sub adult male gaur in Parambikulam WLS

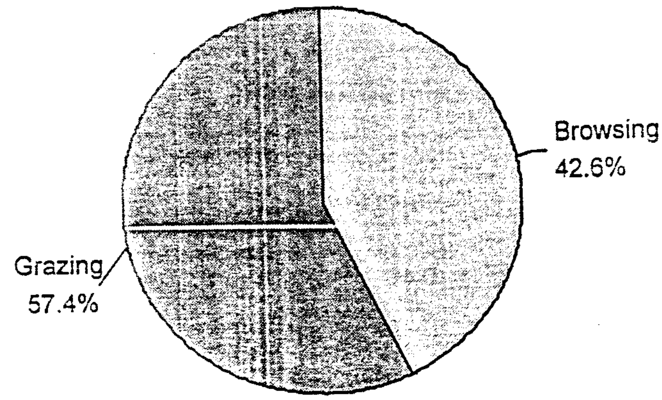


Fig.23. Proportion of time spent in two categories of feeding by sub adult male gaur in dry season in Parambikulam WLS

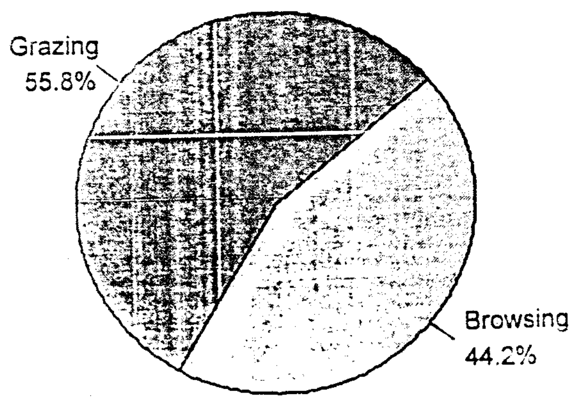


Fig.24. Proportion of time spent in two categories of feeding by sub adult male gaur in first wet season in Parambikulam WLS

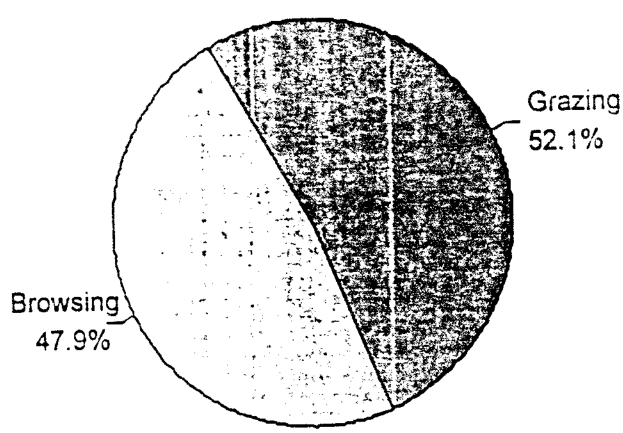
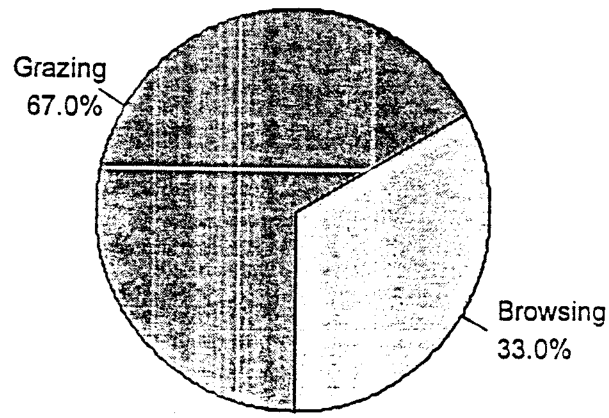


Fig.25. Proportion of time spent in two categories of feeding by sub adult male gaur in second wet season in Parambikulam WLS



Time spent for grazing and browsing by sub-adult female gaur, for over all study period is shown in Figure 26. Grazing accounted for 81.49% and browsing 18.51%. Seasonal analyses indicate a reduction in the time spent for grazing from dry to first wet and second wet season (Figs. 27, 28 and 29).

Fig.26. Proportion of time spent in two categories of feeding by sub adult female gaur in Parambikulam WLS

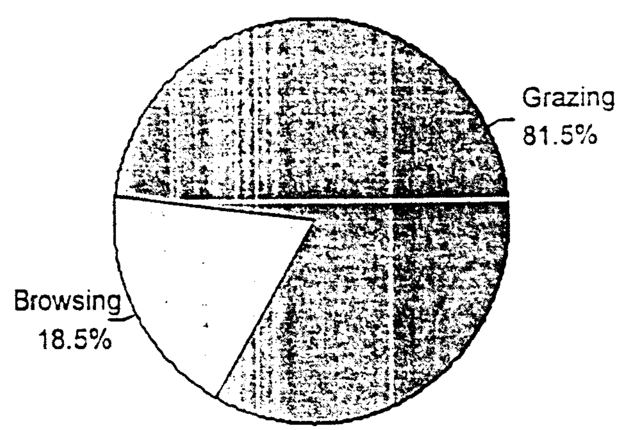


Fig.27. Proportion of time spent in two categories of feeding by sub adult female gaur in dry season in Parambikulam WLS

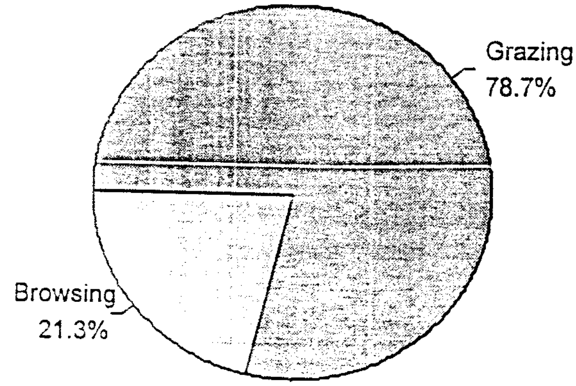


Fig.28. Proportion of time spent in two categories of feeding by sub adult female gaur in first wet season in Parambikulam WLS

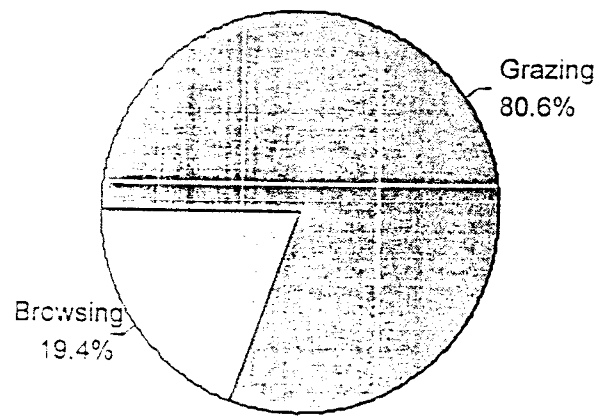
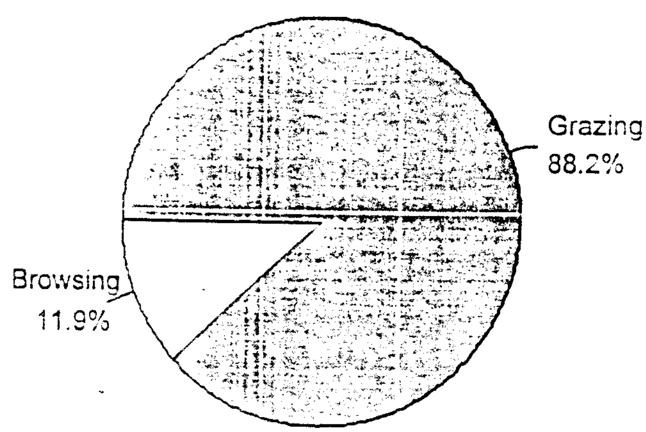


Fig.29. Proportion of time spent in two categories of feeding by sub adult female gaur in second wet season in Parambikulam WL



4.3.8.5 Juvenile

The juveniles spent very less time for browsing (Fig. 30). Browsing was not observed in dry and second wet seasons (Figs. 31, 32 and 33) and the time spent for browsing in first wet season was comparatively less.

Fig.30. Proportion of time spent in two categories of feeding by juvenile gaur in Parambikulam WLS

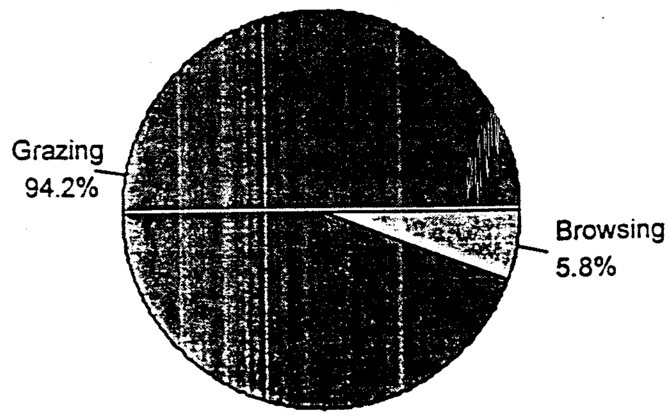


Fig.31. Proportion of time spent in two categories of feeding by juvenile gaur in dry season in Parambikulam WLS

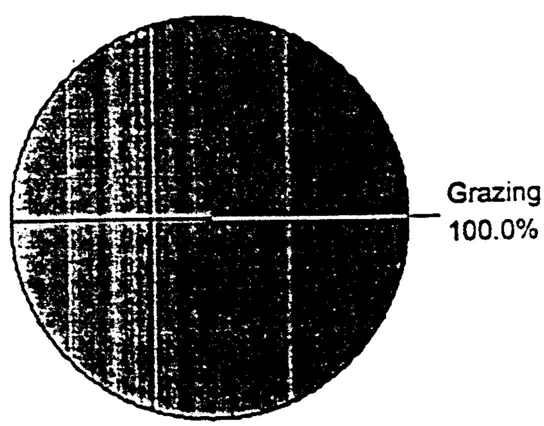


Fig.32. Proportion of time spent in two categories of feeding by juvenile gaur in first wet season in Parambikulam WLS

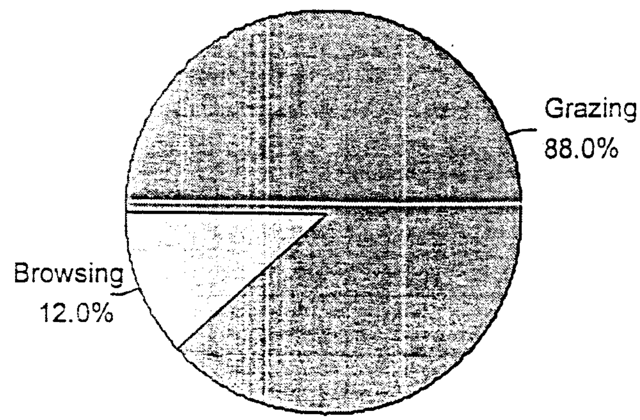
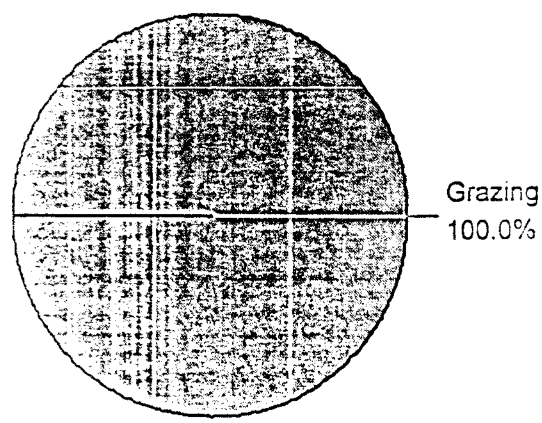


Fig.33. Proportion of time spent in two categories of feeding by juvenile gaur in second wet season in Parambikulam WLS



4.3.8.6 Calf

The over all feeding behaviour of gaur calf is given in Figure 34, and grazing accounted for 92.28% and browsing 7.72%. Percentage of time spent in different seasons for grazing and browsing are shown in Figures 35, 36 and 37. More time was spent in grazing during dry and first wet seasons compared to browsing. No browsing was observed during second wet season.

Fig.34. Proportion of time spent in two categories of feeding by gaur calf in Parambikulam WLS

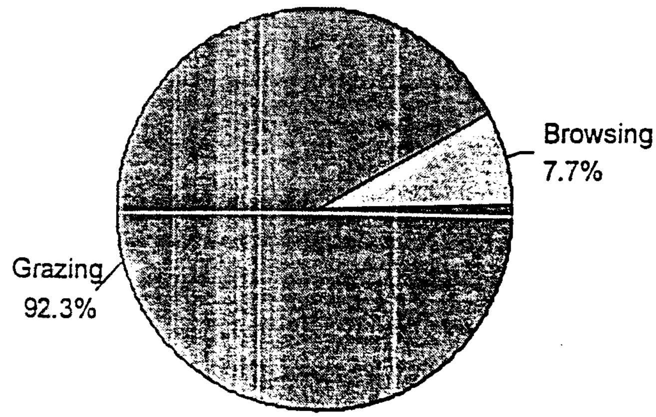


Fig.35. Proportion of time spent in two categories of feeding by gaur calf in dry season in Parambikulam WLS

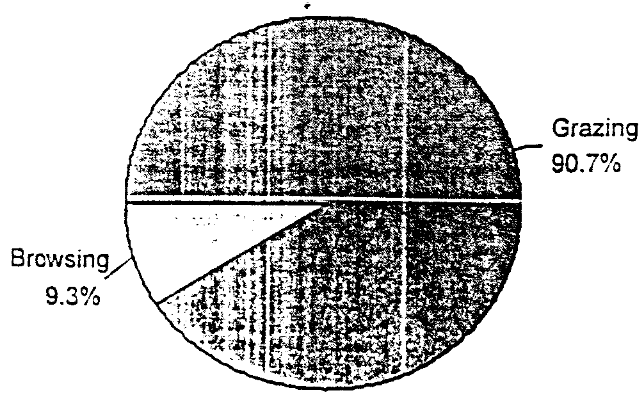


Fig.36. Proportion of time spent in two categories of feeding by gaur calf in first wet season in Parambikulam WLS

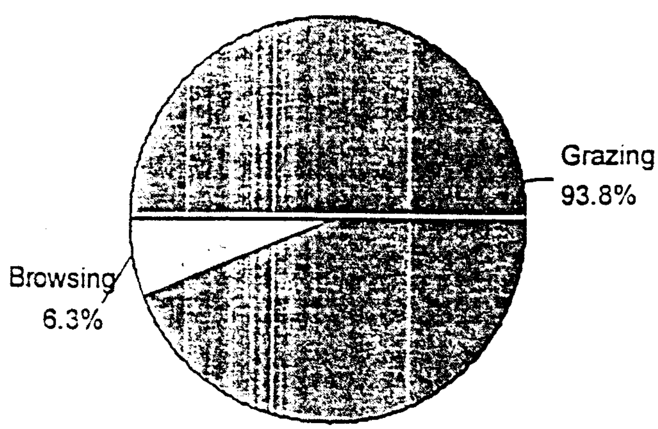
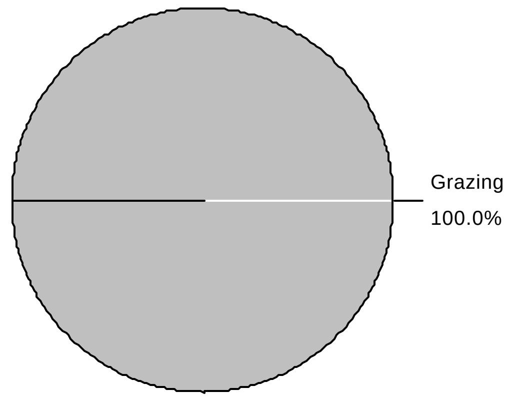


Fig.37. Proportion of time spent in two categories of feeding by gaur calf in second wet season in Parambikulam WLS



The χ^2 (3X6 contingency table) test showed significant variation in frequency of occurrence of grazing (χ^2 =123.568, P<0.001) and browsing (χ^2 =45.916, P<0.001) between different age and sex categories and seasons.

4.4 Discussion

The herbivore diet is influenced by several factors including anatomical and physiological characteristics of the animal, community structure of the plants, and its structural and chemical constituents (Owen-Smith, 1982). Food intake of animals is also influenced by body weight which sets limit to the gut size and the digestibility (Baile, 1975; Bines, 1976). Gaur in Parambikulam feed on a variety of plants indicating the polyphagous feeding habit of the animal. Similar observations have been made by Schaller (1967) in Kanha. European bison (*Bison bonasus*) have also been reported to be polyphagous (Borowski *et al*., 1967; Korockina, 1969b; Borowski and Kossak, 1972; Gebczynska and Krasinska, 1972; Gebczynska *et al*., 1991)

Polyphagous wild animals have greater advantages (Crawley, 1983) and are unlikely to starve and can switch over to plants that become temporarily abundant. Polyphagous animals also benefit by employing seasonal or opportunistic species preference (Westoby, 1974; Crawley, 1983). Further, the cost of energy spent for searching food is also reduced even in an environment of scarcity. The varied diet has undoubtedly enabled gaur to colonize a wide range of vegetation types (Schaller, 1967).

Plants of the families Poaceae and Cyperaceae form the major food of gaur in Parambikulam. Evolution of the plant family Poaceae and the animal family Bovidae are inextricably linked with extraordinary adaptive radiation in both groups occurring contemporarily from historical period (Pilgrim, 1939; Beetle, 1955 & 1958; Stebbins, 1956; Wells and Cooke, 1956; Cooke, 1968). Tropical grasses have a C4 photosynthetic pathway characterised by a specialized leaf anatomy, higher growth rate and nitrogen use efficency (Norton, 1982). They are also capable of accumulating starch and reserve polysacharides which are easily digestible. Further, browse usually contains tannins, essential oils or other aromatic compounds that decreases palatability. Grasses have also the advantage over herbs and shrubs because the growth occurs from the base and are hence protected from grazing damages (Branson, 1953; Langer, 1972). The grazing habit of gaur could thus be attributed also to the strategy to ensure long-term food availability.

The study on habitat use of gaur in Parambikulam indicate the preference of grass lands almost throughout the year (Refer chapter 6). However, principal and preferred food of gaur in Parambikulam varied in number as well as in the rank order of its preference index according to seasons and habitat types. Seasonal and habitat related variation in food preferences have also been reported in European bison (Browski and Kossak, 1972; Gebczynaska and Krasinska, 1972; Gebczynska, 1980; Cabon-Raczynska *et al*., 1987; Gebczynaska et al., 1991) and Alaskan bison (Van Waggoner, 1986). The habitat type, plant species availability and season are the major factors operating on the preference of a species (Crawley, 1983). But the feeding strategy is also based on minimising the concentration of toxins while maximising nutritive value. Genotypic variation in protein content and digestibility found in tropical grasses and shrubs (Cooper, 1973) explains the variation in principal food species in the area.

The proximate factor influencing the decision on consumption of a plant is the palatablity. The present study shows that gaur is a grazer depending mostly on grass species throughout the year. However, there was an increase in the browsing duration in dry season. Jones and Wilson (1987) have reported higher browse species use in dry season where other forages become either sparse or unpalatable. Grasses of tropics have been reported to show an increased content of structural constituents with maturity which reduces digestibility (Reid and Jung, 1965; Gomide *et al*., 1969) and the proportion of stem also increases with maturity (Jones and Wilson, 1987).

Grass species differ widely in mineral content (Fleming, 1973) and differences in sodium content are particularly striking (Hacker *et al*., 1985). Further, plants take up minerals rapidly during early growth and the content of most minerals fall with advancing maturity as dry matter accumulates more rapidly than minerals in matured plants especially due to decrease in leaf percentage where minerals are considerably higher (Jones and Wilson, 1987). Lyttleton (1973) has reported a low protein content at mature stages in dry season due to water stress. Evidences of reduced nitrogen content in plant at high temperature have also been made (Colman and Lazenby, 1970). The higher proportion of matured grasses in the environment during dry season explains an increased browsing duration of gaur in Parambikulam. The number of principal food species and the increased occurrence of highly preferred species in grasslands and moist deciduous forests clearly indicate the importance of these habitats to gaur in Parambikulam. This also supports the findings that these habitats are crucial in maintaining the gaur population in the area.

The increased browsing during dry season could also be due to the high temperature which prompts the animal to move to the shade where browse species occurred in higher propotion. Mixed feeders, depending on the grass, shrubs and herbs in their diet commonly concentrated on grasses during high rainfall periods and high rate of grass growth. They switch to other foods during dry periods (Spinage *et al.*, 1980). The crude protein content of browse is usually much higher than grasses during dry season and browse is often viewed as a protein supplement for both livestock (Varma *et al.*, 1982) and wildlife (Hobbs *et al.*, 1981).

The proportion of time spent in grazing and browsing also show a sexual difference with the males depending more on browse species. Difference in food requirements of animals of the same size have been reported by Crawley (1983). Male - female difference could also be observed in feeding behaviour. The gaur males in the study area are mostly solitary and do not have the advantages of being in the groups and have to avoid frequenting open areas where grass are available in higher quantity. The males observed to spend more time in the forests with more cover and have to depend more on browse which are available in large quantities in such habitats.

Chapter 5

Activity pattern and time budget

5.1 Introduction

Information on activity pattern of animals help in understanding the foraging and survival strategies in their habitat. These, combined with energetic cost of various activities can provide daily, seasonal and annual energy expenditure estimates for each species. Activity pattern and time budget are expected to differ according to the age and sex of the animal. Abiotic factors are also considered to have greater influence on these.

A number of studies have reported activity patterns of different animals. Activity pattern of water buck (Spinage, 1968), black buck (Chattopadhyay and Bhattacharya, 1986), impala (Jarman and Jarman, 1973), warthog (Clough and Hassam, 1970), mountain reed buck (Irby, 1982), Thomson's gazelle (Walther, 1973), Lessar kudu (Mitchell, 1977), generuck and giraffe (Leuthold and Leuthold, 1978), savana buffallo (Stark, 1986) and elephant (McKay, 1973; Santiapillai *et al*., 1984; Santiapillai and Suprahman, 1986; Easa, 1989) have been studied in their natural condition. Comparatively very few studies have been reported on bison. Cabon-Raczynska *et al*., (1987) and Cabon-Raczynska *et al*. (1983) studied the daily activity of European bison in winter and in the period without snow cover respectively. A few studies have also been carried out in enclosure of Prague Zoo (Vajner, 1980) and in Holland (Brink Van Den, 1980). Korockina (1972) described the summer activity of European bison of Bialowieza Primeval forest and Krischke (1984) in Bayerische Wald National Park. Shult (1972) published his observation on American bison's behaviour patterns at Wint Cave National Park.

The present study focused on diurnal activity pattern and time budget of different age and sex categories of gaur and its seasonal variations.

5.2 Methods

The data on activity pattern and time budget were collected through instantaneous scan sampling (Altmann, 1974). Since the animals were observed in groups, the observation period was of 10 minutes with an interval of 5 minutes. Thus four samples were taken in an hour. Observation was initiated with the sighting of the herd and lasted till sunlight favoured visibility or the animal left the location due to some reason. Whenever the animals were found to be disturbed by the observer, the sampling was terminated and was restarted after the of the animals settled.

The animals in the group were classified into different age and sex categories as mentioned in Chapter 3. Activities of the animals were classified as follows

1. Feeding : Feeding on different food species and include both grazing and browsing.
2. Walking : Walking at a steady pace or movements from one location to another while feeding or movements from one place to another while resting.
3. Resting : The animal was considered to be resting while standing still or lying with intermittent ruminating.
4. Drinking : Drinking water from streams, ponds or natural water holes in dry streams.
5. Social behaviour : Licking on individuals of its group members, nursing of calf and playing were included.
6. Others : Alertness, aggressiveness, urination, defecation , reproductive behaviour, vocalization and rubbing were included.

Analyses

The frequency of an activity refers to the number of occurrence of a particular activity during the observed period. Analyses have been done for different age and sex categories and for different seasons. The percentage frequency of occurrence of each activity was estimated from the percentage of samples in which a given activity was recorded. Thus,

$$\text{Percentage frequency of activity } i = \frac{\text{Number of occurrence of } i_{\text{th}} \text{ activity}}{\text{Total occurrence of all activity}} \times 100$$

Since there was no significant annual difference in the activity pattern, the data from three years were pooled both for seasonal and overall pattern and time budget.

The data on diurnal activity pattern of gaur were subjected to statistical analysis using HILOGLINEAR procedure of SPSS/PC+ for testing the seasonal variation in different activities by different age and sex categories.

The HILOGLINEAR backward elimination procedure was used to test the hourly seasonal changes in different activities by different age and sex categories.

Chi-square test was carried out using SPSS/PC+ CROSS TAB procedure to find the differences in frequency distribution of different activities in time budget between different age and sex categories and between seasons (3 x 6 contingency table). Time budget for each activity by different age sex categories was also subjected to χ^2 test.

5.3 Results

5.3.1 Activity pattern

The number of scans were converted into hours by considering 4 scans/hour. Total hours of observation in different seasons on different age and sex categories during the three year study period are summarised in Table 52. The hours of observation were more for adult female and less for juvenile categories in all the seasons. This was due to the higher percentage of adult females and lower percentage of juveniles in the population. Comparatively longer period of observation was made on all age and sex categories during dry season. This could be attributed to the visibility because of reduced plant cover density and leaf shedding. Observation hours on calves were less in second wet season since the majority of the calves during the season were comparatively young. Hour-wise percentage frequency distribution of observations for gaur (all age and sex categories combined) and for different age and sex categories in different seasons are presented in Figures 38, 39, 40, 41, 42, 43 and 44.

Table 52. Hours of observation made on different categories in different seasons

Season	Adult male	Adult female	Sub-adult male	Sub-adult female	Juvenile	Calf	Total
Dry	87.75 (351)	298.75 (1183)	36.5 (146)	102.00 (408)	32.5 (130)	90.25 (361)	644.75 (2579)
Wet 1	72.0 (288)	248.0 (992)	38.25 (153)	64.5 (258)	35.0 (140)	33.5 (134)	491.25 (1965)
Wet 2	48.75 (195)	128.75 (515)	26.0 (104)	45.0 (180)	24.75 (99)	14.75 (59)	288.0 (1152)
Total 1	20.85 (834)	672.5 (2690)	100.75 (403)	211.5 (846)	92.25 (369)	138.5 (554)	1424 (5696)

(Figures in parenthesis are frequencies).

Fig.38. Hour-wise distribution of observation time on gaur

in three seasons (all age and sex classes combined)

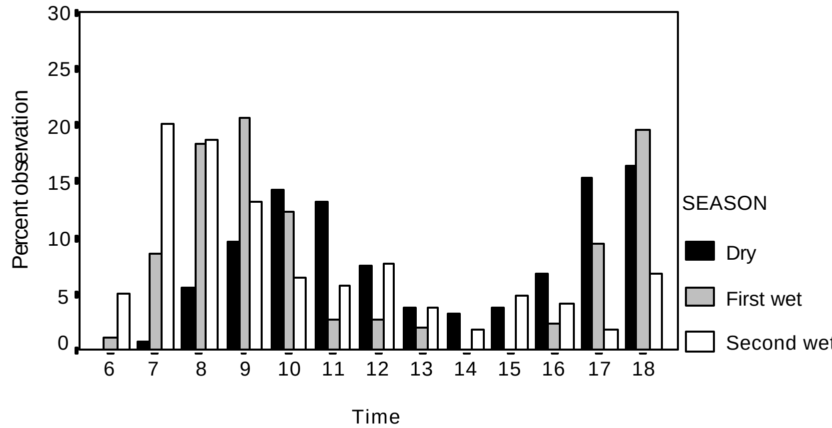


Fig.39. Hour-wise distribution of observation time

on adult male gaur in three seasons

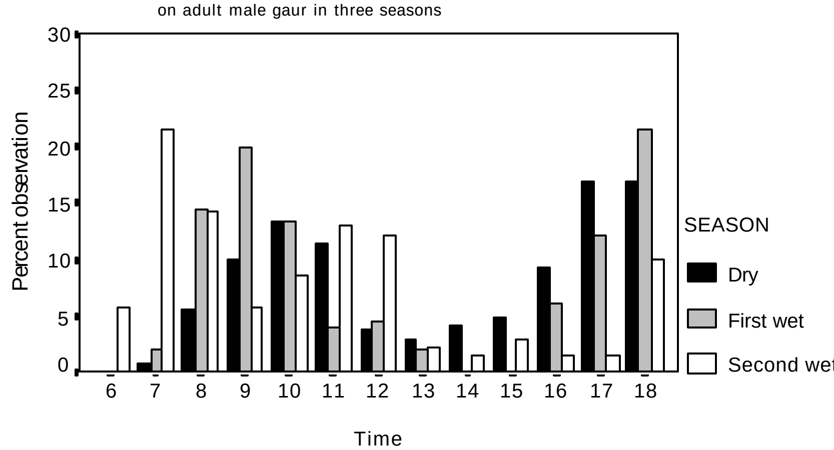


Fig.40. Hour-wise distribution of observation time

on adult female gaur in three seasons

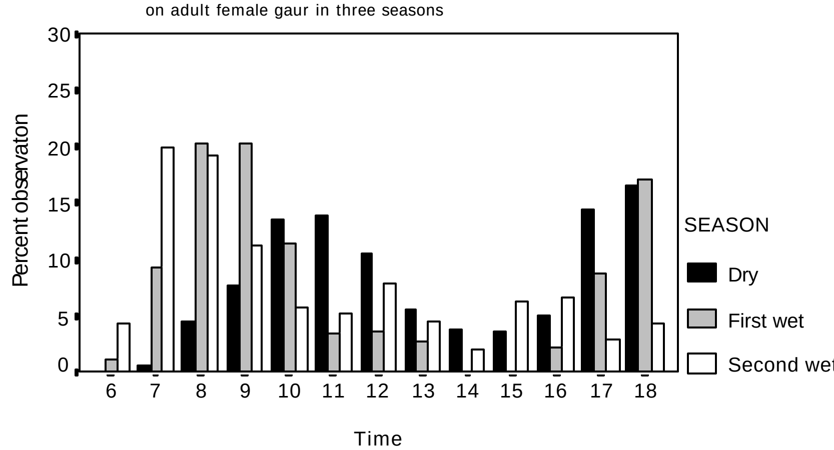


Fig.41. Hour-wise distribution of observation time

on sub adult male gaur in three seasons

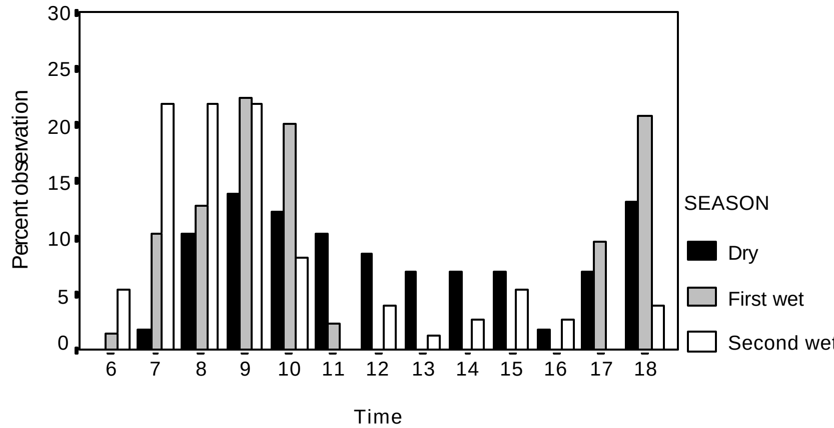


Fig.42. Hour-wise distribution of observation time

on sub adult female gaur in three seasons

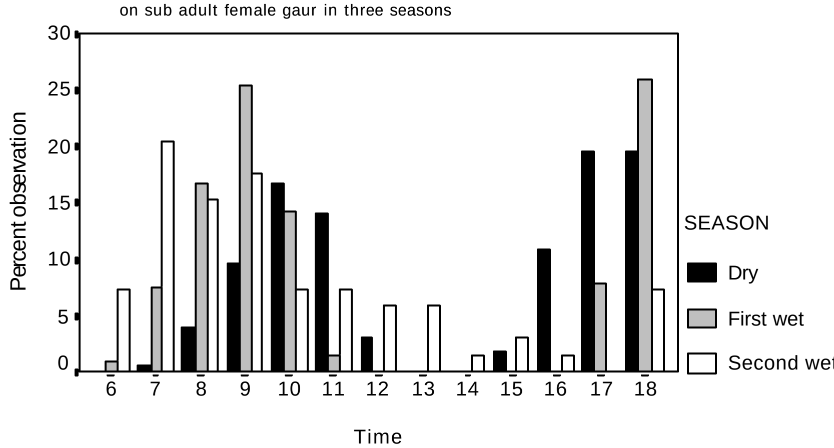


Fig.43. Hour-wise distribution of observation time

on juvenile gaur in three seasons

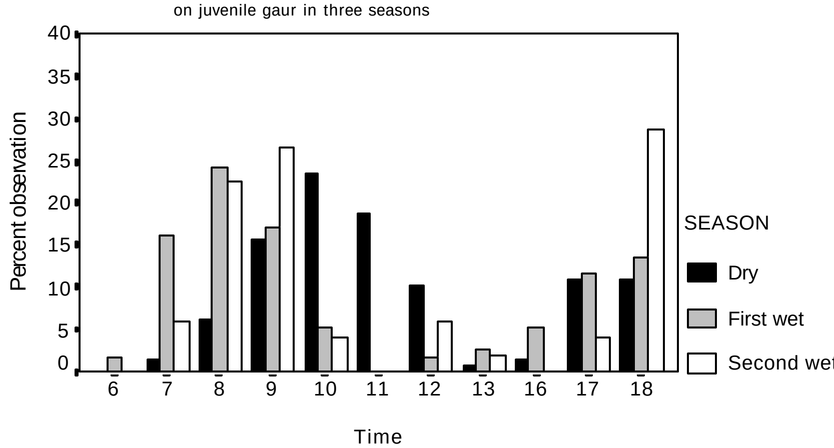
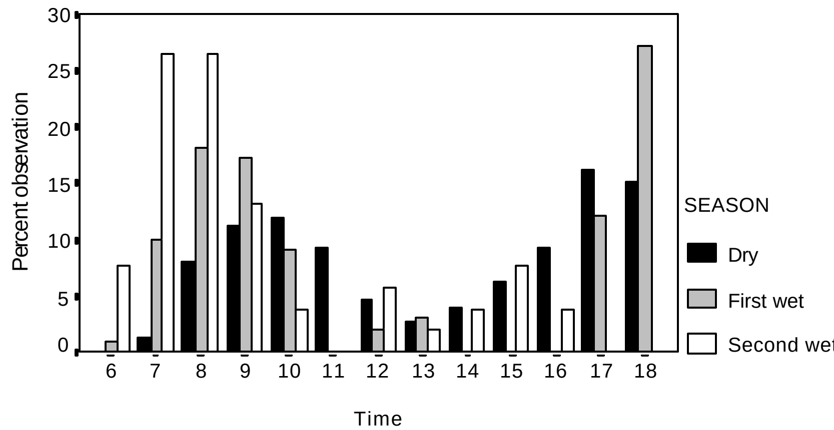


Fig.44. Hour-wise distribution of observation time

on gaur calf in three seasons



5.3.2 Diurnal activity pattern

Activity pattern of all age and sex categories of gaur for the combined period of three years is given in Figure 45. Gaur in Parambikulam Wildlife Sanctuary showed a bimodal diurnal pattern in feeding with peaks in the early morning and evening hours. The feeding reached the peak between 06.00 and 09.00 hours and after 18.00 hours. It was almost reduced to nil during the noon hours. There was a gradual increase in time spent for resting during the noon hours. This reached a peak during late noon hours and then gradually decreased. The animals were observed to lie in the cover during the hottest period of the day and rumination mostly occurred during this resting posture.

Walking was more or less uniform throughout the day and it was rapid during mid day hours since it moved frequently as shades moved from one position to another especially in dry season. The gaur was never seen drinking during morning hours. This activity was observed only during noon hours either before or after resting. Drinking normally occurred after intensive feeding, while moving to canopy cover for resting or at the time of moving to feeding sites. Almost all the observations on drinking were from slow flowing streams or water holes.

Social behaviour was mostly during the resting period after the intensive feeding but also occurred in the early morning hours. Defecation, urination and nursing were observed throughout the day. Vocal communication made by females were observed only during the time of aggregation when the members of family units come closer. Vocalization was also observed both among the males and females in early and late hours of the day during rutting season.

Fig.45. Diurnal activity pattern of gaur in Parambikulam WLS

5.3.3 Seasonal differences in the diurnal activity pattern

Diurnal activity pattern of gaur in dry, first wet and second wet seasons are illustrated in Figures 46, 47 and 48. There was a marked reduction in most of the activities of gaur in dry season compared to other two seasons. Feeding activity prolonged throughout the day without any interruption in first wet season though the occurrence of this activity was low during noon hours. Drinking was between 11.00 and 17.00 hours in dry season. It was in the morning hours in first wet and there was no observation on drinking in second wet season. Social behaviour always followed the pattern of resting or/and walking. Walking followed an almost similar pattern in dry and second wet seasons with a marked reduction in first wet. Other activities did not differ much though there was no observation of such activities between 13.00 and 15.00 hours in dry season.

Fig.46. Diurnal activity pattern of gaur in Parambikulam WLS

in dry season - all age sex classes combined

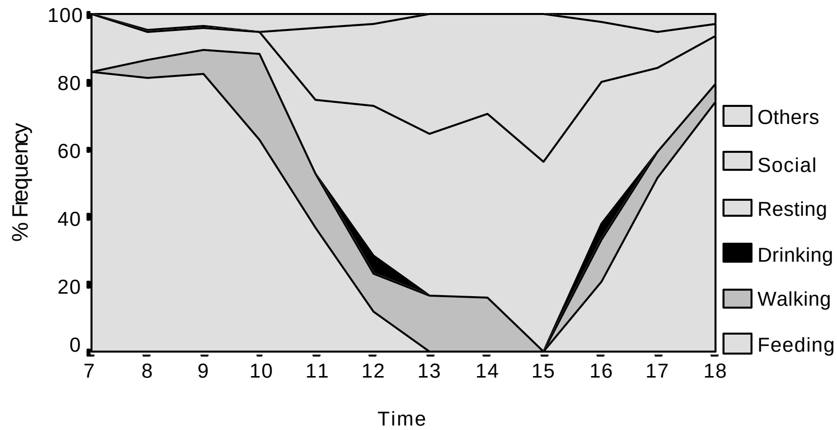


Fig.47. Diurnal activity pattern of gaur in Parambikulam WLS

in first wet season - all age sex classes combined

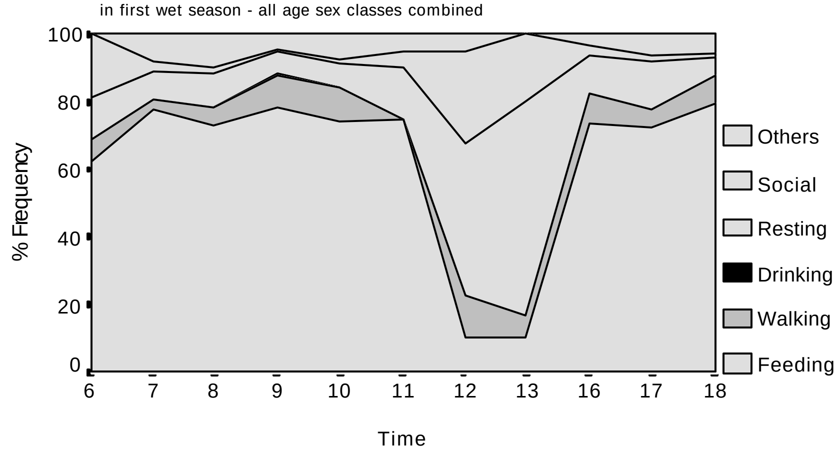
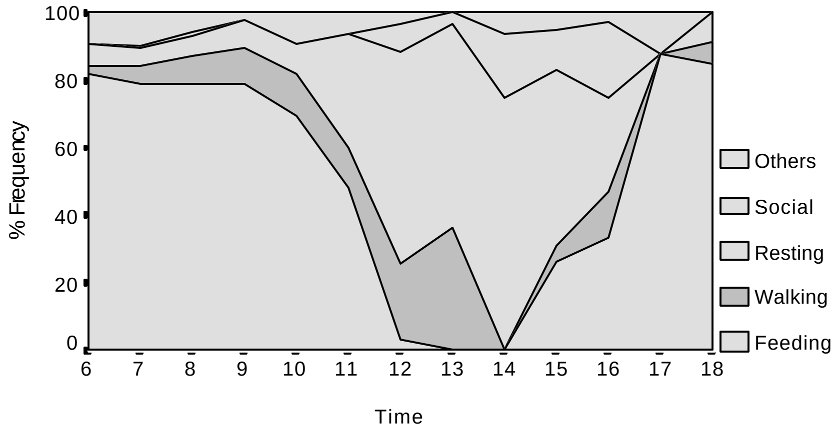


Fig.48. Diurnal activity pattern of gaur in Parambikulam WLS

in second wet season - all age sex classes combined



5.3.4 Activity pattern of different age and sex categories

5.3.4.1 Adult male

Adult male gaur showed a bimodal pattern in feeding in all the seasons except for its occurrence during noon hours in first wet (Figs.49, 50 and 51). The period between 11.00 and 16.00 hours in dry and second wet seasons was dominated by resting followed by walking. Feeding was recorded mostly in the morning and evening hours. However, feeding activity was observed in mid hours to some extent in first wet season. During second wet season, a steep increase in feeding was observed in the evening hours. Resting was much higher in dry and second wet seasons. Considerable decrease in walking was found in first wet season compared to dry and second wet seasons. Social activities were mostly observed during mid hours during resting time.

Fig.49. Diurnal activity pattern of adult male gaur

in Parambikulam WLS in dry season

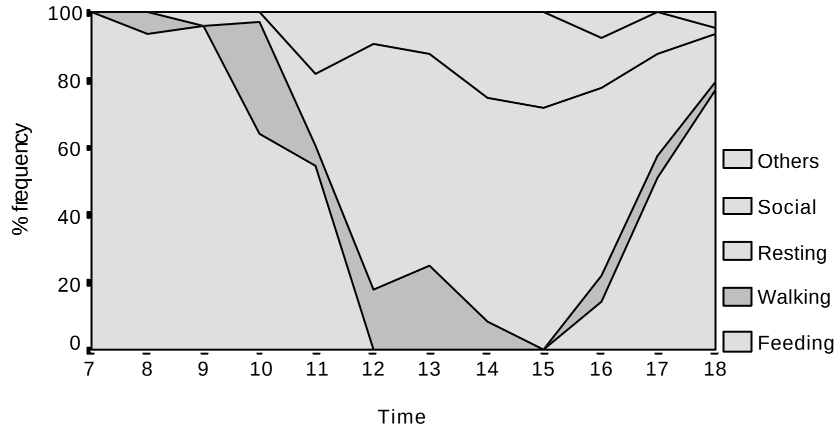


Fig.50. Diurnal activity pattern of adult male gaur

in Parambikulam WLS in first wet season

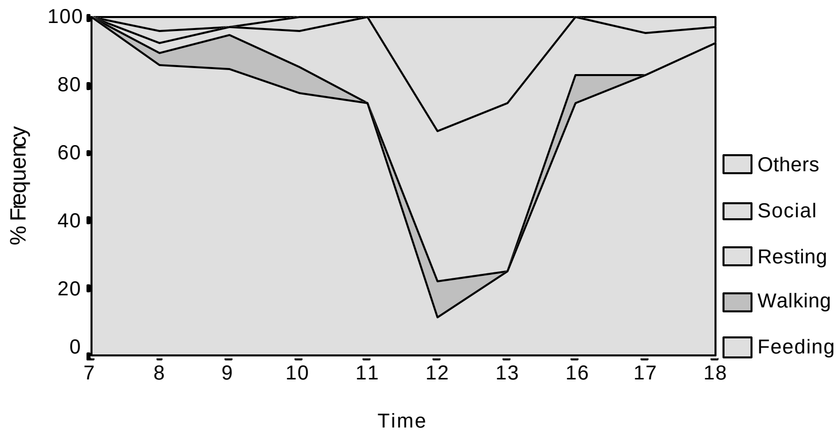
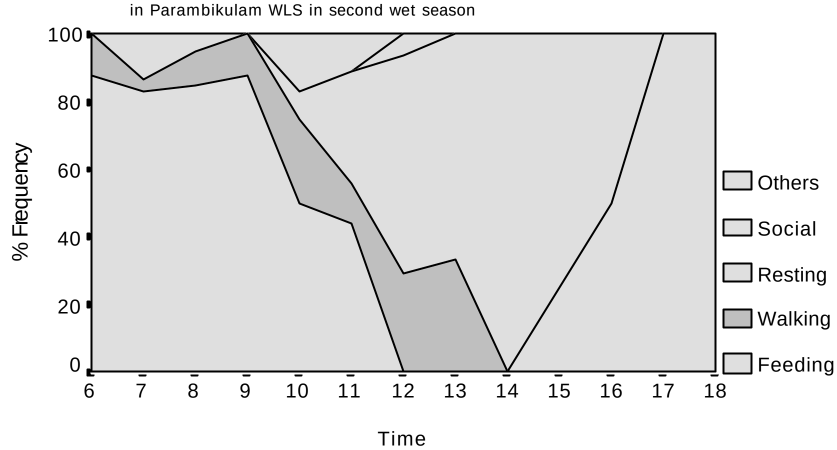


Fig.51. Diurnal activity pattern of adult male gaur

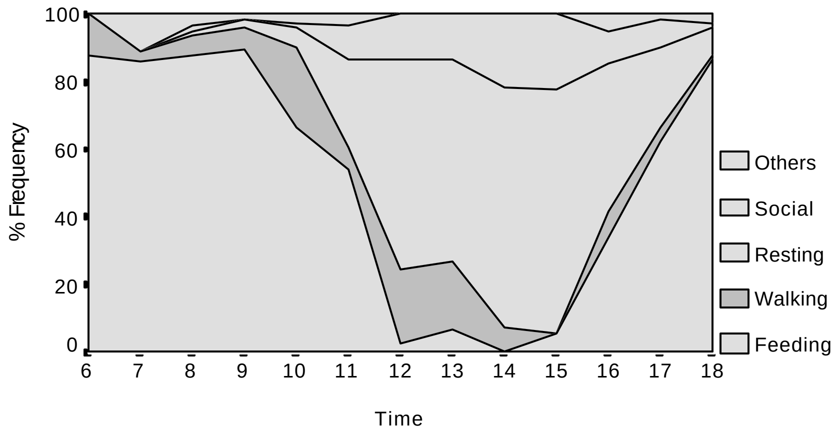
in Parambikulam WLS in second wet season



Overall activity pattern, irrespective of seasons also showed a bimodal feeding pattern with resting, walking and social behaviour occurring between 10.00 and 15.00 h period (Fig. 52).

Fig.52. Diurnal activity pattern of adult male gaur

in Parambikulam WLS



5.3.4.2 Adult female

Results of seasonal analysis on diurnal activity pattern of adult females are given in Figures 53, 54 and 55. Feeding in first wet season showed a polymodal pattern (Fig. 54) with peaks occurring at different hours of the day and continued throughout without break with at least few occurrence of feeding even during noon hours. In contrast, a clear break up in feeding was observed from 13.00 to 15.00 hours during dry season (Fig. 53) and 13.00 to 14.00 hours during second wet season (Fig. 55). The duration of walking and resting activities were greater during dry and second wet seasons compared to first wet season. Social activities were observed more in dry and second wet seasons and no conspicuous difference was observed in other activities between the seasons. Comparatively more time was spent for drinking in dry season especially during mid day.

Fig.53. Diurnal activity pattern of adult female gaur

in Parambikulam WLS in dry season

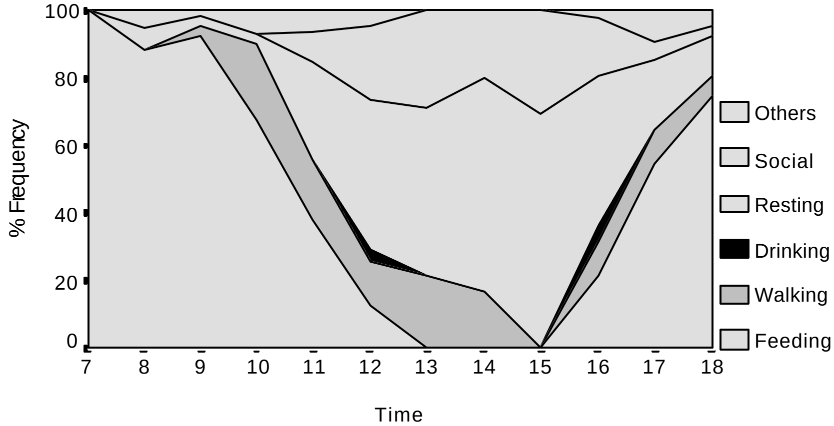


Fig.54. Diurnal activity pattern of adult female gaur

in Parambikulam WLS in first wet season

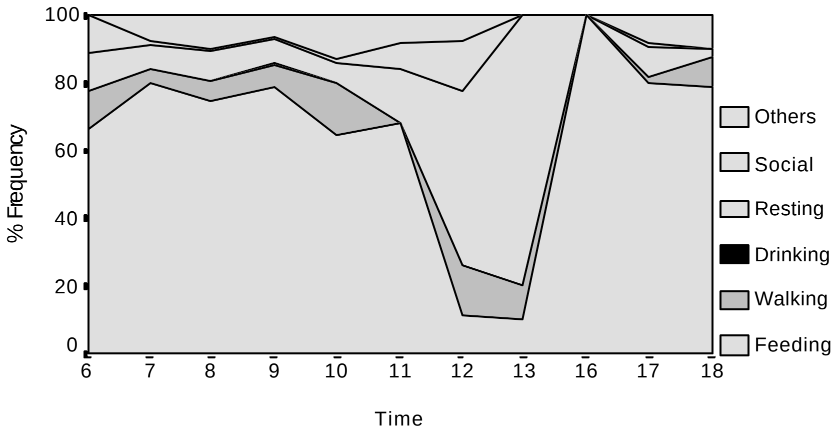
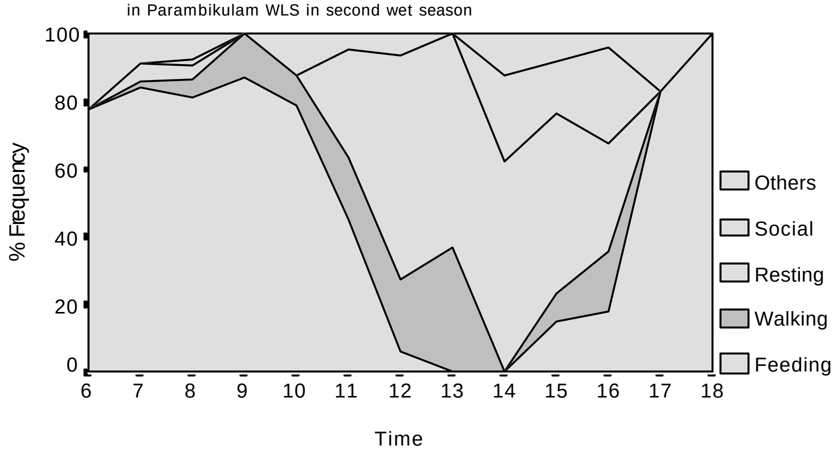


Fig.55. Diurnal activity pattern of adult female gaur

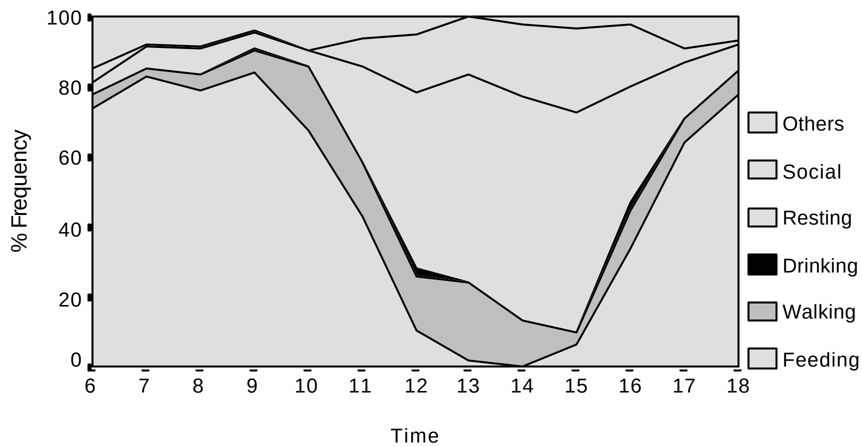
in Parambikulam WLS in second wet season



Overall pattern in activity (irrespective of seasons) of adult female gaur is illustrated in Figure 56. Intensive feeding was observed up to 09.00 hours and then gradually reduced to almost nil by around 13.00 to 14.00 hours. The feeding further reached a peak after 16.00 hours. Considerable amount of time was spent for resting and social activities during noon hours. Walking was observed throughout the day with an increase in noon hours. The other activities were also observed occurring uniformly throughout the day.

Fig.56. Diurnal activity pattern of adult female gaur

in Parambikulam WLS



5.3.4.3 Sub-adult male

Seasonal diurnal activity pattern of sub-adult male gaur is given in Figures 57, 58 and 59. Feeding was observed to occur throughout the day during first wet season and showed very different pattern from other seasons and even from other age and sex categories. There was no feeding between 12.00 and 14.00 hours during second wet season and between 13.00 and 15.00 hours during dry season. There was no observation on drinking activity during first and second wet seasons. Resting period was more during dry and second wet seasons and was between 11.00 and 15.00 hours.

Fig.57. Diurnal activity pattern of sub adult male gaur

in Parambikulam WLS in dry season

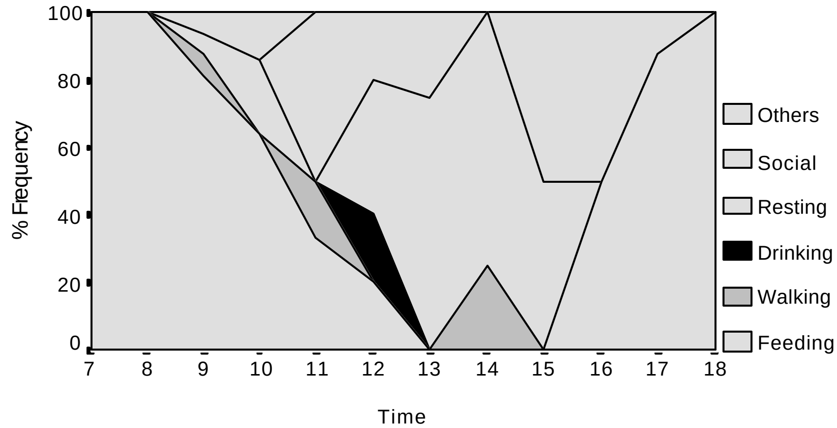


Fig.58. Diurnal activity pattern of sub adult male gaur

in Parambikulam WLS in first wet season

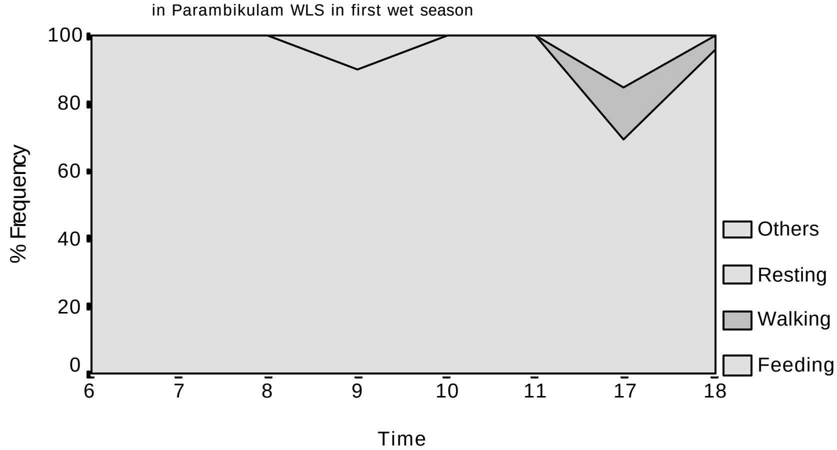
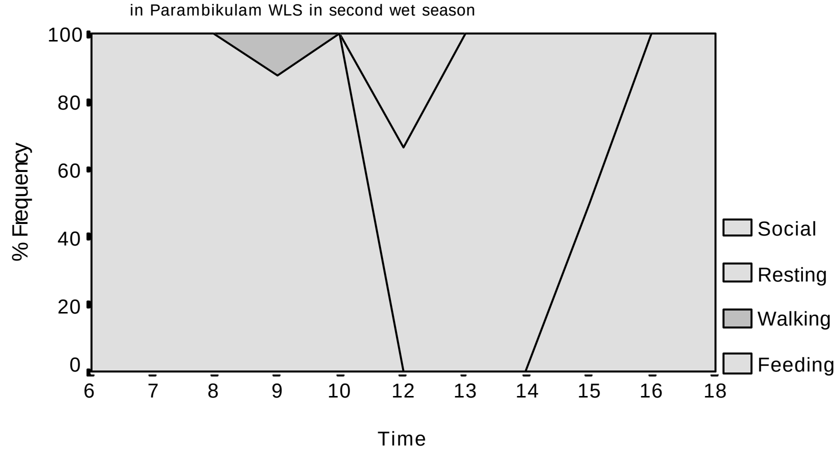


Fig.59. Diurnal activity pattern of sub adult male gaur

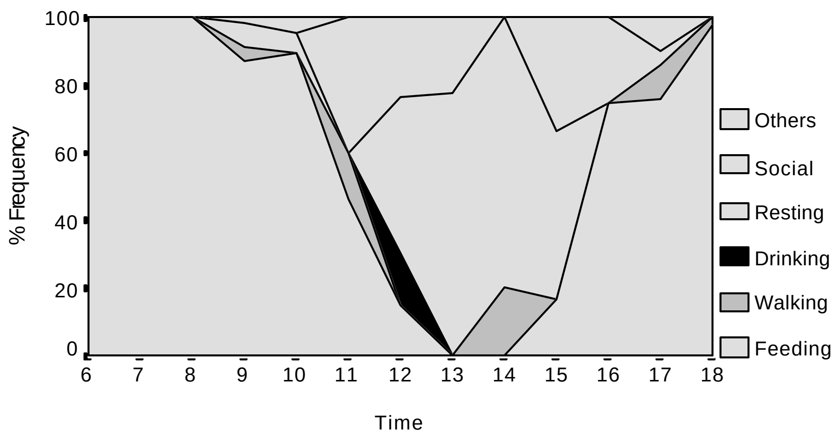
in Parambikulam WLS in second wet season



Diurnal activity pattern of sub-adult male gaur, irrespective of seasons is presented in Figure 60. Feeding showed a steep fall during noon hours. Resting which started from 11.00 hours reached the peak during 12.00 to 14.00 hours. A discontinuous pattern was observed in walking. Social activities were considerably more before and after mid day. Drinking was confined to 11.00 to 13.00 hours before going for rest.

Fig.60. Diurnal activity pattern of sub adult male gaur

in Parambikulam WLS



5.3.4.4 Sub-adult female

Seasonal distribution of activity pattern of sub-adult female gaur are given in Figures 61, 62 and 63. Feeding showed a polymodal pattern in dry and second wet seasons with peaks occurring during morning and evening. Time distribution on resting was remarkably more in dry and second wet seasons. Walking was observed throughout the day in all the seasons except in the evening hours of second wet season. Drinking was observed in late noon hours in dry season and early noon hours in first wet season. There was no observation on drinking in second wet season.

Fig.61. Diurnal activity pattern of sub adult female gaur

in Parambikulam WLS in dry season

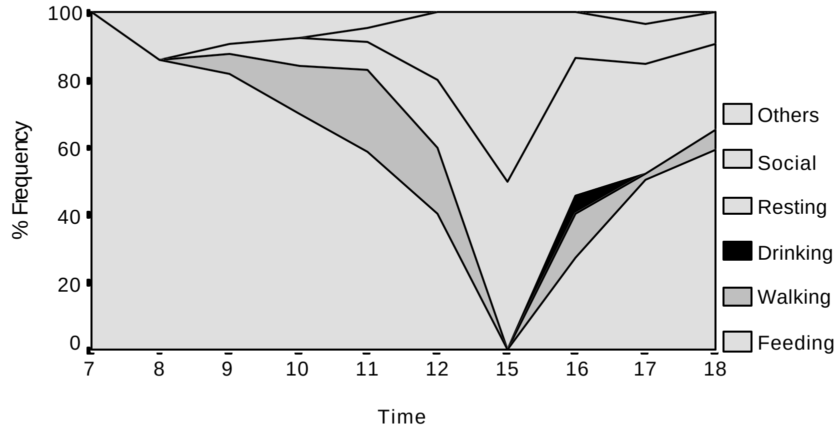


Fig.62. Diurnal activity pattern of sub adult female gaur

in Parambikulam WLS in first wet season

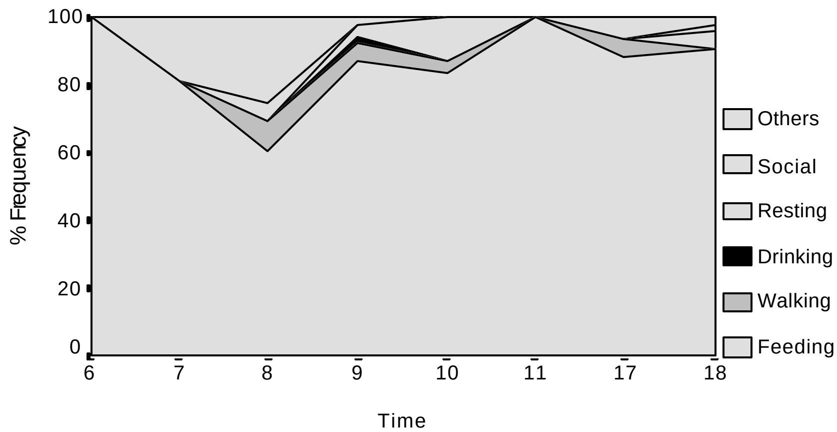
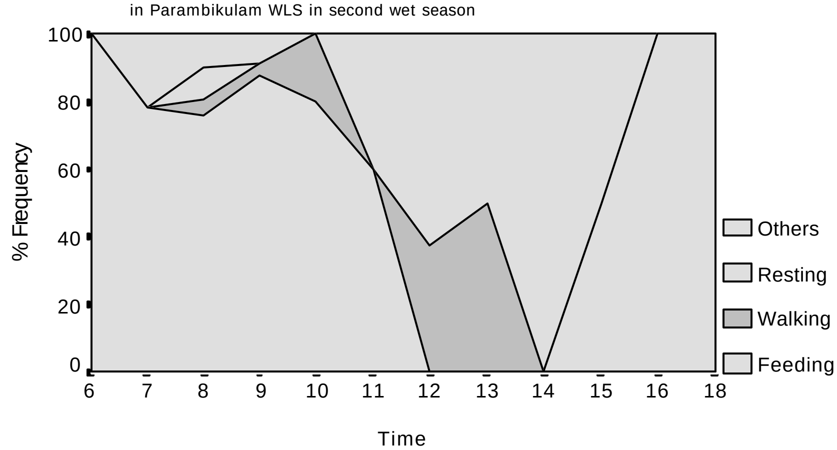


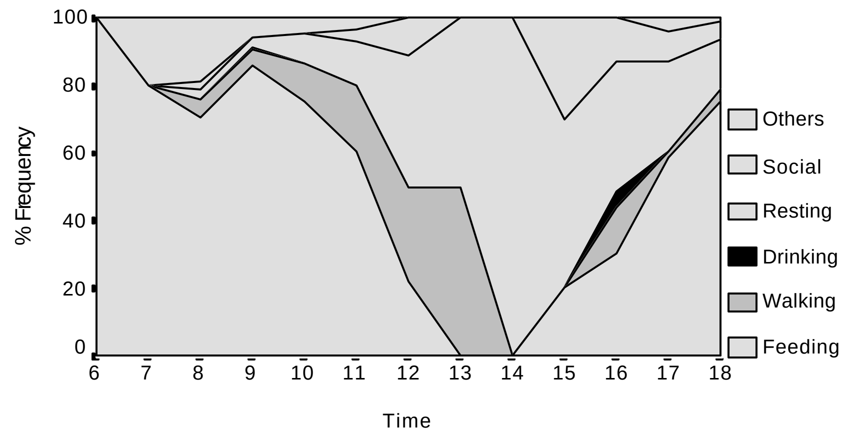
Fig.63. Diurnal activity pattern of sub adult female gaur

in Parambikulam WLS in second wet season



Diurnal activity pattern of sub-adult female gaur, irrespective of seasons is illustrated in Figure 64. It shows that the time spent on feeding was comparatively higher in the morning than the evening hours. Walking was uniformly distributed till 14.00 hours with comparatively low occurrence in the evening. Drinking was observed during late noon hours after the completion of resting and also in the morning hours. Resting was observed during mid day.

Fig.64. Diurnal activity pattern of sub adult female gaur in Parambikulam WLS



5.3.4.5 Juvenile

The seasonal distribution of activities showed a polymodal pattern in feeding (Figs. 65, 66 and 67). Resting period was entirely different from other age and sex categories and was almost uniformly distributed in dry season with peaks in the morning and evening in wet seasons. Social behaviour was observed to occur during noon hours in all seasons. But this was also observed in the morning in the first wet season.

Fig.65. Diurnal activity pattern of juvenile gaur

in Parambikulam WLS in dry season

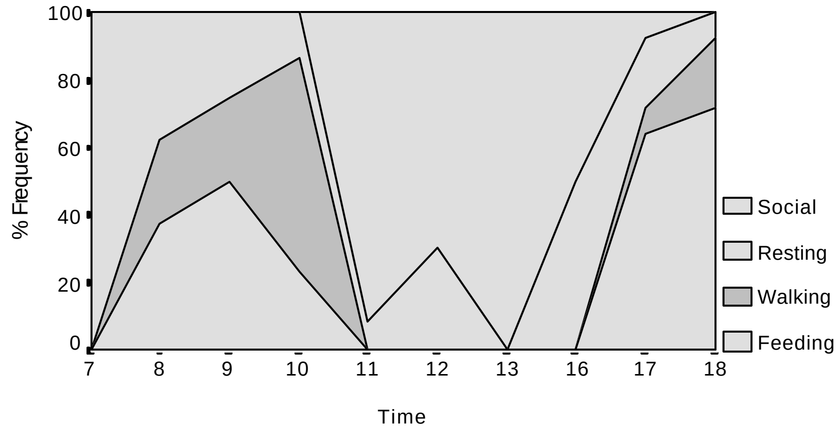


Fig.66. Diurnal activity pattern of juvenile gaur

in Parambikulam WLS in first wet season

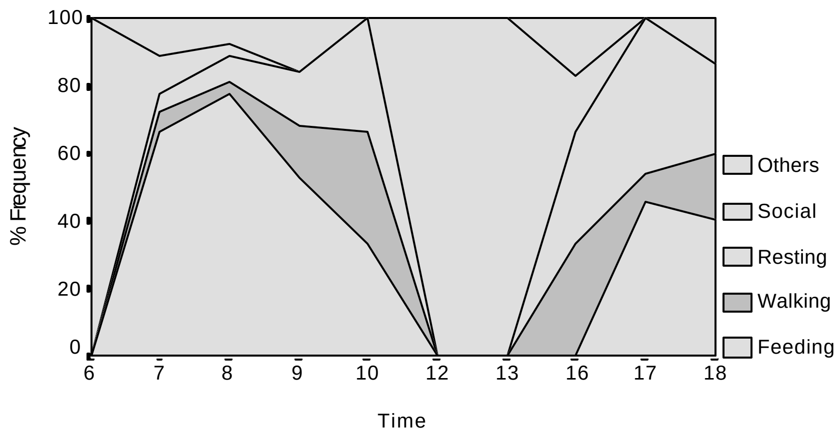
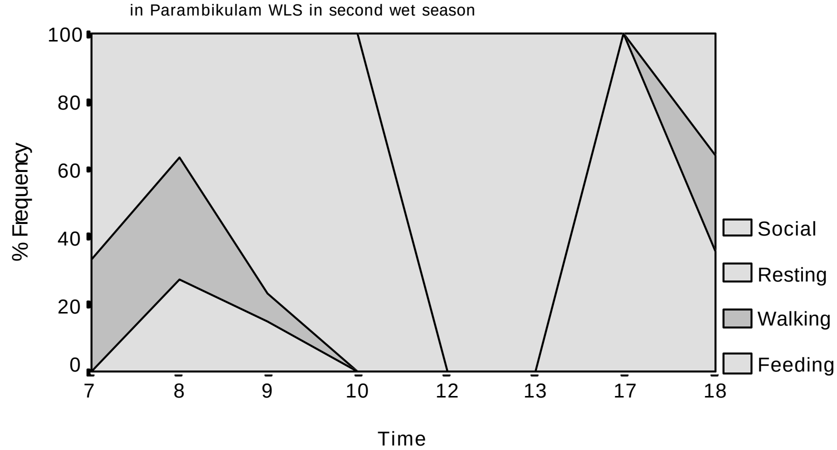


Fig.67. Diurnal activity pattern of juvenile gaur

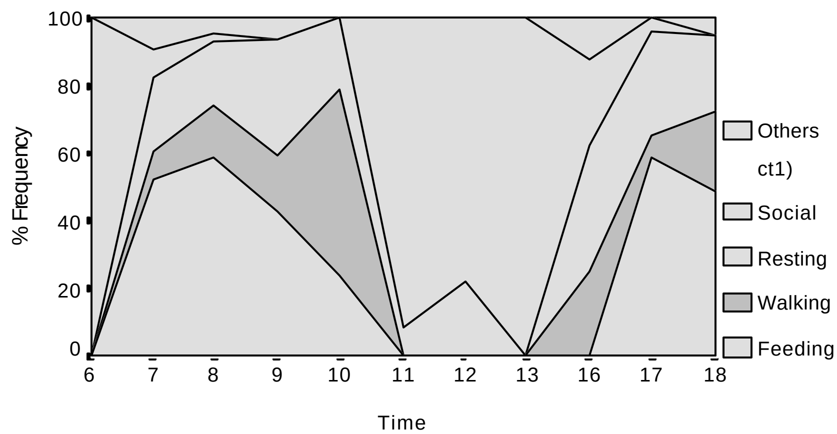
in Parambikulam WLS in second wet season



The overall activity pattern of juvenile gaur showed a bimodal pattern in activities (Fig. 68). The feeding was clearly confined to morning 06.00 to 11.00 hours with the peak at 08.00 hours and then after 16.00 hours. This category spent more time on social behaviour mostly occurring during mid hours. Walking and resting were also observed throughout the day with a break during 11.00 to 13.00 hours when more social activities occurred.

Fig.68. Diurnal activity pattern of juvenile gaur

in Parambikulam WLS



5.3.4.6 Calf

Seasonal analysis on diurnal activity pattern of gaur calves are shown in Figures 69, 70, and 71. Considerable amount of time was spent in social and resting activities and were distributed throughout the day in dry season and second wet seasons compared to the first wet season. The feeding activity was observed slightly more in first wet season than dry and second wet seasons. Drinking was observed before and after noon hours of the day in dry season while this was not observed in first and second wet seasons. Walking was uniformly distributed throughout the day except in second wet season and noticeably more during dry season.

Fig.69. Diurnal activity pattern of gaur calf

in Parambikulam WLS in dry season

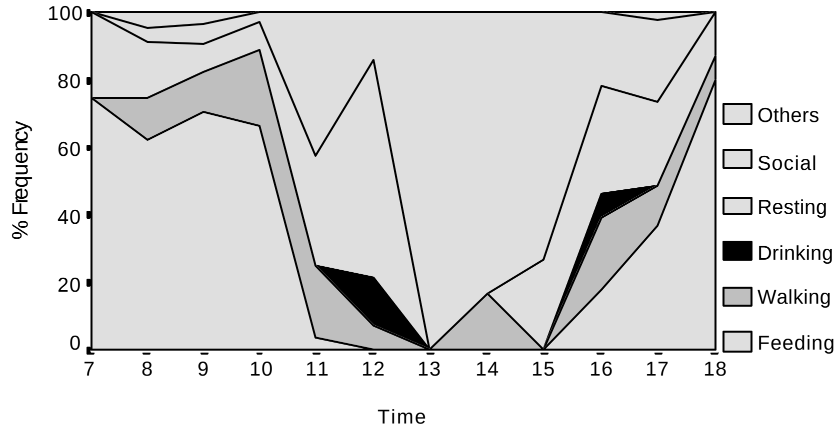


Fig.70. Diurnal activity pattern of gaur calf

in Parambikulam WLS in first wet season

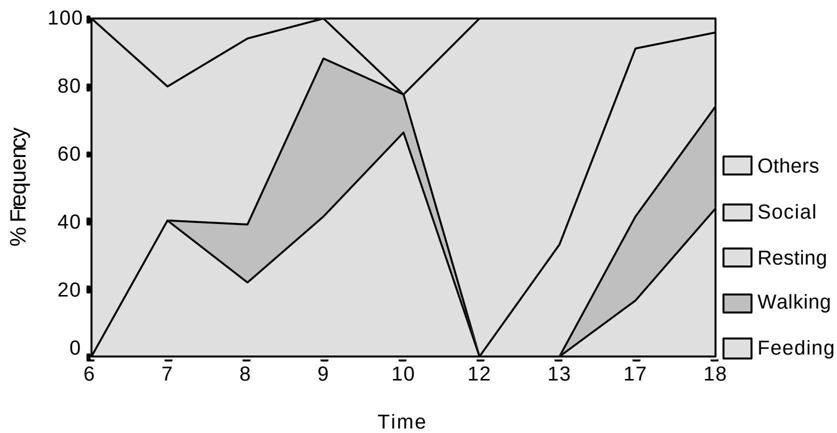
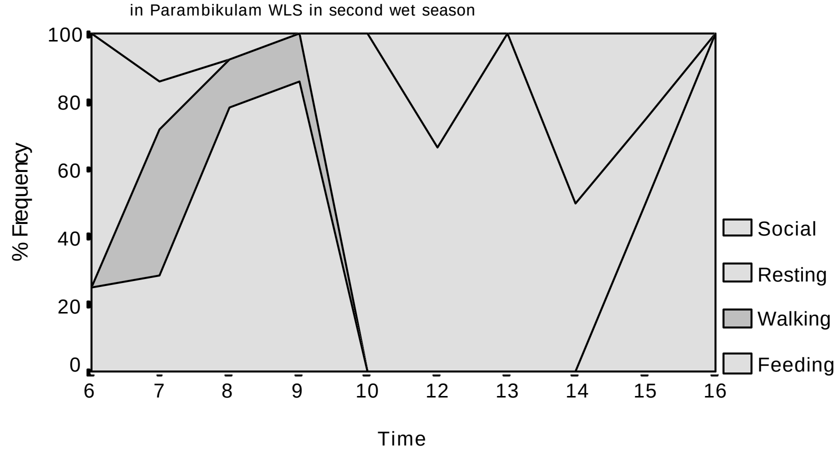


Fig.71. Diurnal activity pattern of gaur calf

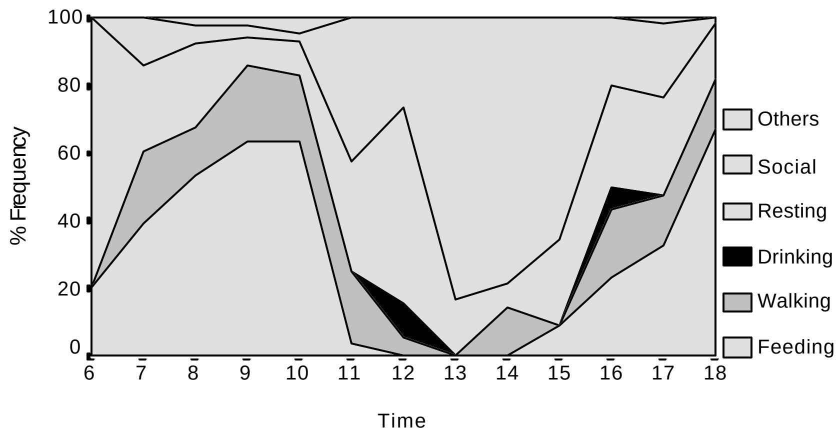
in Parambikulam WLS in second wet season



Observation on activity pattern of gaur calves is illustrated in Figure 72. Distribution of feeding time was confined to the morning and the evening hours and was less compared to other activities. Resting, walking and social activities were observed throughout the day. A major share of time was spent for social activities. Drinking was found only before and after noon hours. The Figure shows an irregular polymodal pattern in resting activity with peaks at different hours of the day.

Fig.72. Diurnal activity pattern of gaur calf

in Parambikulam WLS



5.3.5 Seasonal variation in activities

The results of HILOGLINEAR test for seasonal variation in different activities by different age and sex categories are summarised in Table 53. Results show that three-way and two-way interactions and also the all main effects were significant.

Table 53. Results of HILOGLINEAR test against activity, seasons, hours and age and sex category.

Source of variation	***df***	**Partial c ^{2}**	***P***
Activity	5	5349.357	< 0.01
Season	2	530.717	< 0.01
Hours of the day	12	1810.891	< 0.01
Age and sex category	5	2484.178	< 0.01
Activity x Season	10	91.078	< 0.01
Activity x Hours	60	1702.665	< 0.01
Activity x Age and sex category	25	417.234	< 0.01
Activity x Season x Hours	120	256.247	< 0.01
Activity x Season x Age and sex category	50	124.243	< 0.01
Activity x Hours x Age and sex category	300	437.200	< 0.01

The results of loglinear are given in Table 54. The results indicate that the seasonal influence on activities occurred only during 11.00 to 14.00 hours of the day and after 16.00 hours of the day. It may be inferred that the major activity in the morning hours, the feeding till 11.00 hours of the day, remained the same over the seasons. Only the feeding pattern, between 11.00 to 14.00 hours and after 15.00 hours varies in relation to climate and season. On the other hand, the major activity in the noon hours, the resting remained the same in all the seasons.

5.3.5 Time budget

A total of 1424 hours of observation were made (taking all age and sex categories together). Feeding accounted for 63.36% and resting 16.03%. Percentage of time spent on movement and social activities were 8.81 % and 7.04 % respectively. Feeding, resting and walking accounted for 88.52% in activity time budget. About 5 % of the time was spent for other activities (Fig.73).

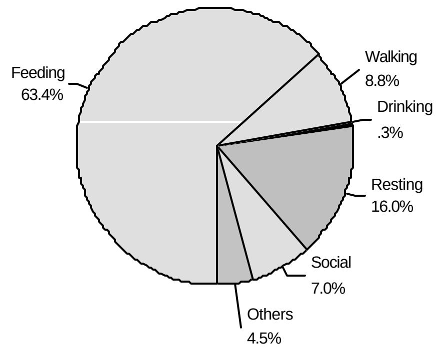
Table 54. Result of analysis through log linear models.

Hours of the day	Effects	*df*	Likelihood ratio c^2	*P*
6-7	AxC *	25	44.449	<0.0097
	S	2	62.244	<0.0001
7-8	AxC *	25	92309	<0.0001
	SxC	10	38.295	<0.0001
8-9	AxC *	25	88.153	<0.0001
	SxC	10	24.841	<0.0057
9-10	AxC *	25	84.572	<0.0001
	SxC	10	33.311	<0.002
10-11	AxC *	25	84.546	<0.0001
	SxC	10	34.479	<0.0002
11-12	AxS *	10	33.080	<0.003
	AxC *	25	131.878	<0.0001
	SxC	10	33.396	<0.0002
12-13	AxS *	10	23.701	<0.0084
	AxC *	25	65.465	<0.0001
	SxC	10	26.518	<0.0031
13-14	AxS *	10	34.967	<0.0001
	AxC *	25	54.573	<0.0006
	SxC	10	39.331	<0.0001
14-15	S	2	102.766	<0.0001
	A	5	135.023	<0.0001
	C	5	86.259	<0.0001
15-16	AxS *	10	42.128	<0.0001
	C	5	100.133	<0.0001
16-17	AxS *	10	58.691	<0.0001
	AxC *	25	46.658	<0.0054
	SxC	10	91.304	<0.0001
17-18	AxS *	10	35.979	<0.0001
	AxC *	25	56.474	<0.0003
	SxC	10	28.316	<0.0016
18-19	AxS *	10	28.405	<0.0016
	AxC *	25	91.311	<0.0001
	SxC	10	49.028	<0.0001

Note: A - Activity, C - Age and sex category, S - Season, * - indicates significant effects related to activity pattern. Effects not including 'A' are not relevant in this context.

Fig.73. Annual activity time budget of gaur

in Parambikulam WLS



Figures 74, 75 and 76 give the activity time budget of gaur in dry, first wet and second wet seasons. In all the seasons, feeding was the major activity. However, considerable variation in time spent on feeding was observed between seasons. The time spent for feeding in first wet season (71.25%) was higher compared to second wet (67.1%) and dry (55.65%) seasons. The difference in the percentage time spent on feeding in different seasons was found to be significant (χ^2 = 231.087, P<0.001). About 19.85 % of the time was spent for resting during dry season compared to 10.79 % in first wet and 16.41 % in second wet seasons. Time spent for resting in different seasons were also significant (χ^2 =213.426, P< 0.001). Percentage of time spent on walking was considerably higher in dry season (10.70%) compared to the first wet (6.36%) and second wet (8.77%) seasons and the difference was found to be significant (χ^2=107.574, P<0.001).

The combined analyses for all age and sex category irrespective of seasons indicated that only 7.04% of time was spent for social behaviour. However, there were significant seasonal difference in the activity (χ^2=205.247, P<0.001).

Fig.74. Activity time budget of gaur in

Parambikulam WLS in dry season

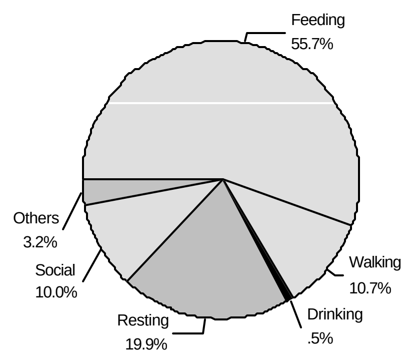


Fig.75. Activity time budget of gaur in

Parabikulam WLS first wet season

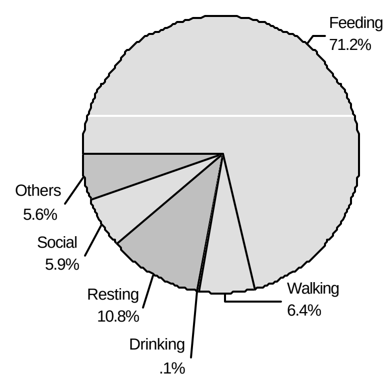
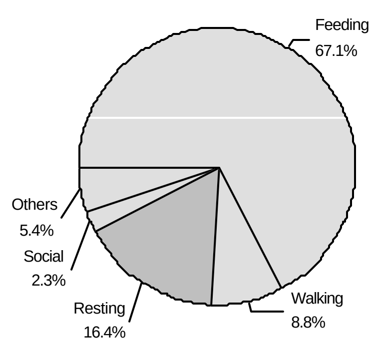


Fig.76. Activity time budget of gaur in

Parambikulam WLS second wet season



5.3.7 Age and sex categories

5.3.7.1 Adult male

Analyses, irrespective of seasons show that the time spent for feeding (70.14%) was higher compared to all other activities (Fig.77). Seasonal activity time budget of gaur are shown in Figures 78, 79 and 80. Percentage distribution of time spent on different activities were found to be significantly dependent on seasons (χ^2=58.629, P<0.001). Time spent for feeding was more in first wet season (79.51%) compared to dry (61.25%) and second wet seasons (72.31%). The difference was found to be significant (χ^2=22.933, P<0.001). The percentage time spent in resting was more in dry season (22.22%) (χ^2=44.313, P<0.001). Social activity events were observed to be more in first wet season (8.33%) compared to other seasons (χ^2=22.706, P<0.001). Walking (8.21%, χ^2=10.453, P<0.005) and other activities were more observed in second wet season.

Fig.77. Annual activity time budget of adult male gaur in Parambikulam WLS

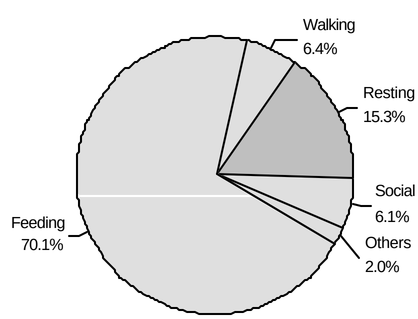


Fig.78. Activity time budget of adult male gaur

in Parambikulam WLS in dry season

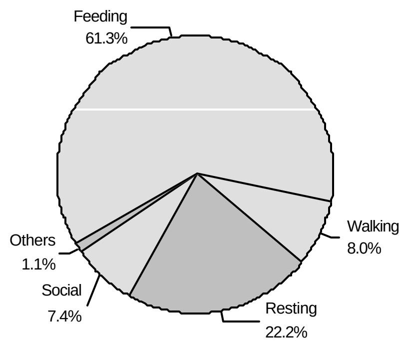


Fig.79. Activity time budget of adult male gaur

in Parambikulam WLS in first wet season

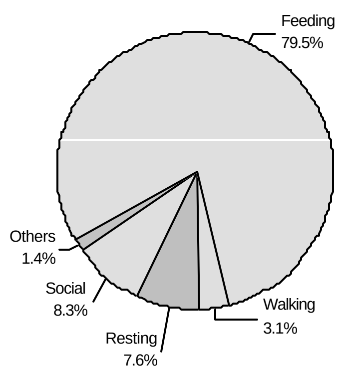
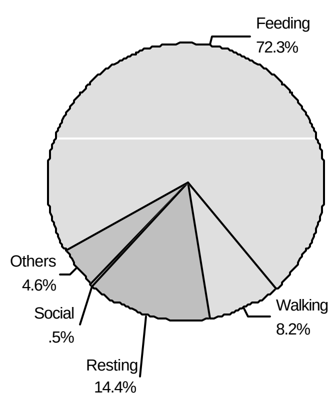


Fig.80. Activity time budget of adult male gaur

in Parambikulam WLS in second wet season



5.3.7.2 Adult female

Time spent in different activities for the entire study period is given in Figure 81 and shows that feeding dominated (62.68%). The analysis of the percentage distribution of time spent in different activities between seasons turned out to be significant (χ^2=89.318, P<0.001). Feeding period was significantly higher in first wet season (69.35%) (χ^2=134.619, P<0.001). Time spent for walking (χ^2=53.711, P<0.001), drinking (χ^2=8.857, P<0.01) and resting (χ^2=109.188, P<0.001) were significantly different and was higher in dry season (Figs. 82, 83 and 84). The other activities were more in second wet season. Time spent in social activities were significantly higher in dry season (χ^2=48.163, P<0.001).

Fig.81. Annual activity time budget of adult female gaur

in Parambikulam WLS

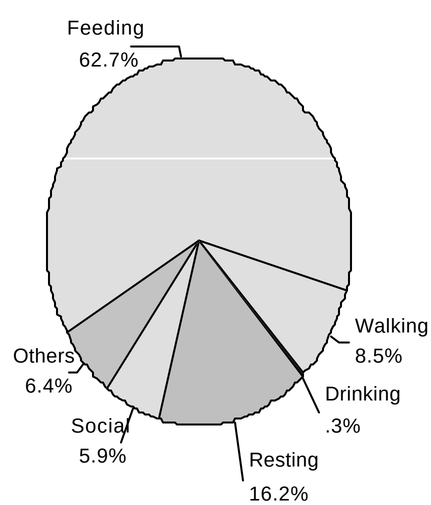


Fig.82. Time budget of adult female gaur in

Parambikulam WLS in dry season

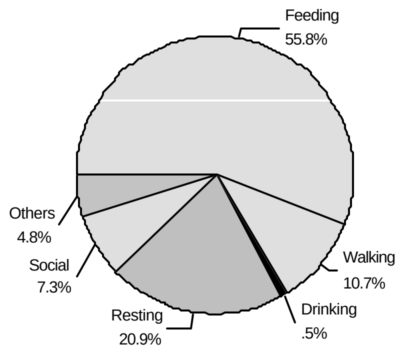


Fig.83. Activity time budget of adult female gaur

in Parambikulam WLS in first wet season

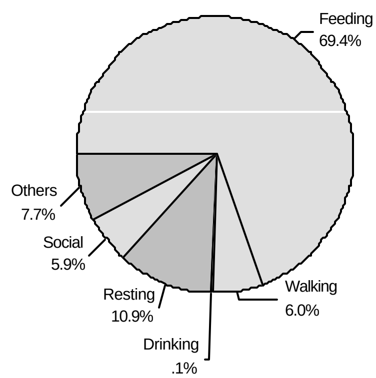
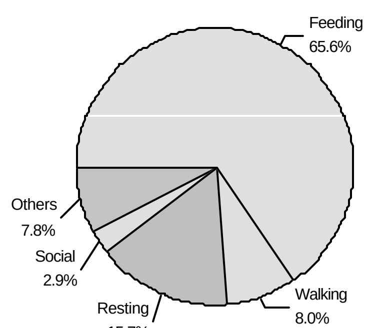


Fig.84. Activity time budget of adult female gaur

in Parambikulam WLS in second wet season



5.3.7.3 Sub-adult male

Time spent in different activities by sub-adult males were found to be influenced by seasons (χ^2=57.693, P<0.001). The combined (irrespective of seasons) analyses indicate that more time was spent in feeding (82.63%) compared to all other activities (Fig.85). Seasonal percentage distribution of time spent in different activities are given in Figures 86, 87 and 88. The time spent for feeding was comparatively more in first wet season (94.12%) (χ^2=14.721, P<0.001). But walking, resting and social activities were comparatively more in dry season (4.11%, 16.44% and 10.96% respectively). The time spent in resting and social activities significantly differed between seasons (χ^2=19.943, P<0.01 and χ^2=28.353, P<0.01 respectively).

Fig.85. Annual activity time budget of sub adult male gaur in Parambikulam WLS

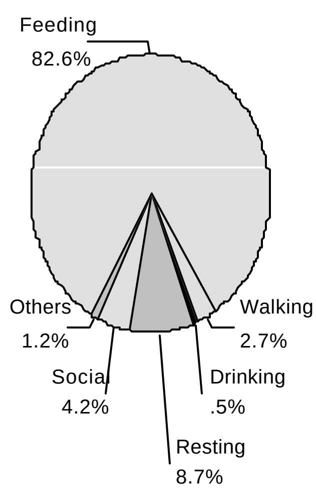


Fig.86. Activity time budget of Subadult male gaur

in Parambikulam WLS in dry season

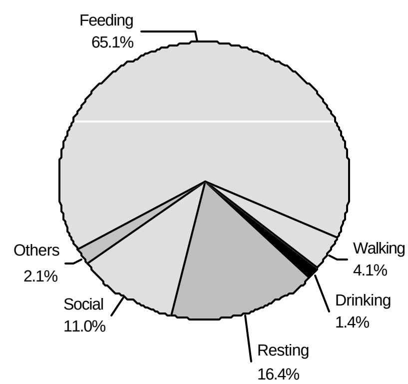


Fig.87. Activity time budget of sub adult male gaur

in Parambikulam WLS in first wet season

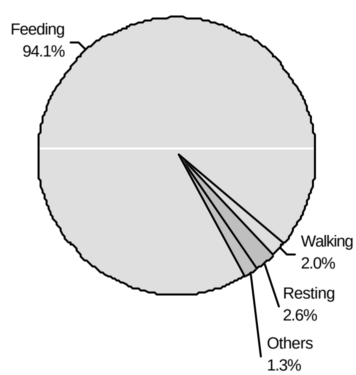
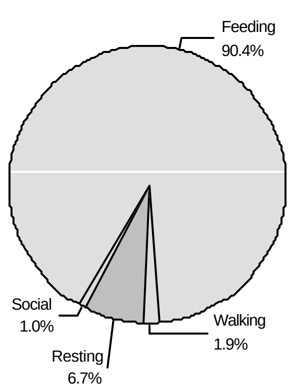


Fig.88. Activity time budget of sub adult male gaur

in Parambikulam WLS in second wet season



5.3.7.4 Sub-adult female

Overall time budget of sub-adult females is given in Figure 89. Feeding was the dominant activity. Percentage distribution of time spent in various activities were dependent on seasons (χ^2=66.645, P<0.001). The time spent in feeding was significantly higher in second wet season (83.72%) than other seasons (χ^2=36.838, P<0.0011) (Figs.90, 91 and 92). Significant seasonal variation was also observed on time spent in social (χ^2=36.839, P<=0.001), resting (χ^2=60.194, P<0.001) and walking (χ^2=33.300, P<0.001) activities. Seasonal variation on time spent in drinking and other activities were not significant.

Fig.89. Annual activity time budget of sub adult female gaur

in Parambikulam WLS

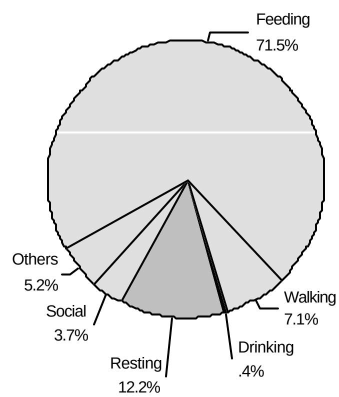


Fig.90. Activity time budget of sub adult female gaur

in Parambikulam WLS in dry season

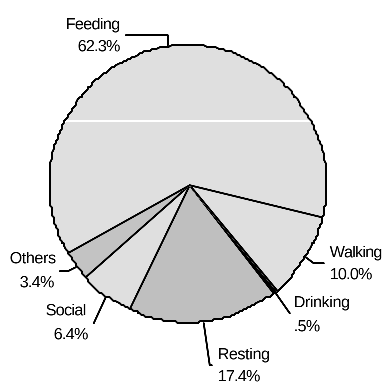


Fig.91. Activity time budget of sub adult female gaur

in Parambikulam WLS in first wet season

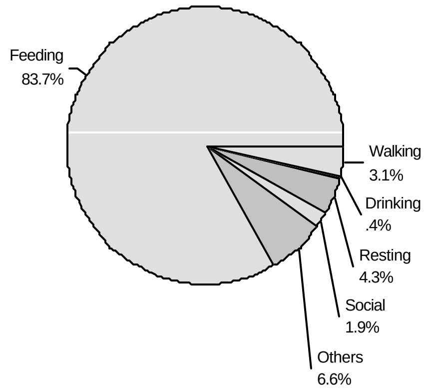
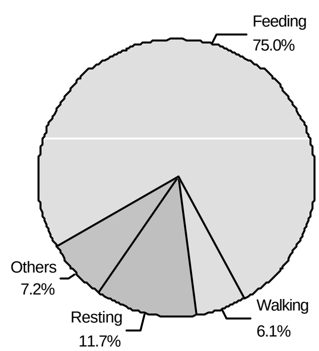


Fig.92. Activity time budget of sub adult female gaur

in Parambikulam WLS in second wet season



5.3.7.5 Juvenile

Analysis from overall observation on juveniles showed that major share of time was spent for feeding (41.73%) (Fig. 93) and the juveniles' various activities were dependent on seasons (χ^2=61.811, P<0.001). Feeding time was more in first wet season (53.37%) followed by second wet season (39.39%) (Figs. 94, 95 and 96). Seasonal variation was found to be significant (χ^2=16.377, P<0.01). There were also significant variations in social (χ^2=26.075, P<0.001) and other (χ^2=20.00, P<0.001) activities. Seasonal variations in time spent for walking and resting were not significant.

Fig.93. Annual activity time budget of juvenile gaur inParambikulam WLS

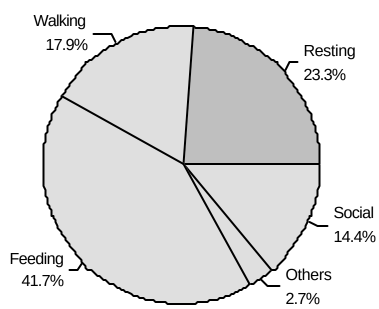


Fig.94. Activity time budget of juvenile gaur in Parambikulam WLS in dry season

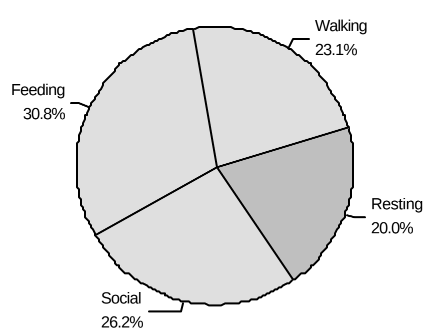


Fig.95. Activity time budget of juvenile gaur in Parambikulam WLS in first wet season

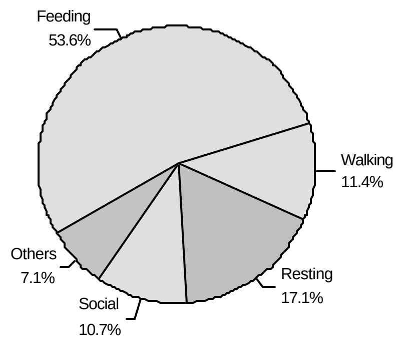
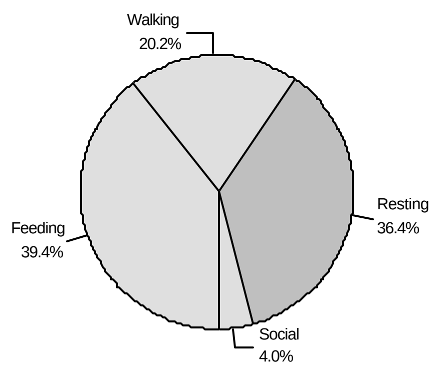


Fig.96. Activity time budget of juvenile gaur in Parambikulam WLS in second wet season



5.3.7.6 Calf

Analysis of overall time budget of gaur calf in different activities showed that more time was spent for feeding (44.40%) (Fig.97). The time spent in different activities were found to be significant (χ^2=29.627, P<0.01). Seasonal percentage distribution of time spent in different activities are given in Figures 98, 99 and 100. Feeding time was slightly more in dry season (47.65%) than first wet season (44.07%). Seasonal variation in feeding time was found to be significant (χ^2=151.122, P<0.001). The observed seasonal difference in all other activities turned out to be significant except in the other activities.

Fig.97. Annual activity time budget of gaur calf

in Parambikulam WLS

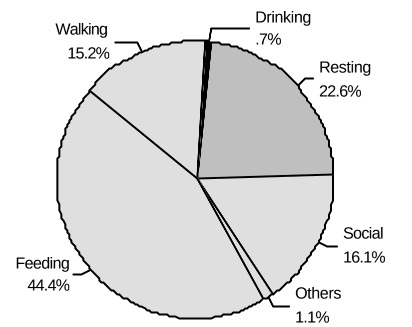


Fig.98. Activity time budget of gaur calf

in Parambikulam WLS in dry season

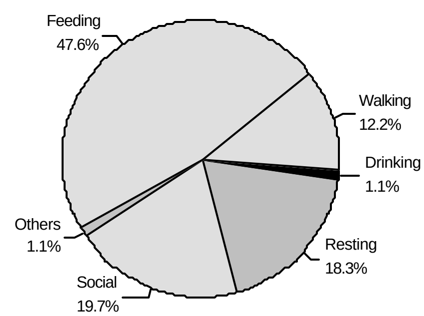


Fig.99. Activity time budget of gaur calf

in Parambikulam WLS in first wet season

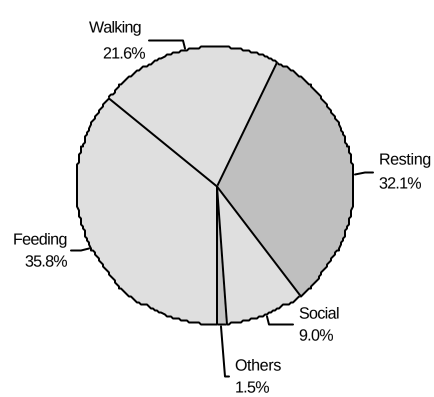
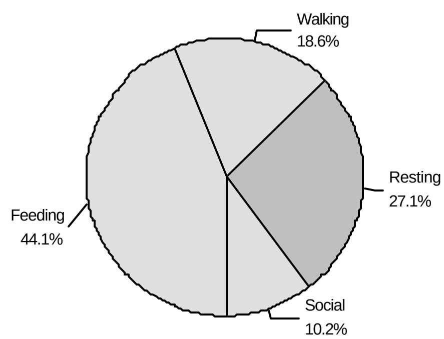


Fig.100. Activity time budget of gaur calf

in Parambikulam WLS in second wet season



5.3.8 Seasonal, age and sex difference in time budget

The χ^2 test on seasonal time budget of different age and sex categories showed that all activities of different age and sex categories differ significantly except in drinking. The χ^2 and *P* values of different activities are given in Table 55.

Table 55. Results of c^2 test on time spent on different activities by different age and category in different season.

Activity	**c^2 value**	***P***
Feeding	134.329	< 0.000
Walking	19.874	< 0.031
Drinking	2.068	0.558
Resting	57.546	< 0.000
Social	40.675	< 0.000
Others	27.799	< 0.001

The χ^2 test on percentage distribution of time spent on a particular activity by different age and sex categories showed that all activities were dependent on age and sex category. The χ^2 values and *P* values of each activity is given in Table 56.

Table. 56. Results of c^2 test on time spent by different age and sex categories for each activity.

Activity	**c^2 value**	***P***
Feeding	2618.708	< 0.000
Walking	333.769	< 0.000
Drinking	13.250	< 0.020
Resting	672.991	< 0.000
Social	200.212	< 0.000
Others	505.352	< 0.000

5.4 Discussion

Survivorship of animal depends on the time allocated to behaviours governing either the animal's probability of avoiding predation or its energy acquisation rate (Caraco, 1979a). Feeding constitutes the major components of all activities in natural populations (Rozin, 1976). Bray (1974) and Pankspepp (1974) have described both physical and physiological control of daily and seasonal feeding. Activity profiles indicate the time budgeting of animals and suggests species resources utilization in relation to its environment.

Majority of wild ungulates are with many phases of daily activity rhythm in which feeding bouts are interspersed with other activities. The present observations in Parambikulam indicate that the daily activity pattern of gaur is of polyphase where feeding is interspersed with resting and walking. Feeding itself showed a bimodal pattern with peaks in the morning and evening. Resting and walking occurred almost throughout in between the feeding bouts but showed a peak during mid hours when social activities were also more. Seasonal differences were evident between the dry and first wet seasons.

The animal spent two third of its time for feeding as evident from the activity time budget and resting and walking was other major components. Significant seasonal differences were also observed in the time spent for feeding. A reduction in feeding time in dry season was mostly compensated by an increased resting time. The first wet season had the highest percentage of time spent on feeding and there were marked reductions in resting and walking. The loglinear analysis for seasonal differences in the activity patterns indicates the influence of feeding activity between 11.00 and 14.00 h and between 14.00 and 15.00 h when the differences in the ambient temperature is maximum. Similar observations were also reported on gaur in undisturbed areas in Mudumalai (Krishnan, 1972) where the animals were actively feeding in the morning and evening. Feeding at times extended up to midnight. But in undisturbed areas gaur turned out crepuscular and nocturnal. In Kanha, Schaller (1967) observed most of the feeding at night and day time was spent for resting.

Cabon-Raczynska *et al*. (1983) reported many phases of daily activity of rhythm in which feeding was interspersed with resting phases. The resting period was prolonged at night. Cabon-Raczynska *et al*. (1987) observed seasonal difference in the diurnal activity of European bison with prolonged resting in hot weather. Similar observations have also been made by Korockina (1972) on European bison and Herrig and Haugen (1970) on American bison.

Time budget mediate relation between the environment, individual requirement and the resulting sociality (Caraco, 1979a). Temperature and food density are important environmental factors influencing activity pattern and time budget. Bligh and Harthoorn (1965) and Vesey-Fitzgerald (1969) observed low grazing and movement in dry season and attributed to the poor ability of buffalo to regulate their body temperature.

The present study conclusively proved the gaur a grazer in Parambikulam. Dry season availability of grass was found to be low and of low palatability due to reasons already discussed. Selection of less fibrous food, switching to browse, or increase ruminating are the options of a ruminant in an environment with low quality food (Beekman and Prins, 1989). Partitioning their time budget for feeding and ruminating would be ideal especially because of the hot climatic conditions. Further, the general tendency of the animal will be to reduce the foraging costs and conserve body energy (Gates and Hudson, 1979). Since resting is closely related to ruminating, the dry season decrease in feeding and increase in resting by gaur in the study area could be considered as the strategy to conserve energy by reducing forage costs.

Advantages of group formation of animals have already been discussed. The mean group size of gaur in Parambikulam was found to vary with season. Group size was observed to be small in dry season with a gradual increase in wet seasons. Feeding has been observed to increase with group size increments (Pulliam, 1973; Powell, 1974). Through time budget relations, survivorship becomes a function of the size of the group. An optimal group size maximize an individual's survivorship through increased feeding and avoidance of predators (Caraco, 1979b). The difference in the activity pattern and time budget between wet seasons could be due to the increased number of calves in the second wet season restricting the movement of the groups. The increased first wet season feeding time thus could be attributed to the high energy requirement of the pregnant females in the population.

Animals of the same size may differ in their requirement as activity rates are related to physiological condition of the animal (Crawley, 1983). Though there were differences in the age-sex categories of gaur in the study area, a pattern emerges in all categories with the highest feeding time in first wet season and lowest in dry season. Synchronisation in activity pattern have been reported in a number of ungulates (Shult, 1972; Gaare *et al.,* 1975; Mitchell, 1977; Leuthold and Leuthold, 1978). Observations in Parambikulam indicate synchronisation in activity only in the feeding in the early morning and late evening, resting during noon hours and walking. The observations agree with those of Cabon-Raczynska *et al.* (1983) on European bison.

Chapter 6

Density distribution and habitat utilisation

6.1 Introduction

Management strategies in a Protected Area must be based on an understanding of the functional relationship between habitat conditions, animal populations and the dynamics of those populations. The importance of determining preferences or avoidance of a given habitat or plant species in terms of its availability has long been recognised (Glading *et al*., 1940; Bellrose and Anderson, 1943; Neu *et al*., 1974). Herbivores are known to favour habitat types or vegetation communities where nutrient intake could be maximised (Westoby, 1974; Owen-Smith and Novellie, 1982; Owen-Smith,1985). Seasonal movements of large herbivores between different habitat types have also been well established (Bell, 1971; McNaughton, 1987).

Mammals especially the gregarious ones often respond to climatic changes and the resultant changes in the habitat by altering herd size and patterns of habitat utilization (McNaughton, 1985). Distribution pattern of large herbivores are reported to be largely influenced by resource availability such as food, shelter and water (Owen-Smith, 1988). In Africa, various ecological parameters and climatic conditions have been found to have high influence on the distribution of large herbivores (Sinclair, 1975 & 1985). Caughley and Goddard (1975) reported aggregation of elephants on the alluvial zone during the rains in response to flush of annual grasses in Luangwa Valley. Elephant distribution in Kalahari sand region was primarily determined by the provision of water supply (Weir, 1971). Krasinska *et al*., (1987) observed changes in the habitat preference of European bison in relation to climatic condition and the resultant food supply. Similar observations on bison reactions have also been made by Jaczewski (1958), Gill (1967) and Krasinski (1978). Larter and Gates (1991) reported a specialised affinity of Wood bison for wet and mesic meadows characterised by key forage species. Krasinski (1978) and Krasinski and Krasinska (1992) mentioned that European bison spent about two thirds of their time in deciduous forests and the rest in open areas.

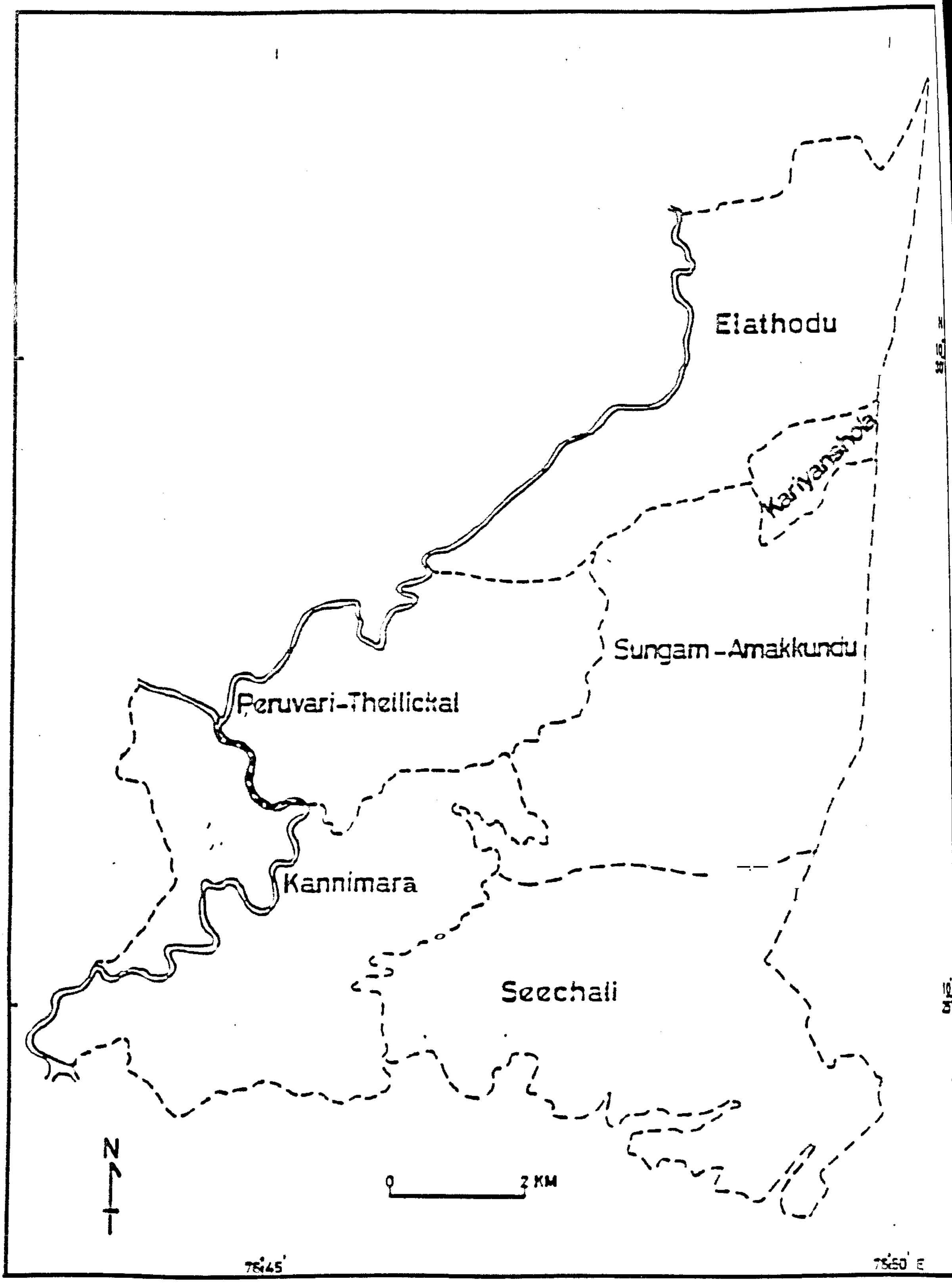
Dinerstein (1979) studying the habitat - animal interaction in Nepal concluded that changes in plant distribution and phenology affected ungulate food habits, energy budget, movement and seasonal distribution. Chital in Bardia, Nepal respond to seasonal changes by shifting the relative time spent in different habitats (Dinerstein, 1987). *Rhinocerus unicornis* reached highest density in areas supporting the greatest habitat diversity (Laurie, 1978). Studies on elephant in South India have shown that density distribution of elephants are highly governed by food and water availability (Sukumar, 1989a & b; Easa, 1989). Foeander (1952) and Kitchener (1961) reported gaur at their highest number in areas formed by aboriginal shifting cultivation. Weigum (1972) and Conry (1981) suggested abundance of grass, forbs and seral browse species in agricultural estates as the most important factors influencing distribution of Malayan gaur in Central Pahang.

Information on seasonal density distribution of gaur has not been reported from any of its ranges in India. The objective of the present study was to collect information on density distribution and habitat use of gaur in relation to season and also to look at the factors responsible for such distribution.

6.2 Methods

The intensive study area was divided in to six zones (Fig. 101) based on natural features such as rivers/streams and vegetation types. Since, a major portion of the study area are of mosaic nature, only evergreen forest which could be clearly demarcated was taken as a separate zone. The zones identified were:

Fig. 101. Map of intensive study area showing different zones



Kariyanshola:- This zone includes the entire evergreen forest patch falling within the Parambikulam Wildlife Sanctuary.

Elathodu:- Areas falling within Padipara, Elathodu and Thekkady are included in this zone. The zone is dominated by moist deciduous forest consisting of *Grewia tiliifolia, Dillenia pentagyna, Emblica officinalis, Tectona grandis, Dalbergia sissoides, Lagerstroemia microcarpa, Terminalia tomentosa, Terminalia bellirica* and *Terminalia paniculata.* The moist deciduous forests have a good under growth dominated by regenerating *Bambusa arundinacea, Desmodium spp., Helicteres isora, Catunaregam spinosa*. The forests bordering Tamil Nadu, in Thekkady is of dry deciduous in nature. A smaller portion of the zone bordering Tamil Nadu has eucalypts plantation. The river Thekkady ar, flowing through the boundary of this zone is perennial though water flow is absent during dry season. The area is unique with a number of grass patches and salt licks.

Seechali:- The foot hills of Vengoli and Shetivara hills, the eastern part of the Thunacadavu and the Seechali areas extending up to the canal leading to tunnel entry are included in this zone. The area is flat on the western side with steep slopes and valleys on the east. The teak plantation of about 50 to 60 year old dominate the zone. The few patches of deciduous forests are confined to Seechali area adjacent to Thunacadavu reservoir. The clear felled and replanted 1981 teak plantation is yet another feature of this zone. Water is available throughout the year because of the Thunacadavu reservoir and the Seechali river. The foot hills of Shetivara and Vengoli and the area all along the reservoir have well grown bamboos. The Seechali marshy area surrounded by bamboos and the small patch of open area near 1981 plantation have natural salt licks.

Sungam:- The zone is dominated by moist deciduous forest with about 70 year old teak plantations confined to the Sungam and Watch tower areas. Moist deciduous forests are distributed in Amakkundu and Anappadi areas. The zone is bordered by the evergreen forest of Kariyanshola on the north and is almost plain with few ups and downs. The under growth of deciduous forest consists of *Zizyphus oenoplia*, *Sida sp*. and *Helicteres isora. Chromolaena odorata*. and *Lantana camara* are also seen almost everywhere in the zone. The zone is characterised by the reservoir of Peruvaripallam and Thunacadavu and also the

waterhole at Amakkundu. A stream flowing through Anappadi has very little water during dry season. Open areas with grass growth and rocky patches are seen in the deciduous forest. The areas all along the tarred road passing through the zone are annually cleared for visibility.

Thellickal:- The areas falling in between Peruvaripallam reservoir and Thekkady ar with the Manjadipallam river in the east are included in this zone. These areas could be broadly called Peruvaripallam - Thellickal area. The zone is dominated by teak plantations of about 35 to 50 years old and moist deciduous patches are confined to the western side in Thellickal and near the reservoir in Peruvaripallam. The terrain is gently undulating. The zone is unique with number of vayals and open grass patches. The Thellickal vayal is surrounded by thick growth of bamboo on almost all sides except the western portion where moist deciduous forests are seen. All the vayals in the zone are dominated by bamboo growth. Water availability during dry season is limited to Thekkady ar while even the waterholes dry up during dry season. The zone has the presence of the largest grass patch on the western side of the river.

Kannimara:- The areas on the west side of the Thunacadavu - Parambikulam road including part of Rock point, Common point and the whole of Pullakal, Kannimara, Kamathala mudi and Thunacadavu are included in the zone. It is almost flat with gently undulating terrain. The zone is dominated by about 50 year old teak plantation interspersed by a number of moist deciduous forest patches and marshy grass lands. Pullakkal vayal (marshy throughout the year) and the Kannimara and Manjadipallam vayals are the major open areas in the zone. The top of Kamathala mudi (a hill in the zone) is of moist deciduous forest. The seepage water of Thunacadavu and Peruvari reservoirs keep the Thunakadavu and Manjadipallam rivers perennial. The Thekkady ar flowing through the Kannimara area is yet another water source.

6.2.1 Habitat and zonal density estimation

Transects of two kilometres length were laid in all the six zones taking care to cover all the major habitats proportionately within the zone. These transects were covered twice in a season with an interval of two months. Attempts to monitor the population with the direct sightings as suggested by Burnham *et al*., (1980) was abandoned after the first attempt due to the low number of sightings. Subsequently, these transects were followed recording the number of dung. The dung sighted from the transects were recorded along with perpendicular distance. The data for two months within the seasons were pooled and analysed using the computer program DISTANCE (Laake *et al*., 1994) for density estimation within the zone and habitat. Density estimates thus developed for zones and seasons were subjected to two way ANOVA to test the seasonal differences between and within the zones. Further, a two way ANOVA was also carried out for habitats and seasons. The analyses were carried out after logarithmic transformation of the dung density.

6.2.2 Food availability

The biomass of food species of gaur, identified through direct observation was measured through clip and weigh method (Wiegert, 1962). A number of quadrats of 1 m x 1 m size for grass and herb and 5 m x 5 m for shrub were laid in different zones and habitats. The details of number of plots laid in each zone and habitat are given in Table

57 and 58 respectively. All the food species were clipped and weighed in the field and sub-samples were oven dried at 60°C constant temperature till the samples reached constant weight. Biomass of each individual species was calculated. Food species were grouped into grass, herb and shrub. The total of these three groups were taken as total food available. Such data were collected for three seasons each during 1994 and 1995. The data were grouped for zones as well as habitat wise biomass.

Table 57. Number of plots laid in different zones in different seasons

Year	1994				1995			
	Season							
Zone	Dry	First wet	Second wet	Total	Dry	First wet	Second wet	Total
Kariyan shola	20	5	5	30	5	5	33	43
Elathodu	10	10	10	30	10	5	5	20
Seechali	18	15	19	52	10	15	14	39
Sungam	19	22	30	71	22	10	45	77
Thellickal	18	28	32	78	23	30	49	102
Kannimara	18	15	25	58	23	36	17	76

Table 58. Number of plots laid in different habitats in different seasons

Year	1994				1995			
	Season							
Habitat	Dry	First wet	Second wet	Total	Dry	First wet	Second wet	Total
Evergreen	30	10	10	50	5	10	33	48
Moist deciduous	37	42	54	133	32	42	80	154
Plantation	33	37	49	119	37	35	58	130
Grassland *(Vayals)*	26	12	13	51	12	24	23	59

The results of biomass estimates for zones were subjected to two way ANOVA for testing the significant effect of zone and season on biomass. ANOVA was also carried out for habitat wise biomass.

6.2.3 Dung density in relation to food availability

The relation between dung density and food availability was worked out by fitting linear regression equation with habitat/zone wise dung density as dependant variable and components of food availability (grass, herb and shrub) as independent variables.

6.2.4 Habitat suitability index (HSI)

The data on grass food species collected through feeding quadrat method (Grobler 1981 & 1983), as described in Chapter 4 was used for estimating HSI. The HSI was calculated as suggested by Novellie and Winkler (1993) as follows

$$HSI = \sum_{i=1}^{k} a_i c_i$$

where, a_i = the acceptability index of species i

$$a_i = \frac{\text{Number of quadrates in which the species was eaten}}{\text{Number of quadrates in which the species was present}}$$

c_i = the percentage aerial cover of species i

k = the number of grass species in the habitat

The mean percentage aerial cover was taken to calculate c_i.

6.3 Results

6.3.1 Density distribution

The dung density estimates for different zones in different seasons in 1994 and 1995 are summarised in Table 59 and 60. The density figures in all zones for all seasons are not very reliable as indicated by the high percentage CV due to the low sample size. However, considering the length of the transect and the sampling effort, these estimates make them comparable.

Table 59. Gaur dung density in different zones in different seasons during 1994

Zone	Sample size	Dung density km^{-2}	%CV
Dry season			
Kariyanshola	2	770.42	70.71
Elathodu	44	1212.00	16.22
Seechali	18	748.17	25.27
Sungam	24	4571.60	48.95
Thellickal	6	115.03	40.82
Kannimara	17	282.96	24.25
First wet season			
Kariyanshola	0	-	-
Elathodu	9	4563.30	66.36
Seechali	3	132.51	57.74
Sungam	23	980.96	36.22
Thellickal	13	265.34	30.26
Kannimara	23	879.88	27.97
Second wet season			
Kariyanshola	3	592.89	57.74
Elathodu	21	1627.50	27.32
Seechali	15	699.63	25.82
Sungam	18	1295.20	30.32
Thellickal	0	0.00	0.00
Kannimara	3	-	-

Fig.102. Zonal dung density of gaur in different season in Parambikulam WLS for 1994

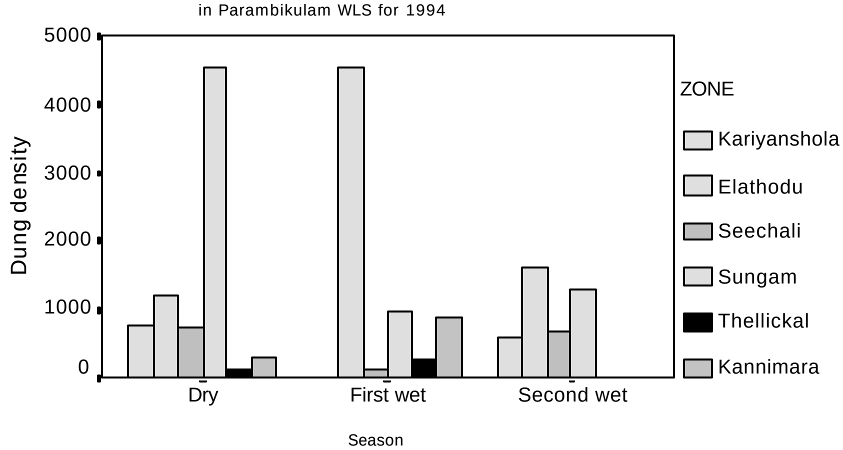
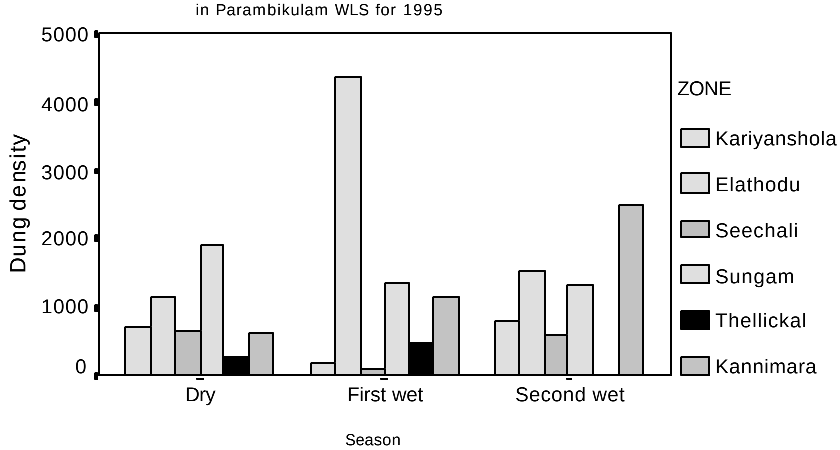


Table 60. Gaur dung density in different zones in different seasons during 1995

Zone	Sample size	Dung density km^{-2}	%CV
Dry season			
Kariyanshola	4	727.27	50.00
Elathodu	43	1155.80	16.31
Seechali	16	636.08	27.13
Sungam	26	1906.30	51.63
Thellickal	14	258.49	26.73
Kannimara	23	620.64	23.43
First wet season			
Kariyanshola	2	181.82	70.71
Elathodu	11	4372.60	64.07
Seechali	3	104.75	57.74
Sungam	25	1346.30	38.73
Thellickal	21	468.25	23.19
Kannimara	29	1152.90	20.92
Second wet season			
Kariyanshola	5	811.69	44.72
Elathodu	21	1543.90	29.46
Seechali	13	580.36	27.74
Sungam	17	1314.50	31.66
Thellickal	0	0.00	0.00
Kannimara	2	2500.00	70.71

Fig.103. Zonal dung density of gaur in different season in Parambikulam WLS for 1995



Sungam and Elathodu areas had higher densities almost throughout the season in both 1994 (Fig. 102) and 1995 (Fig. 103). The Thellickal zone had the lowest throughout. Kariyanshola and Seechali zones showed a conspicuous pattern with medium in dry and second wet seasons and low in first wet season. Kannimara zone had a pattern except in second wet season in 1994 and 1995. The analyses of variance (ANOVA) of dung density data indicated significant effects of zone and season on dung density. There was also a significant interaction between zone and season (Table 61).

Table 61. Influence of season and zone on gaur dung density.

Source of variation	***df***	**Mean square**	***F***	***P***
Season	2	0.731	7.951	< 0.004
Zone	5	3.431	37.305	< 0.001
Season x Zone	9	1.187	12.910	< 0.001
Residual	15	0.092		

6.3.2 Food availability in different zones

Analysis of variance (ANOVA) indicated that zone and season had significant effect on food availability in all the cases except the main effects of zone on shrub availability. Two-way interaction between zone and season in all the cases (total, grass, herb and shrub) turned out to be non- significant (Tables 62, 63, 64 and 65).

Table 62. Influence of zone, season and year on total food availability.

Source of variation	***df***	**Mean square**	***F***	***P***
Zone	5	184.602	5.414	< 0.011
Season	2	258.953	7.594	< 0.010
Year	1	10.061	0.295	0.599
Zone x Season	10	84.496	2.478	0.084
Zone x Year	5	12.003	0.353	0.869
Season x Year	2	125.376	3.677	0.064
Residual	10	34.098		

Table 63. Influence of zone, season and year on grass food availability.

Source of variation	*df*	Mean square	*F*	*P*
Zone	5	165.422	5.582	< 0.010
Season	2	175.368	5.819	< 0.020
Year	1	15.951	0.538	0.480
Zone x Season	10	53.342	1.800	0.184
Zone x Year	5	46.869	1.582	0.251
Season x Year	2	160.857	5.428	< 0.025
Residual	10	29.633		

Table 64. Influence of zone, season and year on herb food availability.

Source of variation	*df*	Mean square	*F*	*P*
Zone	5	52.632	4.181	< 0.026
Season	2	60.559	4.811	< 0.034
Year	1	48.595	3.860	0.078
Zone x Season	10	19.638	1.560	0.247
Zone x Year	5	33.772	2.683	0.086
Season x Year	2	1.051	0.084	0.921
Residual	10	12.589		

Table 65. Influence of zone, season and year on shrub food availability.

Source of variation	*df*	Mean square	*F*	*P*
Zone	5	782.271	2.794	0.078
Season	2	1072.380	3.830	< 0.058
Year	1	419.451	1.498	0.249
Zone x Season	10	589.345	2.105	0.128
Zone x Year	5	186.638	0.667	0.658
Season x Year	2	516.518	1.845	0.208
Residual	10	280.012		

The results of biomass estimation for food species are summarised in Tables 66 to 69. Elathodu zone had almost uniform availability of grass food species throughout the seasons in both the years. This was true of Seechali, Sungam and Kannimara zones also with a reduction in the dry season. Kariyanshola had the lowest throughout except during dry season of 1995. The Thellickal zone though showed a pattern in the first two seasons of 1994 and 1995 recorded low biomass in second wet season of 1995 compared to 1994.

Table 66. Zonal grass food availability in different seasons (gram dry biomass/m^2).

	1994			1995		
	Season					
Zone	**Dry**	**First wet**	**Second wet**	**Dry**	**First wet**	**Second wet**
Kariyan shola	1.884	2.830	8.163	19.377	5.325	5.925
Elathodu	17.070	18.258	16.742	17.070	20.818	14.233
Seechali	9.532	10.790	22.185	10.384	15.124	12.104
Sungam	15.093	25.068	31.280	9.180	18.142	21.356
Thellickal	11.957	27.521	32.027	10.437	27.565	9.941
Kannimara	11.957	16.748	28.679	10.437	38.840	17.563

Sungam had an almost uniform herb availability throughout the season in both the years. However, the first year recorded a comparatively higher biomass. The Seechali area did not follow any particular pattern recording higher biomass in second wet season in first year and in first wet season in second year. Kannimara zone had the highest biomass in the first wet season of 1994 and 1995 but had difference in other seasons. Elathodu followed a pattern with the highest biomass during the first wet season but had a low herb availability in the dry season of 1995. Thellickal zone had highest in first wet season. Kariyanshola with low herb availability throughout the seasons in the both years recorded the highest dry season herb availability in 1995.

Table 67. Zone-wise herb food availability in different seasons (gram dry biomass/m^2).

	1994			1995		
	Season					
Zone	Dry	First wet	Second wet	Dry	First wet	Second wet
Kariyan shola	1.269	0.649	1.239	11.087	1.982	2.114
Elathodu	6.493	13.118	6.585	2.561	12.793	8.875
Seechali	3.184	3.518	6.031	0.913	9.887	7.481
Sungam	19.499	15.494	11.150	6.341	8.779	8.110
Thellickal	5.180	17.465	8.597	1.843	7.727	3.085
Kannimara	3.771	18.151	12.175	5.507	9.302	3.315

Seechali, Sungam, Thellickal and Elathodu followed almost similar pattern in the shrub food availability with highest during first wet seasons. Kannimara zone did not follow any particular pattern and recorded the highest in the second wet season of 1994 and first wet season of 1995. Kariyanshola had the lowest throughout.

Table 68. Zone-wise shrub food availability in different seasons (gram dry biomass/m^2).

	1994			1995		
	Season					
Zone	Dry	First wet	Second wet	Dry	First wet	Second wet
Kariyan shola	0.134	0.264	0.184	0.440	0.405	0.008
Elathodu	24.448	30.911	9.933	12.303	34.484	0.068
Seechali	26.719	17.287	23.851	51.339	13.988	34.670
Sungam	3.787	28.650	12.824	3.602	118.210	1.746
Thellickal	2.008	2.141	1.342	3.523	22.149	3.607
Kannimara	16.621	18.202	22.198	11.962	34.514	1.396

Total food availability estimates indicate that Sungam and Thellickal followed a pattern with the highest biomass in the first wet seasons in both the years. Seechali, Elathodu and Kannimara did not follow any pattern.

Table 69. Zonal total food availability in different seasons (gram dry biomass/m^2).

	1994			1995		
	Season					
Zone	Dry	First wet	Second wet	Dry	First wet	Second wet
Kariyan shola	1.096	1.248	3.195	10.301	2.571	2.682
Elathodu	16.004	20.762	11.087	10.645	22.698	7.725
Seechali	13.145	10.532	17.356	20.879	13.00	18.085
Sungam	12.793	23.071	18.418	6.374	48.377	10.404
Thellickal	6.382	15.709	13.989	5.268	19.147	5.544
Kannimara	10.783	17.700	21.017	9.302	27.552	7.425
Total g/m^2	10.034	14.837	14.177	10.462	22.224	8.644

The multiple linear regression equation (1) fitted using stepwise regression showed that the effect of herb food availability was significant, but could explain only 20% of the variation in dung density between zones.

The critical difference was calculated to make pairwise comparisons between zones. The CD value calculated was 1035.274 at $\propto$ level of 0.05. The dung density of Elathodu zone in first wet season and Sungam zone in dry season significantly differed from other zones. The estimated low dung density of Thellickal during second wet season also differed much from Elathodu, Sungam and Kannimara zones. However, this zone did not significantly differ from Kariyanshola and Seechali zones.

While comparing the seasonal effects within the zones, the Elathodu zone was found to be much preferred during first wet season and Sungam was preferred during dry season. All other zones did not show much difference between seasons.

6.3.3 Habitat use

Dung density estimates for different habitats in different seasons for the year 1994 and 1995 are summarised in Table 70 and 71 respectively. These are represented in Figures 104 and 105 . Grass lands were the most preferred habitat irrespective of season in both the years. However, the first wet season of 1994 showed a high preference for plantation but the high percentage of CV indicate that the results need not be reliable. Moist deciduous forest formed the second preferred habitat. Evergreen was the least preferred considering the low sample size and the resultant high CV for the estimates in such habitats.

Table 70. Seasonal dung density of gaur in different habitat during 1994

Habitat	Sample size	Dung density km^{-2}	% CV
Dry Season			
Evergreen	2	770.42	70.71
Moist deciduous	64	835.95	18.42
Plantation	27	697.02	36.91
Grassland (*Vayal*)	11	3832.10	12.24
First Wet Season			
Evergreen	0	0.00	0.00
Moist deciduous	50	561.44	20.41
Plantation	23	2552.20	60.01
Grassland (*Vayal*)	44	1881.40	17.40
Second Wet Season			
Evergreen	3	592.89	57.74
Moist deciduous	39	1988.70	36.21
Plantation	18	409.54	23.57
Grassland (*Vayal*)	61	3314.20	22.39

Fig.104. Seasonal dung density of gaur in different habitats

in Parmbikulam WLS for 1994

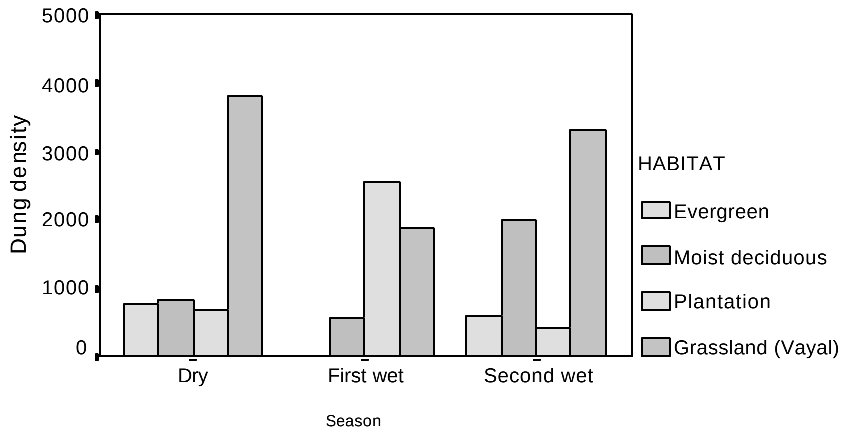
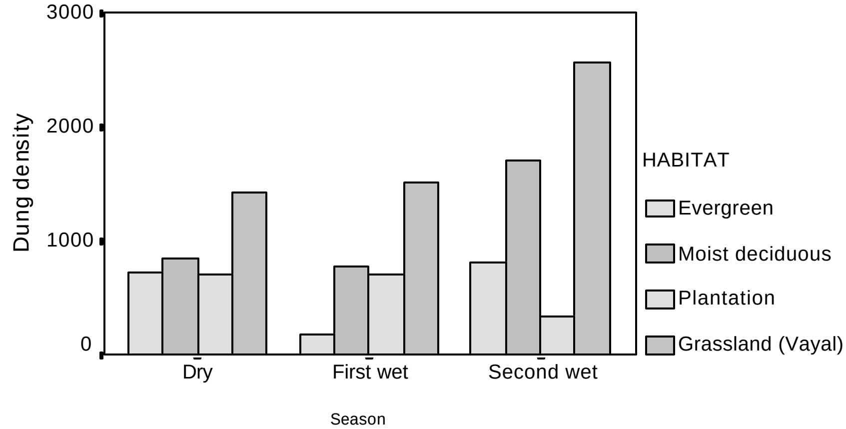


Table 71. Seasonal dung density of gaur in different habitat during 1995

Habitat	Sample size	Dung density km $^{-2}$	% CV
Dry Season			
Evergreen	4	727.27	50.00
Moist deciduous	64	835.95	18.42
Plantation	27	697.02	36.91
Grassland (*Vayal*)	41	1428.60	20.78
First Wet Season			
Evergreen	2	181.82	70.71
Moist deciduous	65	770.97	18.59
Plantation	27	697.02	36.91
Grassland (*Vayal*)	43	1523.20	20.12
Second Wet Season			
Evergreen	5	811.69	44.72
Moist deciduous	38	1701.70	29.56
Plantation	15	326.66	25.82
Grassland (*Vayal*)	59	2563.30	21.34

Fig.105. Seasonal dung density of gaur in different habitats

in Parmbikulam WLS for 1995



Results of ANOVA for habitat wise dung density also indicated significant influence of habitat type on dung density (Table. 72). The season and habitat two way interaction turned out to be non significant indicating preference of the animals towards a particular habitat type.

Table 72. Influence of habitat and season on gaur during density.

Source of variation	***df***	**Mean square**	***F***	***P***
Season	2	0.082	0.592	0.570
Habitat	3	2.251	16.253	< 0.000
Season x Habitat	6	0.720	5.196	< 0.009
Residual	11	0.138		

6.3.4 Food availability in different habitat

Habitat wise food availability of grass, herb and shrub in different seasons is given in Tables 73, 74 and 75 respectively. Grass evidently was dominating in grasslands followed by moist deciduous forests except during dry and wet season of 1995. Herb food availability did not follow any pattern and varied between seasons and years in different habitats. Shrub availability was high in moist deciduous forests irrespective of season and year. Grassland dominated in total food availability except for a minor difference in dry season of 1994 (Table. 76). This was followed by moist deciduous forests.

Table 73. Habitat-wise grass food availability in different seasons (gram dry biomass/m^2)

	1994			1995		
Habitat	**Season**					
	Dry	**First wet**	**Second wet**	**Dry**	**First wet**	**Second wet**
Evergreen	1.904	3.053	9.431	19.377	7.606	5.925
Moist deciduous	20.381	22.789	28.834	7.149	21.042	18.539
Plantation	4.725	14.037	21.331	5.723	21.940	11.116
Grassland	41.545	91.579	120.007	63.368	72.296	64.827

Table 74. Habitat-wise herb food availability in different seasons (gram dry biomass/m^2)

	1994			1995		
Habitat	**Season**					
	Dry	**First wet**	**Second wet**	**Dry**	**First wet**	**Second wet**
Evergreen	1.152	1.181	2.800	11.087	2.114	0.188
Moist deciduous	13.428	13.598	8.170	5.868	5.621	1.381
Plantation	4.137	10.928	11.037	3.013	5.146	1.723
Grassland	2.544	31.158	12.773	5.660	35.410	2.544

Table 75. Habitat-wise shrub food availability in different seasons (gram dry biomass/m^2)

	1994			1995		
Habitat	**Season**					
	Dry	**First wet**	**Second wet**	**Dry**	**First wet**	**Second wet**
Evergreen	0.136	0.170	0.170	0.440	0.297	0.008
Moist deciduous	17.832	29.100	18.755	21.648	73.808	5.985
Plantation	12.77	8.087	10.643	7.659	10.506	5.122
Grassland	0.048	1.693	0.002	1.429	0.177	0.639

Table 76. Habitat-wise total food availability in different seasons (gram dry biomass/m^2)

	1994			1995		
Habitat	Season					
	Dry	First wet	Second wet	Dry	First wet	Second wet
Evergreen	1.064	1.468	4.134	10.301	3.408	2.632
Moist deciduous	17.214	21.829	18.586	11.555	35.435	10.048
Plantation	7.213	11.017	14.337	5.465	13.748	7.128
Grassland	14.812	41.477	44.261	23.486	25.983	33.625
Total g/m^2	10.076	18.948	20.330	12.702	19.644	13.371

Two way ANOVA indicated significant effects of habitat type on food availability except in the case of herb (Tables. 77, 78, 79 and 80). The two way interaction in all the cases (total, grass, herb and shrub availability) were not significant indicating that within habitat difference did not follow a pattern.

Table 77. Influence of habitat, season and year on total food availability.

Source of variation	*df*	Mean square	*F*	*P*
Habitat	3	817.940	18.861	< 0.002
Season	2	131.104	3.203	0.124
Year	1	8.816	0.203	0.668
Habitat x Season	6	80.154	1.848	0.239
Habitat x Year	3	21.414	0.494	0.700
Season x Year	2	51.392	1.185	0.368
Residual	6	43.368		

Table 78. Influence of habitat, season and year on grass food availability.

Source of variation	*df*	Mean square	*F*	*P*
Habitat	3	5917.328	36.361	< 0.000
Season	2	460.094	2.827	0.136
Year	1	155.082	0.953	0.367
Habitat x Season	6	185.807	1.142	0.438
Habitat x Year	3	158.647	0.975	0.464
Season x Year	2	366.817	2.236	0.188
Residual	6	162.737		

Table 79. Influence of habitat, season and year on herb food availability.

Source of variation	*df*	Mean square	*F*	*P*
Habitat	3	153.952	1.795	0.248
Season	2	57.472	0.670	0.546
Year	1	4.982	0.058	0.818
Habitat x Season	6	67.359	0.786	0.612
Habitat x Year	3	17.320	0.202	0.891
Season x Year	2	61.997	0.723	0.523
Residual	6	85.750		

Table 80. Influence of habitat, season and year on shrub food availability.

Source of variation	*df*	Mean square	*F*	*P*
Habitat	3	1003.024	9.558	< 0.011
Season	2	230.470	2.196	0.192
Year	1	33.382	0.318	0.593
Habitat x Season	6	211.689	2.017	0.207
Habitat x Year	3	63.664	0.607	0.635
Season x Year	2	133.904	1.276	0.345
Residual	6	104.946		

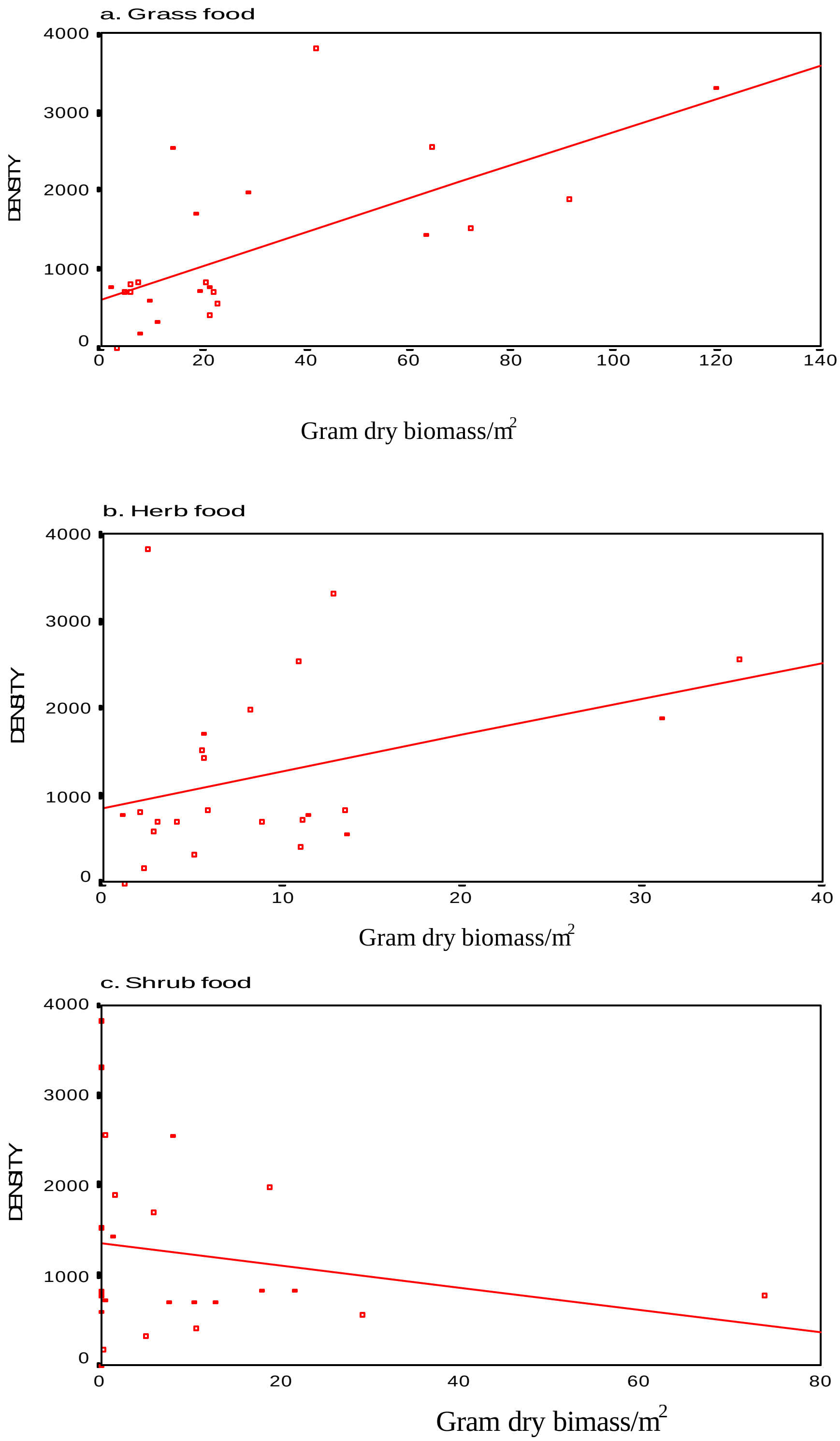
6.3.5 Dung density in relation to food availability

Multiple regression analyses showed that the relation between dung density in different habitat types and availability of individual food items (grass, herb and shrub) taken separately was significant (Figs. 106a,b,c). The multiple regression equation fitted using stepwise regression was as follows

y (dung density) = 617.0702+21.3091(Grass)

(216.64) (5.14) Adj.R^2 = 0.43764

Fig. 106. Scatter plots with regression line for dung density against food items



6.3.6 Habitat suitability index (HSI)

Habitat suitability indices for annual and different seasons are given in Table 81. Grasslands have the highest index values throughout except in second wet season indicating maximum suitability of this habitat for gaur in Parambikulam Wildlife Sanctuary. Though the second wet season index was higher for riverine habitat, overall suitability index of grassland habitat (77.17) confirms the importance of grasslands for gaur.

Table 81. Habitat suitability index for different habitat types in different seasons.

Habitat	Annual	Dry season	First wet season	Second wet season
Evergreen	26.00	26.00	0.00	0.00
Moist deciduous	49.07	42.41	53.73	57.84
Plantation	43.26	41.37	46.53	42.11
Grassland	77.17	73.50	86.06	75.84
Riverine	73.38	62.20	0.00	78.45

6.4 Discussion

Wild ungulates often ranged over wide geographical areas, moving seasonally in response to their temporal abundance and quality of forages in different portions of their total range (McNaughton, 1987). At the regional level, animals select landscape through migrations, home range placement, or nomadism at behavioural frequencies of a few times a year. This enables the animals to attain the presumed goal of fitness maximisation by maintaining intake and avoiding environmental stresses. Climate, soils, proximity to water or salt licks and physical barriers to movement can regulate such decisions. Within landscapes, animals select plant communities, or large vegetation patches at a frequency of many times a year to optimise foraging efficiency due to food quantity and quality. Selection of feeding sites within plant communities in turn depends on the forage density, quality and availability.

Gaur in Parambikulam was found to use grasslands at a higher rate compared to other habitats as evident from the density distribution. Studies on food plants have confirmed the important contribution of grass to the diet of gaur in the area (Refer chapter 4). Quantity of grass food species were also found to be higher in grasslands. Further, the statistical test confirmed the influence of grass on density distribution in different habitats. Moist deciduous forests, the habitat preferred next to grasslands had the higher number of principal food and also a comparatively higher grass availability. The studies on food habits have also shown the higher percentage of preferred food species in grasslands and moist deciduous forests.

Schaller (1967) observed seasonal difference in habitat use by gaur in Kanha and correlated with food and water. Brander (1923) has also recorded similar observations. Krishnan (1972) observed seasonal movements in Mudumalai at the onset of rains and gaur confined themselves to the swampy grass areas in summer. Conry (1989) has observed the utilization of secondary forests in Malaysia at a higher rate. Seasonal differences in habitat use due to food availability has also been reported in Bison (Gill, 1967; Van Waggoner and Hinkes, 1986; Krasinski and Krasinska, 1992). Borowski and Kossak (1972) and Krasinski (1978) reported preference of mixed deciduous and deciduous forests by European bison. Krasinska *et al.* (1987) observed food availability related seasonal difference in habitat use of European bison. Meadows are of greater importance to American bison living in the wooded area of Elk Island National Park (Shackleton, 1968), Wide Cave National Park (Shult, 1972) and Wood Buffalo National park (Fuller, 1960). Duncan (1975) reported consistent seasonal pattern of habitat use by Topi and related the pattern to plant community distinguished by plant structure avoiding mature and flowered grasses. Owen-Smith (1979) observed compensation of habitat and seasonal difference in forage abundance by seasonal habitat selection by Greater Kudu.

Watson and Moss (1970) have given examples to show that the dispersion of many animals are related to their food supply and have speculated several possibilities for such dispersions. Nair and Jayson (1988) have reported extensive use of natural forests and plantations in the area. However, the study was confined to small area (Anappady) and was not extensive especially since this was not representative of Parambikulam Wildlife Sanctuary.

Density distribution of gaur in different zones was significant in relation to seasons. Elathodu and Sungam had a higher density almost throughout the year except for a minor difference in second wet season. The quantity of food available also showed significant seasonal difference in different zones. However, density distribution in different zones was found to be not influenced by food availability.

The higher density zones Sungam and Elathodu are characterised by the dominant vegetation of moist deciduous forests interspersed with a number of grassland patches. These areas have also a number of salt licks and year round water availability within or adjacent areas.

Tropical and subtropical soils are often deficient in a wide variety of mineral elements varying from locality to locality (McDowell, 1985). Physical attributes of vegetation are also shown to affect habitat use (Jarman and Sinclair, 1979). The animals show high selectivity of habitat and forage species in different seasons (McNaughton and Georgiadis, 1986). Feeding habit and group composition, and the year round higher utilization rate of grasslands followed by moist deciduous forests by gaur in Parambikulam indicate the crucial role played by these habitats in maintaining the population in the area. The seasonal preference of zones with moist deciduous forests interspersed with grasslands also confirms this observation.

Chapter 7
Effect of fire

7.1 Introduction

The effect of fire on forest eco-systems have been reviewed and intensively studied in many parts of the world (Trapnell, 1959; West, 1965; Daubenmire, 1968; Kozlowski and Ahlgren, 1974; Rodgers, 1979; Ovington, 1984; Booysen and Tainton, 1984; Rodgers *et. al*, 1986). However, works on such aspect in the Indian condition are comparatively few.

Hot fires late in the dry season were more damaging than the early cooler fires in Serengetti's Northern wood lands. Damage to edge regeneration, fire penetration and internal damage on bush thickets were significantly higher during late burnt compared to early burnt in evergreen/semi evergreen bush thickets in Serengetti. Heavy burning have favoured the spread of nutritious grasses at the expense of coarser species in Northern part of Serengetti. Burning thus have lead directly and indirectly to an increase in primary production (Hulbert, 1969; Hadley, 1970). Norton-Griffiths (1979) considers the inhibition of or even complete suppression of tree recruitement as the most important influence of fire. Norton – Griffiths (1979) consider that fire along with other disruptive forces would help to maintain a mossaic of communities of peak diversity and productivity. According to him, prevention of these forces could be highly detrimental to these eco-systems.

Production of grasses may be higher in burnt plots because of higher nutrient available from ash (Coutinho, 1982). But studeis have also showed that direct contribution of ash to soil fertility is negligible and increased production in burnt areas as jointly caused by increased mineralisation from higher soil temperature (Hulbert, 1988). It has also been shown that burning some times has only negligible effect on some grasses (Coutinho, 1982) or always reduces production in others (Kucera, 1981). Soil organic matter transformations often increase as a result of high soil temperature, with oxidation of nitrification inhibitors and increased cation availability (Johns 1985). The resulting increase in soil nitrate and ammonium concentration stimulates plant growth (Wright and Bailey, 1982). The C_4 carbon pathway grasses, typical of the tropics have greater nitrogen fixing abilities and are often favoured by fire (Neyra and Dobereiner, 1978).

Rodgers (1986) doesn't consider fire, though mostly caused by man as unnatural. The presence of fire tolerant trees in the deciduous forests is mentioned as an evidence for long term exposures to fire and consequent selection of characters for such trees. According to Leshmik and Sontheimer (1975), pastorists inhabiting in India have traditionally burnt forest lands to improve the short term grazing value. Tribal people with hunting and covering cultures and shifting cultivators are reported to use fire to facilitate hunting, honey collection, travel, etc. (Lal, 1974; Sopher, 1980; Ramakrishnan, 1985).

Rodgers *et al.* (1986) didn't observe any change in the tree layer parameters and shrub densities in burnt and unburnt plots. However, there were structural as well as compositional changes in the shrub and ground layer species. The increased number of species in the burnt plots were mostly due to opportunistic weeds.

In South Asia, burning leads to improved habitat condition for grazing wild cattle, flowered plain system (Wharton 1968). Deshmukh (1985) consider fire impact as one of gains and losses.

7.2 Method

Effect of fire on vegetation was studied by establishing permanent experimental plots in different habitat types. Three habitat types viz. moist deciduous, plantation and grassland were selected in different locations. Burning was carried out in the month of April for dry season and in the months between December and January representing cold season. Two 100m X 50m size plots were burnt in each habitat type in April, 1994 and three 100m X 50m plots each were burnt in plantation and moist deciduous habitat types in December, 1994. Attempts to conduct the experiments in grassland during cold season did not succeed due to the wet nature of these marshy areas.

The experiments were conducted in the Thellickal Valiya Vayal and Kothala Vayal for grassland habitat type in dry season. Thellickal and Sungam Watch Tower area were selected for experiments in plantation. Moist deciduous forests in Thellickal and Anappady were also selected. For cold burning, plantations in Sungam, Thunacadavu IB, and Kannimara were selected. Moist deciduous forests in Anappady, Rockpoint and Thellickal were burnt during cold season.

Burning were done through slash burning method. All the plants within demarcated plot were slash cut and left for two days to dry up and burning was done during late evening hours after 7 pm.

Quadrats of 1 m^2 (for grass and herb) and 25 m^2 (for shrub) were laid at every 25 m point of a line within the experimental plot of 100 X 50 m. Plant species within the selected quadrats were identified and the biomass estimated through Clip and Weigh method. Data were collected before burning and the consecutive seasons (five seasons for summer burn and two seasons for cold burn) after burning. Care was taken to avoid the quadrats selected for previous seasons while estimating biomass and identifying plant species. Quadrats were also laid in the adjacent unburnt areas as control. The samples collected from quadrats were segregated and weighed in the field. These were later brought to the laboratory and oven dried at 60° constant temperature. Further dry weight of the plants was measured and the values are expressed in gm. dry biomass/m^2.

7.3 Results

7.3.1 Summer burn

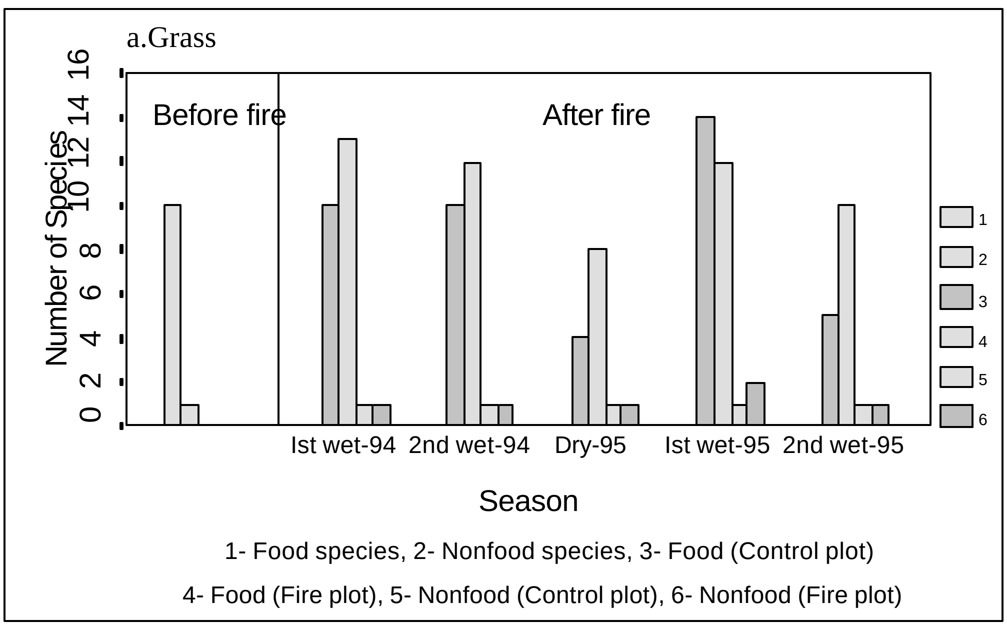
7.3.1.1 Moist deciduous

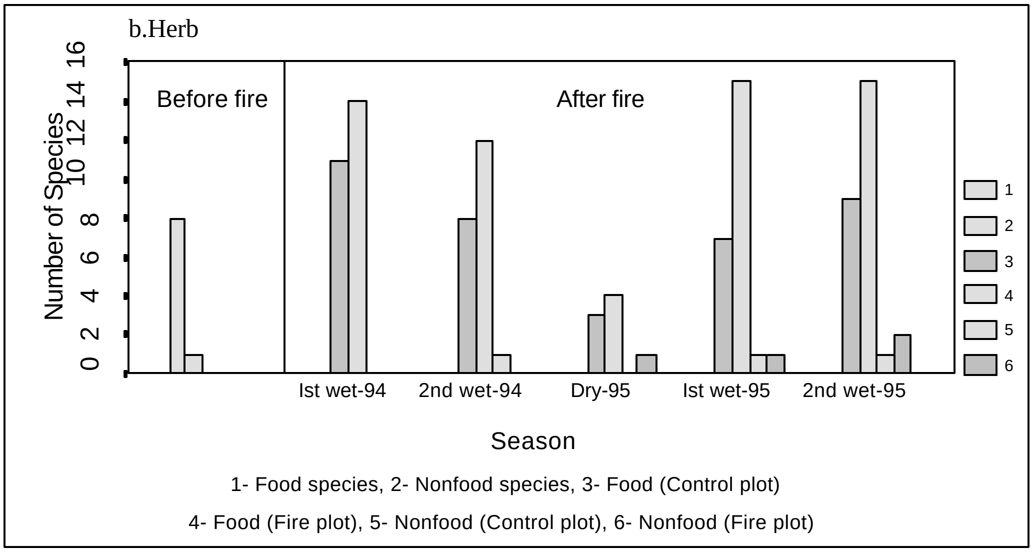
Grass

An increase in number of grass food species was observed compared to control, in all the seasons after burning except first wet season of 1995. However, there was no considerable variation in the number of non-food species (Fig. 107a).

Dry biomass of food and non-food grass species of gaur in moist deciduous forest showed an increase in the consecutive four seasons after burn compared to control.

Figure. 107. Number of plant species in moist deciduous habitat type - before and after fire (Summer burn) treatment




b.Herb
Number of Species
0 2 4 6 8 10 12 14 16
Before fire
After fire
Ist wet-94
2nd wet-94
Dry-95
Ist wet-95
2nd wet-95
Season
1
2
3
4
5
6
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire plot)

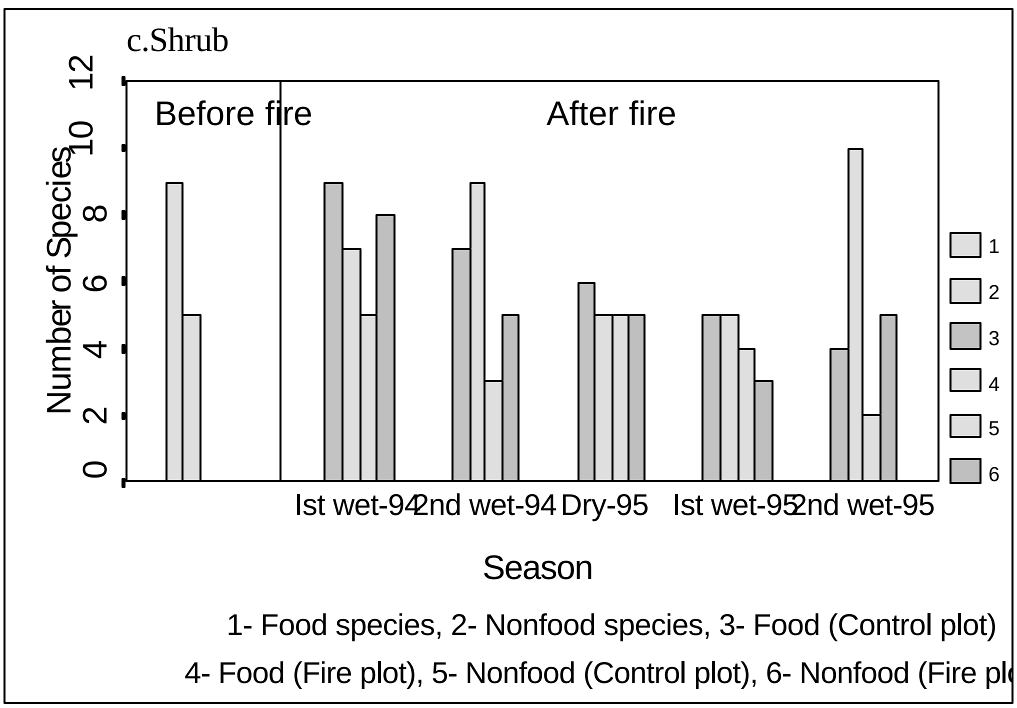
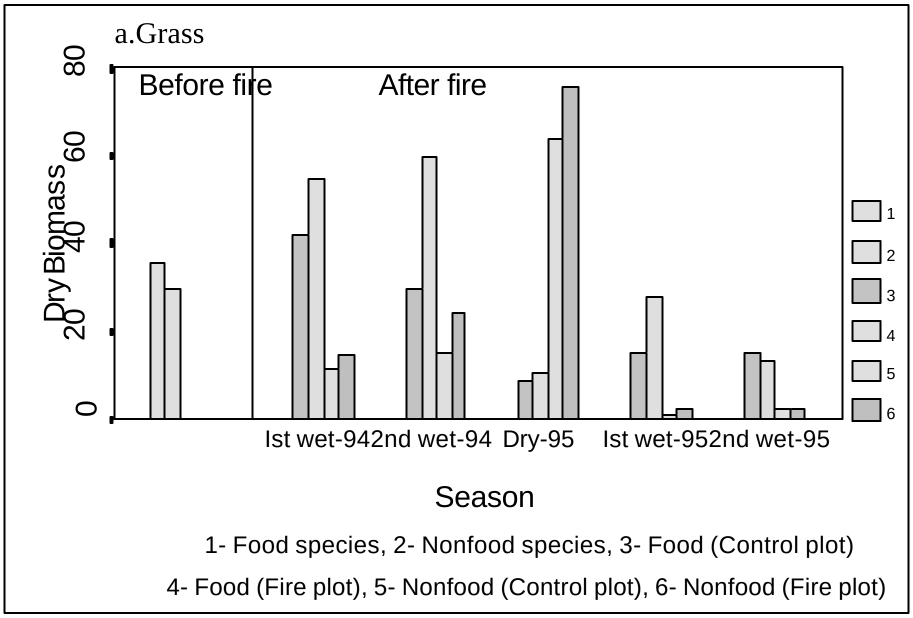
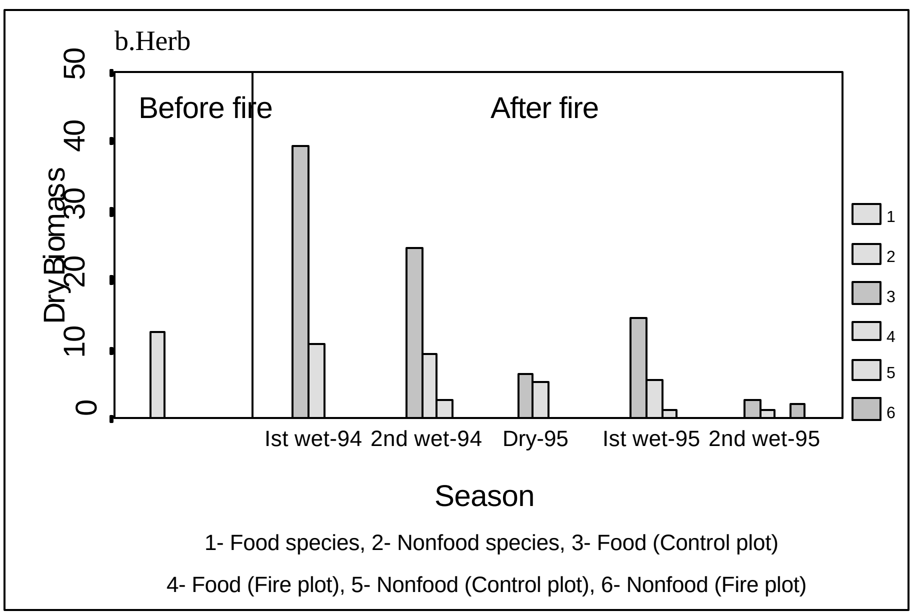
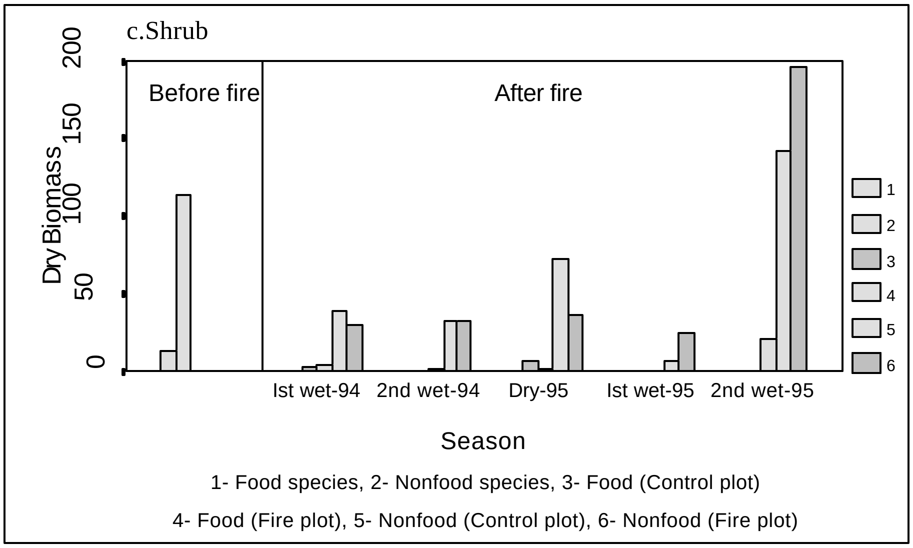

c.Shrub
Number of Species
0 2 4 6 8 10 12
Before fire
After fire
Ist wet-94
2nd wet-94
Dry-95
Ist wet-95
2nd wet-95
Season
1
2
3
4
5
6
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire pl

Figure. 108. Aboveground plant biomass (gram dry weight/m^2) in moist deciduous habitat type - before and after fire (Summer burn) treatment.







The dry biomass of grass food species in second wet season of 1995 was comparatively less (Fig. 108a). The dry biomass of food species was higher than non-food species in all the seasons except in dry, 1995. The figure clearly indicates that the proportion of food species in the plots increased compared to the proportion before burning.

The changes in grass species composition in the plots before fire, control and after fire in different seasons are given in Tables 82 to 86.

Table 82. Grass species composition in moist deciduous during first wet 1994
(Summer burn)

Before burn	Control	After burn
Brachiaria ramosa	*Brachiaria ramosa*	*Brachiaria ramosa*
Digitaria bicornis	*Commelina benghalensis*	*Commelina benghalensis*
Digitaria setigera	*Cynodon dactylon*	*Cynodon dactylon*
Eleusine indica	*Cyperus distans*	*Digitaria ciliaris*
Eragrostis unioloides	*Kyllinga monocephala*	*Digitaria setigera*
Kyllinga monocephala	*Leersia hexandra*	*Kyllinga monocephala*
Mariscus pictus	*Mariscus pictus*	*Leersia hexandra*
Oplismenus compositus	*Oryza rufipogon*	*Mariscus pictus*
Paspalidium flavidum	*Panicum notatum*	*Oplismenus compositus*
Themeda triandra	*Paspalidium flavidum*	*Oryza rufipogon*
		Panicum notatum
		Paspalidium flavidum

Table 83. Grass species composition in moist deciduous during second wet 1994
(Summer burn)

Control	After burn
Brachiaria ramosa	*Brachiaria ramosa*
Commelina benghalensis	*Commelina benghalensis*
Cynodon dactylon	*Cynodon dactylon*
Digitaria setigera	*Digitaria ciliaris*
Kyllinga monocephala	*Digitaria setigera*
Mariscus pictus	*Kyllinga monocephala*
Oplismenus compositus	*Leersia hexandra*
Oryza rufipogon	*Mariscus pictus*
Panicum notatum	*Oplismenus compositus*
Paspalidium flavidum	*Oryza rufipogon*
	Panicum notatum
	Paspalidium flavidum

Table 84. Grass species composition in moist deciduous during dry 1995
(Summer burn)

Control	After burn
Brachiaria ramosa	*Brachiaria ramosa*
Digitaria setigera	*Cynodon dactylon*
Kyllinga monocephala	*Digitaria ciliaris*
Oplismenus compositus	*Digitaria setigera*
	Kyllinga monocephala
	Mariscus pictus
	Oplismenus compositus
	Oryza rufipogon

Table 85. Grass species composition in moist deciduous during first wet 1995
(Summer burn)

Control	After burn
Brachiaria ramosa	*Brachiaria ramosa*
Cynodon dactylon	*Cynodon dactylon*
Cyperus kurzii	*Cyrtococcum decurrens*
Cyrtococcum decurrens	*Digitaria ciliaris*
Dactyloctenium aegyptium	*Digitaria setigera*
Digitaria ciliaris	*Eleusine indica*
Digitaria setigera	*Fimbristylis annua*
Eleusine indica	*Ischaemum indicum*
Kyllinga monocephala	*Kyllinga monocephala*
Mariscus pictus	*Oplismenus compositus*
Oplismenus compositus	*Ottochloa nodosa*
Ottochloa nodosa	*Paspalidium flavidum*
Panicum notatum	*Themeda triandra*
Paspalidium flavidum	

Table 86. Grass species composition in moist deciduous during second wet 1995
(Summer burn)

Control	After burn
Brachiaria ramosa	*Brachiaria ramosa*
Cyrtococcum decurrens	*Digitaria ciliaris*
Digitaria setigera	*Digitaria griffithii*
Mariscus pictus	*Digitaria setigera*
Oplismenus compositus	*Kyllinga monocephala*
	Mariscus pictus
	Oplismenus compositus
	Ottochloa nodosa
	Panicum psilopodium
	Paspalidium flavidum

Herb

A comparison with control indicates an increase in the number of herb food species in all the seasons after fire (Fig. 107b). However, dry biomass of herb food and non-food species showed decreasing trend after fire (Fig. 108b).

Changes in herb species composition within the plots before fire, control and after fire in different seasons are given in Tables 87 to 91.

Table 87. Herb species composition in moist deciduous during first wet 1994
(Summer burn)

Before burn	Control	After burn
Achyranthes aspera	*Acalypha racemosa*	*Ageratum conyzoides*
Micranthus oppositifolius	*Alternanthera pungens*	*Alternanthera pungens*
Mimosa pudica	*Centrosema pubescens*	*Centrosema pubescens*
Sida cordata	*Curculigo orchioides*	*Curculigo orchioides*
	Globba marantina	*Eclipta prostrata*
	Justicia trinervia	*Globba marantina*
	Micranthus oppositifolius	*Hemidesmus indicus*
	Mimosa pudica	*Hibiscus lobatus*
	Mitracarpus verticillatus	*Justicia trinervia*
	Phyllanthus urinaria	*Micranthus oppositifolius*
	Synedrella nodiflora	*Mimosa pudica*
		Mitracarpus verticilatus
		Phyllanthus urinaria
		Synedrella nodiflora

Table 88. Herb species composition in moist deciduous during second wet 1994
(Summer burn)

Control	After burn
Achyranthes aspera	*Achyranthes aspera*
Alternanthera pungens	*Ageratum conyzoides*
Centrosema pubescens	*Alternanthera pungens*
Globba ophioglossa	*Centrosema pubescens*
Hemidesmus indicus	*Curculigo orchioides*
Justicia trinervia	*Hemidesmus indicus*
Micranthus oppositifolius	*Hibiscus lobatus*
Mimosa pudica	*Justicia trinervia*
Synedrella nodiflora	*Micranthus oppositifolius*
	Mimosa pudica
	Phyllanthus urinaria
	Synedrella nodiflora

Table 89. Herb species composition in moist deciduous during dry 1995
(Summer burn)

Control	After burn
Justicia trinervia	*Alternanthera pungens*
Micranthus oppositifolius	*Alysicarpus monilifer*
Mimosa pudica	*Centrosema pubescens*
	Mimosa pudica
	Ocimum gratissimum

Table 90. Herb species composition in moist deciduous during first wet 1995
(Summer burn)

Control	After burn
Centrosema pubescens	*Acalypha racemosa*
Curculigo orchioides	*Ageratum conyzoides*
Globba ophioglossa	*Alternanthera pungens*
Hemidesmus indicus	*Barleria courtallica*
Micranthus oppositifolius	*Centrosema pubescens*
Mimosa pudica	*Curculigo orchioides*
Peperomia pellucida	*Globba marantina*
Synedrella nodiflora	*Hemidesmus indicus*
	Hibiscus lobatus
	Ichnocarpus frutescens
	Ludwigia hyssopifolia
	Micranthus oppositifolius
	Mimosa pudica
	Peperomia pellucida
	Sida acuta
	Sida beddomei

Table 91. Herb species composition in moist deciduous during second wet 1995
(Summer burn)

Control	After burn
Achyranthes aspera	*Achyranthes aspera*
Ageratum conyzoides	*Ageratum conyzoides*
Asparagus	*Alternanthera pungens*
Centrosema pubescens	*Cardiospermum helicacabum*
Dipteracanthus prostrata	*Centrosema pubescens*
Justicia trinervia	*Curculigo orchioides*
Micranthus oppositifolius	*Desmodium heterophyllum*
Mimosa pudica	*Dipterocanthus prostrata*
Rungia sp.	*Elephantopus scaber*
Sida beddomei	*Globba ophioglossa*
	Hibiscus lobatus
	Justicia trinervia
	Merremia umbullata
	Micranthus oppositifolius
	Mimosa pudica
	Sida beddomei
	Synedrella nodiflora

Shrub

Figure 107c does not show considerable variation in the number of food species except in the second wet season of 1995. The number of non-food shrub species increased considerably except in dry and first wet seasons of 1995. However, dry biomass of shrub non-food species gradually increased after fire from 30.45g/m^2 to 196.38g/m^2. This increase was rapid compared to dry biomass of shrub food species (Fig. 108c).

The changes in shrub species composition within the plots before fire, control and after fire in different seasons are given in Tables 92 to 96.

Table 92. Shrub species composition in moist deciduous during first wet 1994
(Summer burn)

Before burn	Control	After burn
Bambusa arundinacea	*Abutilon sp.*	*Abutilon sp.*
Cassia occidentalis	*Asclepias curassavica*	*Asclepias cruassavica*
Desmodium laxiflorum	*Cassia occidentalis*	*Cassia occidentalis*

Continued..

Eupatorium odoratum	*Desmodium gangeticum*	*Crotalaria striata*
Helicteres isora	*Desmodium laxiflorum*	*Desmodium gangeticum*
Jatropha tanjorensis	*Eupatorium odoratum*	*Desmodium laxiflorum*
Lantana camara	*Hibiscus lobatus*	*Eupatorium odoratum*
Pogostemon paniculatus	*Lantana camera*	*Lantana camera*
Pseudarthria viscida	*Pogostemon paniculatus*	*Naringi crenulata*
Randia dumatorum	*Pseudarthria viscida*	*Pogostemon paniculatus*
Sida mysorensis	*Randia dumatorum*	*Pseudarthria viscida*
Urena lobata	*Sida rhombifolia*	*Randia dumatorum*
Ziziphus oenoplia	*Triumfetta rhomboidea*	*Sida rhombifolia*
Ziziphus xylopyrus	*Ziziphus oenoplia*	*Triumfetta rhomboidea*
		Ziziphus oenoplia

Table 93. Shrub species composition in moist deciduous during second wet 1994
(Summer burn)

Control	After burn
Desmodium laxiflorum	*Cassia occidentalis*
Eupatorium odoratum	*Crotalaria striata*
Helicteres isora	*Desmodium gangeticum*
Lantana camera	*Desmodium laxiflorum*
Pogostimon paniculatus	*Eupatorium odoratum*
Randia dumatorum	*Hibiscus furcatus*
Sida rhombifolia	*Lantana camara*
Triumfetta rhomboidea	*Pogostemon paniculatus*
Urena lobata	*Pseudarthria viscida*
Ziziphus oenoplia	*Randia dumatorum*
	Sida rhombifolia
	Triumfetta rhomboidea
	Urena lobata
	Ziziphus oenoplia

Table 94. Shrub species composition in moist deciduous during dry 1995
(Summer burn)

Control	After burn
Abutilon sp.	*Abutilon sp.*
Bambusa arundinacea	*Cassia occidentalis*
Cassia occidentalis	*Eupatorium odoratum*
Eupatorium odoratum	*Jatropha tanjorensis*
Helicteres isora	*Lantana camara*
Jatropha tanjorensis	*Randia dumatorum*
Lantana camara	*Sida mysorensis*
Randia dumatorum	*Sida rhombifolia*
Sida mysorensis	*Solanum torvum*
Solanum torvum	*Ziziphus oenoplia*
Ziziphus oenoplia	

Table 95. Shrub species composition in moist deciduous during first wet 1995
(Summer burn)

Control	After burn
Barleria courtallica	*Achyranthes aspera*
Crotalaria striata	*Cassia occidentalis*
Cassia occidentalis	*Eupatorium odoratum*
Eupatorium odoratum	*Randia dumatorum*
Randia dumatorum	*Sida mysorensis*
Sida mysorensis	*Sida rhombifolia*
Sida rhombifolia	*Ziziphus oenoplia*
Triumfetta rhomboidea	*Ziziphus xylopyrus*
Ziziphus oenoplia	

Table 96. Shrub species composition in moist deciduous during second wet 1995
(Summer burn)

Control	After burn
Eupatorium odoratum	*Abutilon sp.*
Pseudarthria viscida	*Bambusa arundinacea*
Randia dumatorum	*Crotalaria striata*
Sida rhombifolia	*Desmodium gangeticum*
Triumfetta rhomboidea	*Desmodium laxiflorum*
Ziziphus xylopyrus	*Eupatorium odoratum*
	Helicteres isora
	Hibiscus lobatus
	Lantana camara
	Ocimum greatissimum
	Pseudarthria viscida
	Randia dumatorum
	Sida rhombifolia
	Triumfetta rhomboidea
	Ziziphus oenoplia

7.3.1.2 Plantation

Grass

No considerable variation in the number of grass non-food species was observed during consecutive seasons after burning. But there was slight variation in the number from dry season, 1995 onwards (Fig. 109a). The number of grass food species was lower in the fire plot than control during first wet, 1994 reaching equal number in second wet, 1994 and thereafter number of grass food species increased in fire plot.

The dry biomass of food and non-food grass species in control plot was higher than the burnt plot in all the seasons except in second wet season, 1995 where there was a slight increase in the burnt plot (Fig. 110a).

The changes in grass species composition within the plots before fire, control and after fire in different seasons are given in Tables 97 to 101.

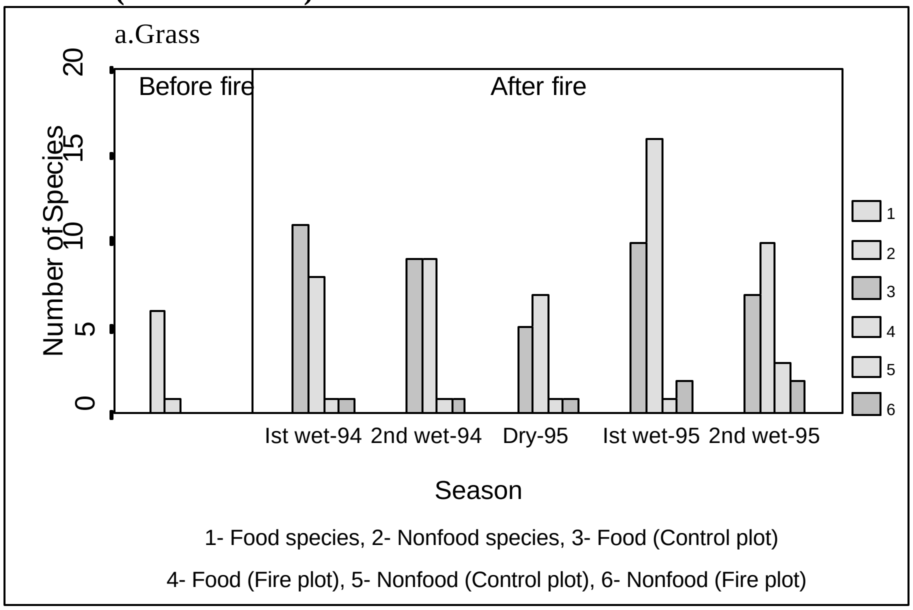
Table 97. Grass species composition in plantation during first wet 1994
(Summer burn)

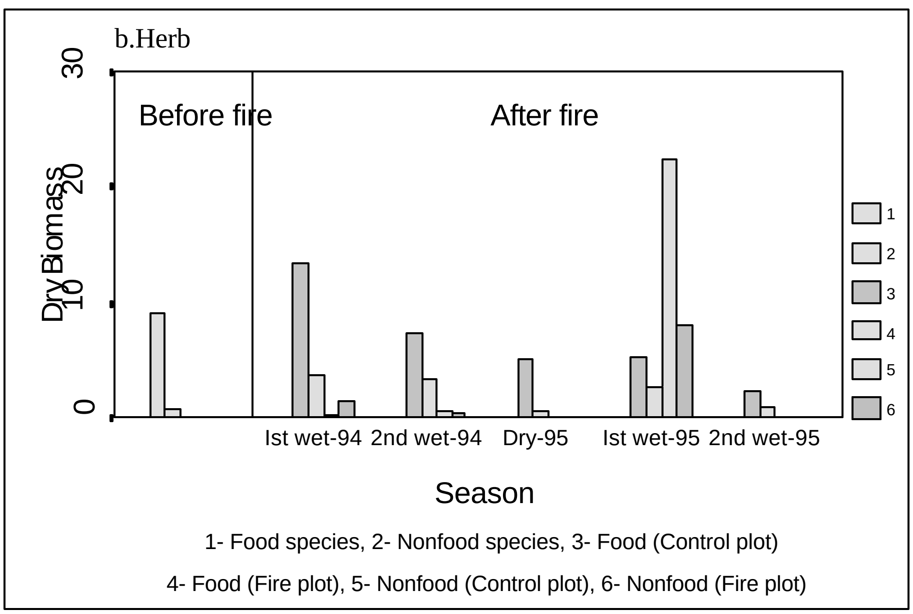
Before burn	Control	After burn
Digitaria setigera	*Commelina benghalensis*	*Commelina benghalensis*
Imperata cylindrica	*Cyperus kurzii*	*Cyperus kurzii*
Kyllinga monocephala	*Digitaria bicornis*	*Digitaria setigera*
Oplismenus compositus	*Digitaria setigera*	*Kyllinga monocephala*
Paspalidium flavidum	*Imperata cylindrica*	*Leersia hexandra*
Panicum notatum	*Kyllinga monocephala*	*Mariscus pictus*
	Leersia hexandra	*Oplismenus compositus*
	Mariscus pictus	*Panicum notatum*
	Oplismenus compositus	
	Panicum notatum	
	Paspalidium flavidum	

Table 98. Grass species composition in plantation during second wet 1994
(Summer burn)

Control	After burn
Commelina benghalensis	*Brachiaria ramosa*
Digitaria bicornis	*Commelina benghalensis*
Digitaria setigera	*Cynodon dactylon*
Imperata cylindrica	*Digitaria ciliaris*
Kyllinga monocephala	*Digitaria setigera*
Leersia hexandra	*Kyllinga monocephala*
Oplismenus compositus	*Leersia hexandra*
Panicum notatum	*Mariscus pictus*
Themeda triandra	*Oplismenus compositus*
	Oryza rufipogon
	Panicum notatum
	Paspalidium flavidum

Figure. 109. Number of plant species in plantation habitat type - before and after fire (Summer burn) treatment





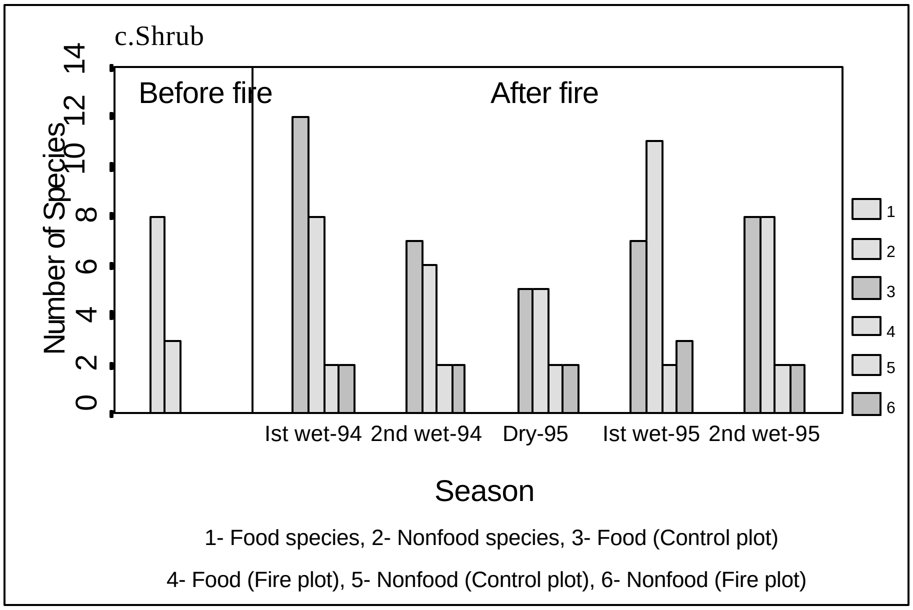
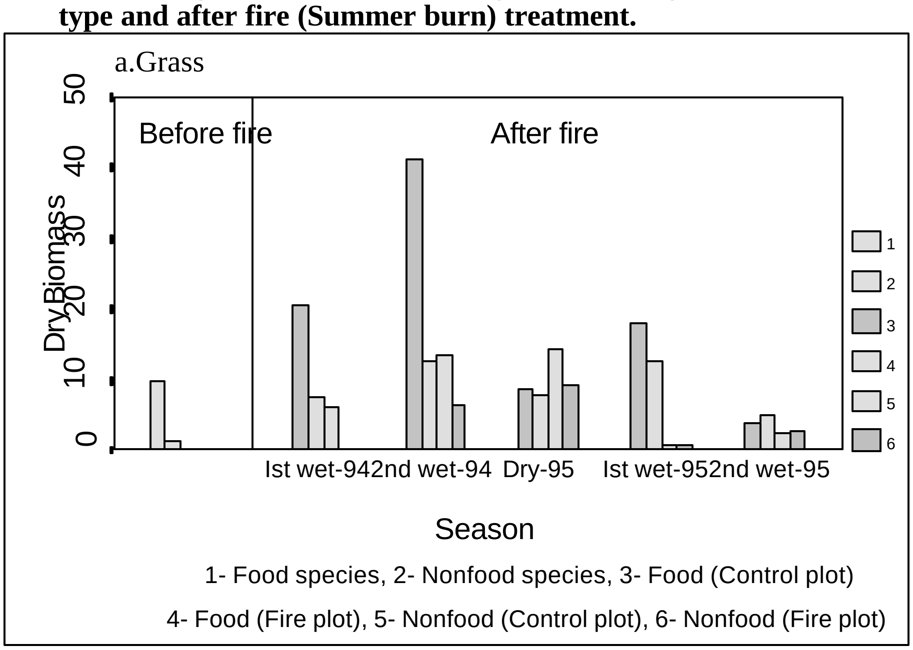
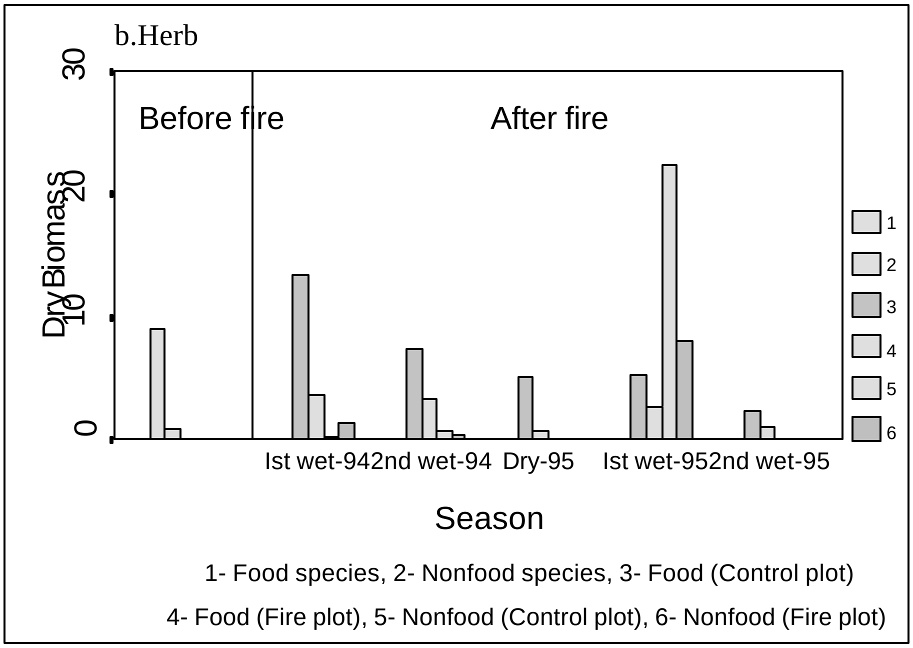


Figure. 110. Aboveground plant biomass (gram dry weight/m^2) in plantation habitat type and after fire (Summer burn) treatment.




b.Herb
Dry Biomass
0
10
20
30
Before fire
After fire
1
2
3
4
5
6
Ist wet-94
2nd wet-94
Dry-95
Ist wet-95
2nd wet-95
Season
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire plot)

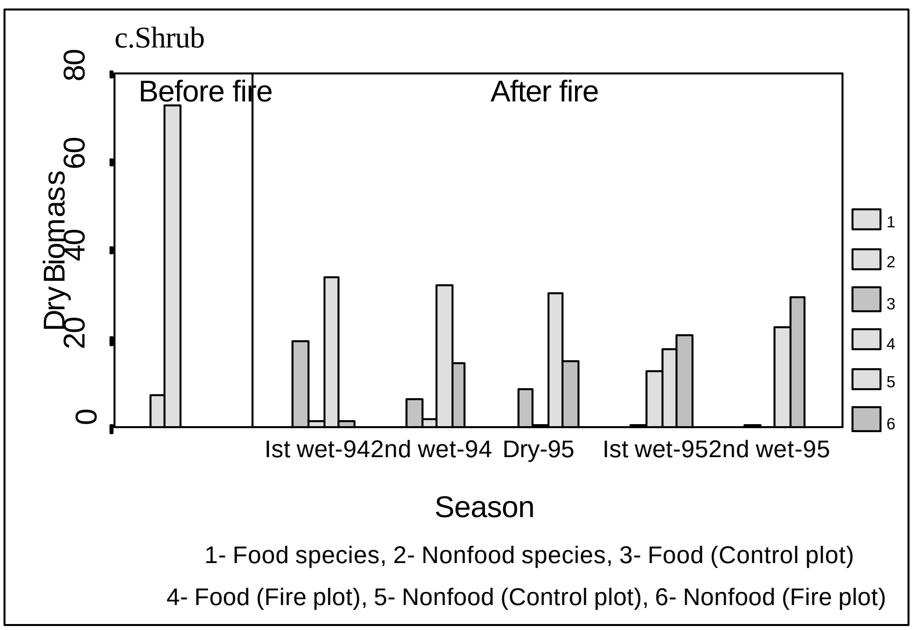

c.Shrub
Dry Biomass
0
20
40
60
80
Before fire
After fire
1
2
3
4
5
6
Ist wet-94
2nd wet-94
Dry-95
Ist wet-95
2nd wet-95
Season
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire plot)

Table 99. Grass species composition in plantation during dry 1995
(Summer burn)

Control	After burn
Digitaria setigera	*Cynodon dactylon*
Imperata cylindrica	*Cyperus kurzii*
Kyllinga monocephala	*Digitaria setigera*
Oplismenus compositus	*Imperata cylindrica*
Themeda triandra	*Kyllinga monocephala*
	Oplismenus compositus
	Themeda triandra

Table 100. Grass species composition in plantation during first wet 1995
(Summer burn)

Control	After burn
Commelina benghalensis	*Apluda mutica*
Cyperus kurzii	*Commelina benghalensis*
Cyrtococcum decurrens	*Cynodon dactylon*
Digitaria setigera	*Cyperus kurzii*
Eleusine indica	*Cyrtococcum decurrens*
Kyllinga monocephala	*Digitaria ciliaris*
Mariscus pictus	*Digitaria setigera*
Oplismenus compositus	*Eragrostis tenella*
Oryza granulata	*Kyllinga monocephala*
Panicum psilopodium	*Mariscus pictus*
	Murdannia japonica
	Oplismenus compositus
	Ottochloa nodosa
	Panicum psilopodium
	Paspalidium flavidum
	Paspalum scrobiculatum
	Scleria laevis

Table 101. Grass species composition in plantation during second wet 1995
(Summer burn)

Control	After burn
Digitaria setigera	*Cyperus kurzii*
Imperata cylindrica	*Digitaria setigera*
Kyllinga monocephala	*Imperata cylindrica*
Mariscus pictus	*Kyllinga monocephala*
Oplismenus compositus	*Mariscus pictus*
Ottochloa nodosa	*Oplismenus compositus*
Panicum notatum	*Ottochloa nodosa*
Rotboellia cochinchinensis	*Panicum notatum*
Scleria habecarpa	*Panicum psilopodium*
	Rotboellia cochinchinenesis
	Themeda triandra

Herb

A decrease in the number of herb food species was noted in all the seasons after fire compared to control (Fig. 109b). The number of non-food species also decreased after burning. Almost the same pattern was followed in the case of changes in dry biomass of herb species (Fig. 110b).

The changes in herb species composition within the plots before fire, control and after fire in different seasons are given in Tables 102 to 106.

Table 102. Herb species composition in plantation during first wet 1994
(Summer burn)

Before burn	Control	After burn
Achyranthes aspera	*Centrosema pubescens*	*Centrosema pubescens*
Centerosema pubescens	*Curculigo orchioides*	*Curculigo orchioides*
Micranthus oppositifolius	*Eclipta protrata*	*Eclipta protrata*
Mimosa pudica	*Globba marantina*	*Globba marantina*
Palkodi	*Globba ophioglossa*	*Globba ophioglossa*
Hemidesmus indicus	*Hemidesmus indicus*	*Hemidesmus indicus*
Uraria hamosa	*Ichnocarpus frutescens*	*Ichnocarpus frutescens*
	Merremia umbellata	*Justicia trinervia*
	Micranthus oppositifolius	*Laportea interrupta*
	Mimosa pudica	*Merremia umbellata*
	Phyllanthus urinaria	*Micranthus oppositifolius*
		Mimosa pudica
		Ocimum gratissimum
		Phylanthus urinaria

Table 103. Herb species composition in plantation during second wet 1994
(Summer burn)

Control	After burn
Centrosema pubescens	*Centrosema pubescens*
Eclipta prostrata	*Curculigo orchioides*
Globba ophioglossa	*Eclipta prostrata*
Hemidesmus indicus	*Globba marantina*
Micranthus oppositifolius	*Globba ophioglossa*
Mimosa pudica	*Hemidesmus indicus*
Phyllanthus urinaria	*Ichnocarpus frutescens*
	Justicia trinervia
	Micranthus oppositifolius
	Mimosa pudica
	Phyllanthus urinaria

Table 104. Herb species composition in plantation during dry 1995
(Summer burn)

Control	After burn
Hemidesmus indicus	*Hemidesmus indicus*
Ichnocarpus frutescens	*Ichnocarpus frutescens*
Micranthus oppositifolius	*Micranthus oppositifolius*
Mimosa pudica	*Mimosa pudica*

Table 105. Herb species composition in plantation during first wet 1995
(Summer burn)

Control	After burn
Biophytum reinwardtii	*Biophytum reinwardtii*
Centrosema pubescens	*Centrosema pubescens*
Curculigo orchioides	*Curculigo orchioides*
Globba ophioglossa	*Curcuma vamana*
Hemidesmus indicus	*Desmodium heterophyllum*
Merremia umbellata	*Elephantopus scaber*
Micranthus oppositifolius	*Globba ophioglossa*
Mimosa pudica	*Hemidesmus indicus*
Thunbergia fragrans	*Merremia umbellata*
	Micranthus oppositifolius
	Mimosa pudica
	Phyllanthus urinaria
	Synedrella nodiflora
	Thunbergia fragrans

Table 106. Herb species composition in plantation during second wet 1995
(Summer burn)

Control	After burn
Alysicarpus monilifer	*Alysicarpus monilifer*
Centrosema pubescens	*Centrosema pubescens*
Dipterocanthus prostrata	*Crotalaria striata*
Justicia trinervia	*Curculigo orchioides*
Micranthus oppositifolius	*Dipteracanthus prostrata*
Mimosa pudica	*Hemidesmus indicus*
	Ichnocarpus indicus
	Justicia trinervia
	Mimosa pudica
	Synedrella nodiflora
	Uraria hamosa

Shrub

The number of food species was either same or higher in control plot than burnt plot except in first wet season during 1995 (Fig. 109c). Dry biomass of food and non-food shrub species were higher in control plot than the burnt plot till dry, 1995 and thereafter a slight increase was observed in burnt plot.

The changes in shrub species composition within the plots before fire, control and after fire in different seasons are given in Tables 107 to 111.

Table 107. Shrub species composition in plantation during first wet 1994
(Summer burn)

Before burn	**Control**	**After burn**
Cycas	*Desmodium gangeticum*	*Desmodium gangeticum*
Desmodium laxiflorum	*Desmodium laxiflorum*	*Desmodium laxiflorum*
Eupatorium odoratum	*Desmodium triquetrum*	*Desmodium triquetrum*
Helicteres isora	*Eupatorium odoratum*	*Eupatorium odoratum*
Lantana camara	*Helicteres isora*	*Helicteres isora*
Pseudarthria viscida	*Lantana camara*	*Randia dumatorum*
Randia dumatorum	*Pseudarthria viscida*	*Sida rhombifolia*
Sida mysorensis	*Randia dumatorum*	*Triumfetta rhomboidea*
Urena lobata	*Sida rhombifolia*	*Ziziphus oenoplia*
Ziziphus oenoplia	*Thespesia lampas*	*Ziziphus xylopyrus*
Ziziphus xylopyrus	*Triumfetta rhomboidea*	
	Urena lobata	
	Ziziphus oenoplia	
	Ziziphus xylopyrus	

Table 108. Shrub species composition in plantation during second wet 1994
(Summer burn)

Control	**After burn**
Desmodium gangeticum	*Desmodium gangeticum*
Desmodium laxiflorum	*Desmodium laxiflorum*
Eupatorium odoratum	*Eupatorium odoratum*
Helicteres isora	*Helicteres isora*
Pseudarthria viscida	*Randia dumatorum*
Randia dumatorum	*Sida rhombifolia*
Sida rhombifolia	*Triumfetta rhomboidea*
Triumfetta rhomboidea	*Ziziphus oenoplia*
Ziziphus oenoplia	

Table 109. Shrub species composition in plantation during dry 1995
(Summer burn)

Control	After burn
Eupatorium odoratum	*Desmodium laxiflorum*
Helicteres isora	*Eupatorium odoratum*
Lantana camara	*Helicteres isora*
Pseudarthria viscida	*Lantana camara*
Randia dumatorum	*Randia dumatorum*
Sida rhombifolia	*Sida rhombifolia*
Ziziphus oenoplia	*Ziziphus oenoplia*

Table 110. Shrub species composition in plantation during first wet 1995
(Summer burn)

Control	After burn
Desmodium gangeticum	*Achyranthes aspera*
Desmodium laxiflorum	*Desmodium laxiflorum*
Desmodium triaqulare	*Desmodium trianqulare*
Eupatorium odoratum	*Eupatorium odoratum*
Helicteres isora	*Helicteres isora*
Randia dumatorum	*Hibiscus lobatus*
Sida rhombifolia	*Lantana camara*
Triumfetta rhomboidea	*Pogostemon paniculatus*
Ziziphus oenoplia	*Randia dumatorum*
	Sida acuta
	Sida cordifolia
	Sida mysorensis
	Sida rhombifolia
	Ziziphus oenoplia

Table 111. Shrub species composition in plantation during second wet 1995
(Summer burn)

Control	After burn
Bambusa arundinacea	*Desmodium gangeticum*
Desmodium gangeticum	*Desmodium laxiflorum*
Desmodium laxiflorum	*Eupatorium odoratum*
Eupatorium odoratum	*Helicteres isora*
Helicteres isora	*Randia dumatorum*
Randia dumatorum	*Sida mysorensis*
Sida mysorensis	*Sida rhombifolia*
Sida rhombifolia	*Triumfetta rhomboidea*
Tiumfetta rhomboidea	*Ziziphus oenoplia*
Ziziphus oenoplia	*Ziziphus xylopyrus*

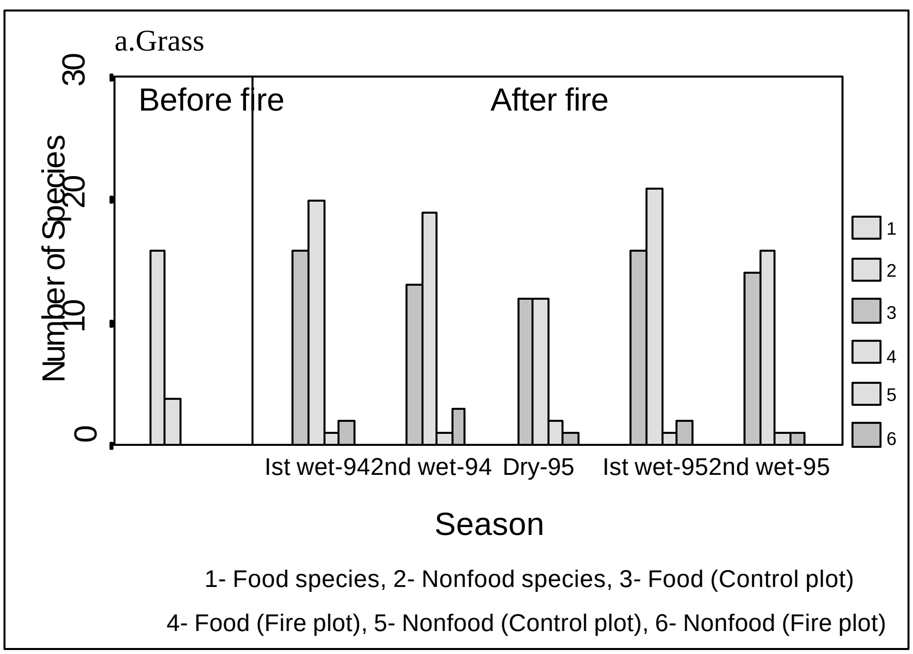
7.3.1.3 Grassland

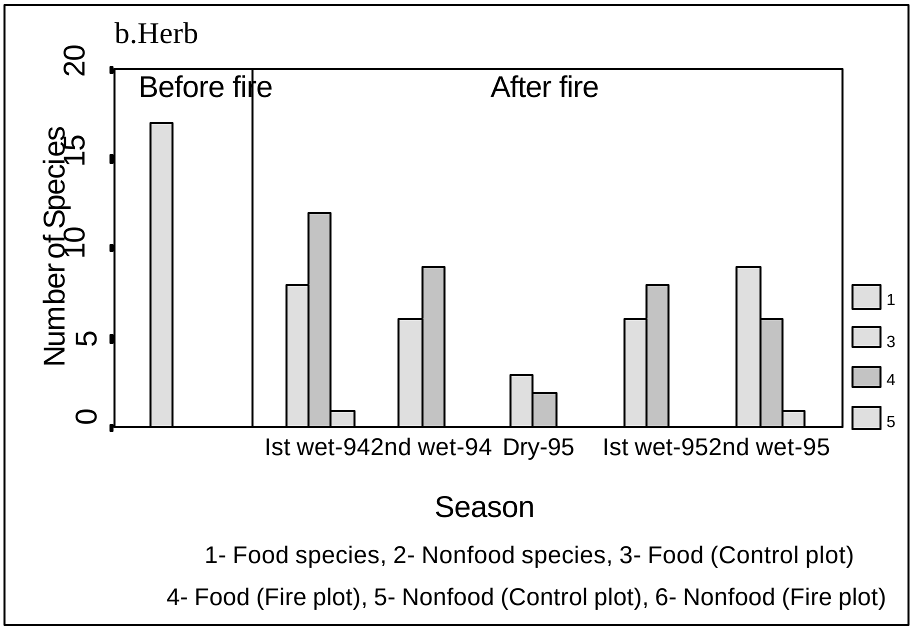
Grass

Number of grass food species in burnt plots was higher than the control plots in all the seasons (Fig. 111a). Dry biomass of both food and non-food grass species were higher in control plots than burnt plots upto dry season of 1995 and thereafter the dry biomass of food and non-food grass species increased in burnt plots (Fig. 112a).

The changes in grass species composition within the plots before fire, control and after fire in different seasons are given in Tables 112 to 116.

Figure. 111. Number of plant species in grassland habitat type - before and after fire (Summer burn) treatment




b.Herb
Before fire
After fire
Number of Species
0
5
10
15
20
Ist wet-94
2nd wet-94
Dry-95
Ist wet-95
2nd wet-95
Season
1
3
4
5
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire plot)

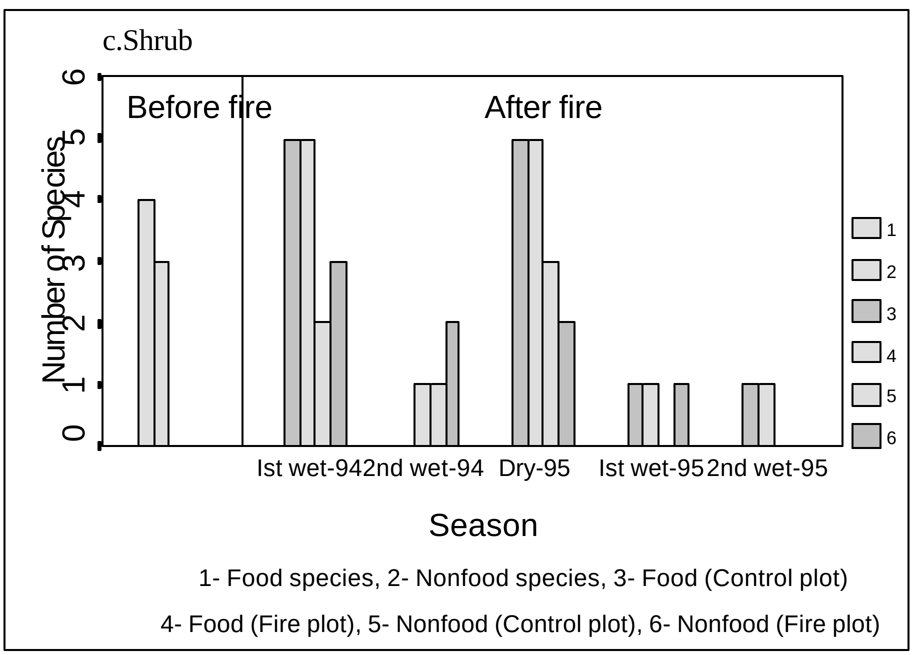
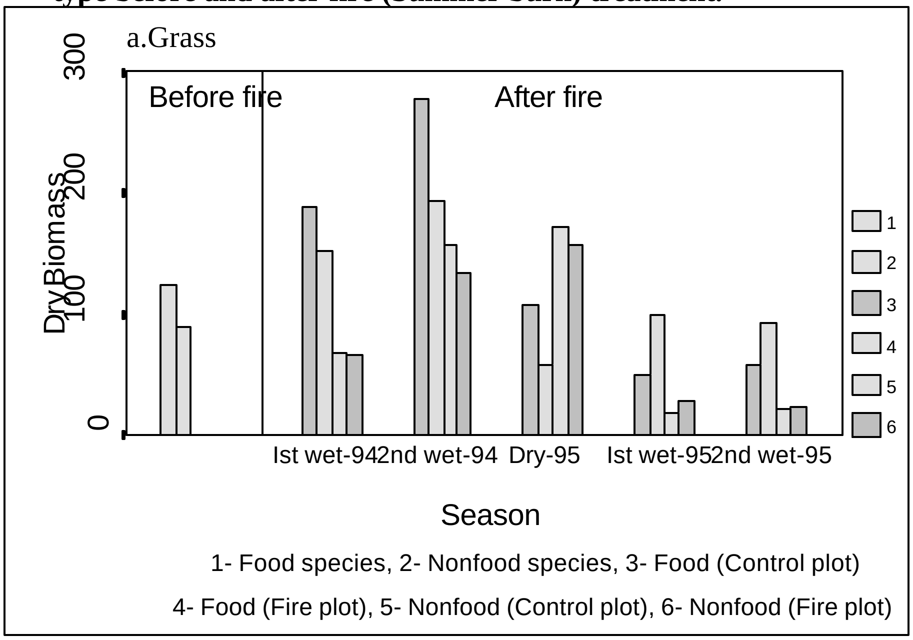
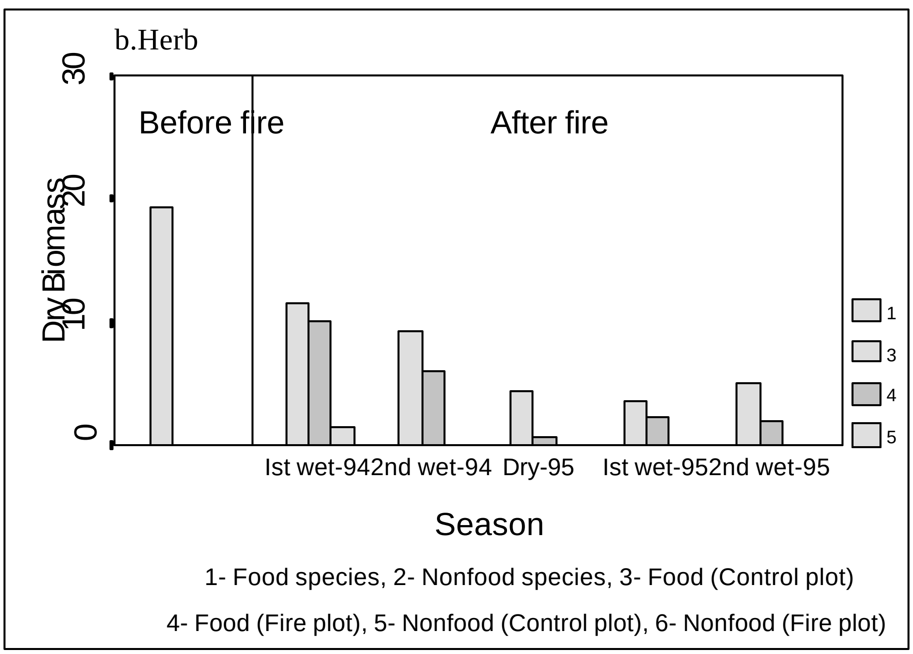

c.Shrub
Before fire
After fire
Number of Species
0
1
2
3
4
5
6
Ist wet-94
2nd wet-94
Dry-95
Ist wet-95
2nd wet-95
Season
1
2
3
4
5
6
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire plot)

Figure. 112. Aboveground plant biomass (gram dry weight/m^2) in grassland habitat type before and after fire (Summer burn) treatment.





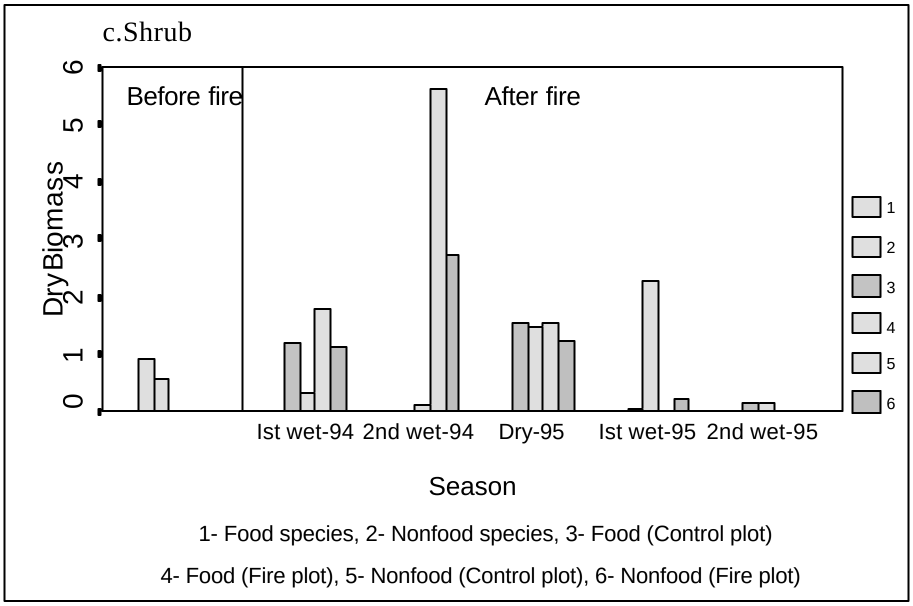


Table 112. Grass species composition in grassland during first wet 1994
(Summer burn)

Before burn	Control	After burn
Axonopus compressus	*Axonopus compressus*	*Axonopus compressus*
Brachiaria ramosa	*Brachiaria ramosa*	*Brachiaria ramosa*
Commelina benghalensis	*Commelina benghalensis*	*Commelina benghalensis*
Commelina clavata	*Cyperus distans*	*Cyperus distans*
Cyrtococcum decurrens	*Cyperus iria*	*Cyperus iria*
Cyperus exaltatus	*Echinochloa colona*	*Cyperus zollingeri*
Cyperus zollingeri	*Eleusine indica*	*Echinochloa colona*
Echinochloa colona	*Fimbristylis dichotoma*	*Eleusine indica*
Eleusine indica	*Ischaemum indicum*	*Eragrostis unioloides*
Eragrostis unioloides	*Ischaemum rangacharianum*	*Fimbristylis annua*
Fimbristylis annua	*Kyllinga monocephala*	*Fimbristylis dichotoma*
Ischaemum cannanorensis	*Leersia hexandra*	*Imperata cylindrica*
Ipomoea setosa	*Panicum psilopodium*	*Ischaemum indicum*
Kyllinga monocephala	*Paspalum scrobiculatum*	*Ischaemum rangacharianum*
Leersia hexandra	*Scleria stipularis*	*Kyllinga monocephala*
Paspalum conjugatum	*Themeda triandra*	*Leersia hexandra*
Paspalum scrobiculatum		*Panicum notatum*
Sporobolus indicus		*Paspalum conjugatum*
Themeda trindra		*Paspalum scrobiculatum*
		Sporobolus indicus
		Themeda trindra

Table 113. Grass species composition in grassland during second wet 1994
(Summer burn)

Control	After burn
Axonopus compressus	*Axonopus compressus*
Brachiaria ramosa	*Brachiaria ramosa*
Commelina benghalensis	*Commelina benghalensis*
Cyperus iria	*Cynodon dactylon*
Ehinochloa colona	*Cyperus distans*
Eleusine indica	*Cyperus iria*
Ischaemum indicum	*Cyperus zollingeri*
Kyllinga monocephala	*Echinochloa colona*
Leersia hexandra	*Eleusine indica*
Paspalidium flavidum	*Eragrostis unioloides*
Scleria stipularis	*Imperata cylindrica*
Themeda trindra	*Ischaemum indicum*
	Kyllinga monocephala
	Leersia hexandra
	Panicum psilopodium
	Paspalidium flavidum
	Paspalum scrobiculatum
	Scleria elata
	Sporobolus indicus
	Themeda triandra

Table 114. Grass species composition in grassland during dry 1995
(Summer burn)

Control	After burn
Axonopus compressus	*Axonopus compressus*
Commelina benghalensis	*Brachiaria ramosa*
Cynodon dactylon	*Commelina benghalensis*
Dactyloctenium aegyptium	*Cynodon dactylon*
Imperata cylindrica	*Imperata cylindrica*
Ischaemum indicum	*Ischaemum indicum*
Kyllinga monocephala	*Kyllinga monocephala*
Kyllinga triceps	*Kyllinga triceps*
Leersia hexandra	*Paspalidium flavidum*
Paspalidium flavidum	*Paspalum scrobiculatum*
Paspalum scrobiculatum	*Scleria elata*
Scleria exaltata	*Themeda triandra*
Themeda triandra	

Table 115. Grass species composition in grassland during first wet 1995
(Summer burn)

Control	After burn
Commelina benghalensis	*Axonopus compressus*
Cynodon dactylon	*Brachiaria ramosa*
Cyperus comperessus	*Commelina benghalensis*
Cyperus distans	*Cyperus compressus*
Cyperus iria	*Cyperus distans*
Cyperus kurzii	*Cyperus iria*
Echinochloa colona	*Cyperus kurzii*
Eleusine indica	*Cyprus pilosus*
Eragrostis tenella	*Cyrtococcum decurrens*
Eragrostis unioloides	*Echinochloa colona*
Ischaemum indicum	*Eleusine indica*
Kyllinga monocephala	*Eragrostis tenella*
Leersia hexandra	*Eragrostis unioloides*
Ottochloa nodosa	*Fimbristylis dichotoma*
Paspalum scrobiculatum	*Imperata cylindrica*
Themeda triandra	*Ischaemum indicum*
	Kyllinga monocephala
	Leersia hexandra
	Ottochloa nodosa
	Paspalum scrobiculatum
	Scleria laevis
	Themeda triandra

Table 116. Grass species composition in grassland during second wet 1995
(Summer burn)

Control	After burn
Axonopus compressus	*Axonopus compressus*
Commelina benghalensis	*Brachiaria ramosa*
Cynodon dactylon	*Commelina benghalensis*
Cyperus iria	*Cynodon dactylon*
Cyperus kurzii	*Cyperus exaltatus*
Cyrtococcum decurrens	*Cyperus kurzii*
Eleusine indica	*Cyperus pilosus*
Ischaemum indicum	*Cyrtococcum decurrens*
Ischaemum rangacharianum	*Eleusine indica*
Kyllinga monocephala	*Imperata cylindrica*
Leersia hexandra	*Ischaemum indicum*
Paspalum scrobiculatum	*Ischaemum rangacharianum*
Scleria stipularis	*Kyllinga monocephala*
Themeda triandra	*Leersia hexandra*
	Paspalum scrobiculatum
	Themeda triandra

Herb

Number of herb food species was more in burnt plots in first and second wet seasons of 1994 and first season of 1995 (Fig. 111b). Complete absence of non-food species in the burnt plots throughout and in some seasons in the control need special mention. Dry biomass of herb food species also showed decreasing trend in all the seasons after fire (Fig. 112b).

The changes in herb species composition in the plots before fire, control and after fire in different seasons are given in Tables 117 to 121.

Shrub

The number of shrub food species in both control and burnt plots were similar (Fig. 111c). However, the number of non-food species did not follow any pattern. There was a marked reduction in the biomass of shrub in burnt plots during first wet season. However, there were seasons without shrub also (Fig. 112c).

The changes in shrub species composition in the plots before fire, control and after fire in different seasons are given in Tables 122 to 126.

Table 117. Herb species composition in grassland during first wet 1994
(Summer burn)

Before burn	**Control**	**After burn**
Ageratum conyzoides	*Ageratum conyzoides*	*Ageratum conyzoides*
Alysicarpus glumaceous	*Ammannia baccifera*	*Centella asiatica*
Acrocephalus hispidus	*Centella asiatica*	*Desmodium heterophyllum*
Centella asiatica	*Desmodium heterophyllum*	*Globba marantina*
Centerosema pubescens	*Hydrolea zeylanica*	*Hibiscus furcatus*
Desmodium heterophyllum	*Lobelia alsinoides*	*Hydrolea zeylanica*
Eclipta prostrata	*Mimosa pudica*	*Ipomoea deccana*
Hydrolea zeylanica	*Nasaea lanceolata*	*Lindernia pusilla*
Ipomoea deccana	*Rawolfia serpentina*	*Lobelia alsinoides*
Indigofera spicata		*Mimosa pudica*
Justicia trinervia		*Mitracarpus verticilatus*
Ludwigia hyssopifolia		*Nasaea lanceolata*
Melochia corchorifolia		
Micranthus oppositifolius		
Mimosa pudica		
Phyllanthus urinaria		

Table 118. Herb species composition in grassland during second wet 1994
(Summer burn)

Control	After burn
Centella asiatica	*Centella asiatica*
Desmodium heterophyllum	*Desmodium heterophyllum*
Ipomoea deccana	*Hydrolaea zeylanica*
Lobelia alsinoides	*Ipomoea deccana*
Micranthus oppositifolius	*Lobelia alsinoides*
Mimosa pudica	*Micranthus oppositifolius*
	Mimosa pudica
	Micranthus oppositifolius
	Nasaea lanceolata

Table 119. Herb species composition in grassland during dry 1995
(Summer burn)

Control	After burn
Centella asiatica	*Mimosa pudica*
Desmodium heterophyllum	*Smithia geminiflora*
Mimosa pudica	

Table 120. Herb species composition in grassland during first wet 1995
(Summer burn)

Control	After burn
Ammannia baccifera	*Ammannia baccifera*
Desmodium heterophyllum	*Centella asiatica*
Hydrolea zeylanica	*Desmodium heterophyllum*
Lobelia alsinoides	*Hydrolea zeylanica*
Micranthus oppositifolius	*Lobelia alsinoides*
Mimosa pudica	*Micranthus oppositifolius*
	Mimosa pudica
	Sida cordifolia

Table 121. Herb species composition in grassland during second wet 1995
(Summer burn)

Control	After burn
Ageratum conyzoides	*Ageratum conyzoides*
Alternanthera pungens	*Alternanthera pungens*
Centella asiatica	*Centella asiatica*
Desmodium heterophyllum	*Desmodium heterophyllum*
Justicia trinervia	*Justicia trinervia*
Melochia corchorifolia	*Mimosa pudica*
Micranthus oppositifolius	
Mimosa pudica	
Rawolfia serpentina	
Smithia geminiflora	

Table 122. Shrub species composition in grassland during first wet 1994
(Summer burn)

Before burn	Control	After burn
A.curassavica	*Asclepias curassavica*	*Desmodium gangeticum*
Bambusa arundinacea	*Bambusa arundinacea*	*Desmodium laxiflorum*
Crotalaria striata	*Crassocephalum crepidioides*	*Desmodium triquetrum*
Eupatorium odoratum	*Desmodium laxiflorum*	*Eupatorium odoratum*
Flemingia strobilifera	*Eupatorium odoratum*	*Helicteres isora*
Sida rhombifolia	*Flemingia strobilifera*	*Randia dumatorum*
Urena lobata	*Hibiscus furcatus*	*Sida rhombifolia*
	Triumfetta rhomboidea	
	Ziziphus oenoplia	
	Ziziphus xylopyrus	

Table 123. Shrub species composition in grassland during second wet 1994
(Summer burn)

Control	After burn
Eupatorium dumatorum	*Ageratum conyzoides*
	Asclepias curassavica
	Eupatorium odoratum

Table 124. Shrub species composition in grassland during dry 1995
(Summer burn)

Control	After burn
Asclepias curassavica	*Asclepias curassavica*
Bambusa arundinacea	*Bambusa arundinacea*
Eupatorium odoratum	*Eupatorium odoratum*
Flemingia strobilifera	*Felmingia strobilifera*
Randia dumatorum	*Melochia corchorifolia*
Sida rhombifolia	*Staurogyne sp.*
Triumfetta rhomboidea	*Triumfetta rhomboidea*
Urena lobata	

Table 125. Shrub species composition in grassland during first wet 1995
(Summer burn)

Control	After burn
Cassia occidentalis	*Ageratum conyzoides*
	Cassia occidentalis

Table 126. Shrub species composition in grassland during second wet 1995
(Summer burn)

Control	After burn
Bambusa arundinacea	*Bambusa arundinacea*

7.3.2 Cold burn

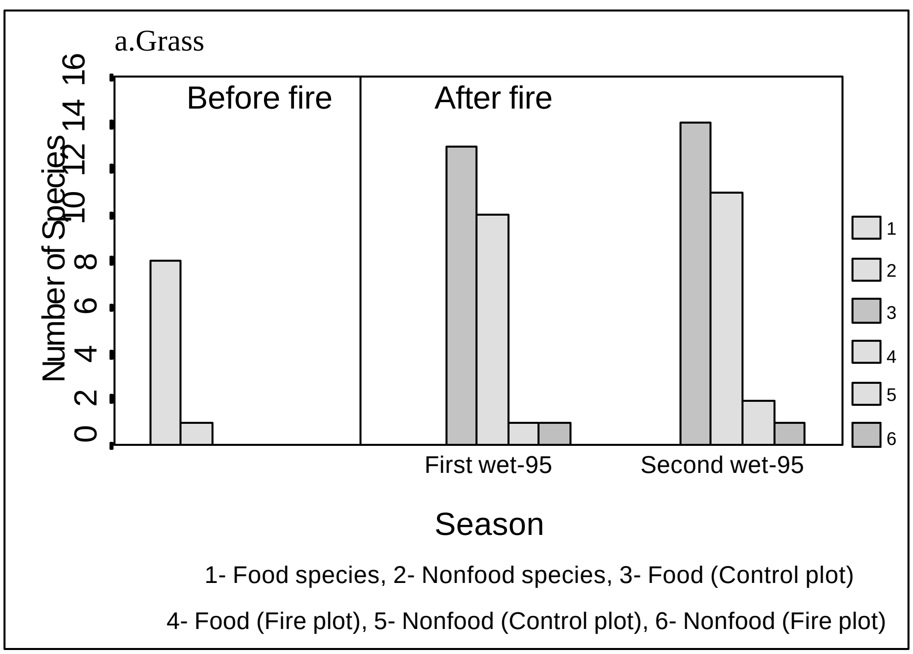
7.3.2.1 Moist deciduous

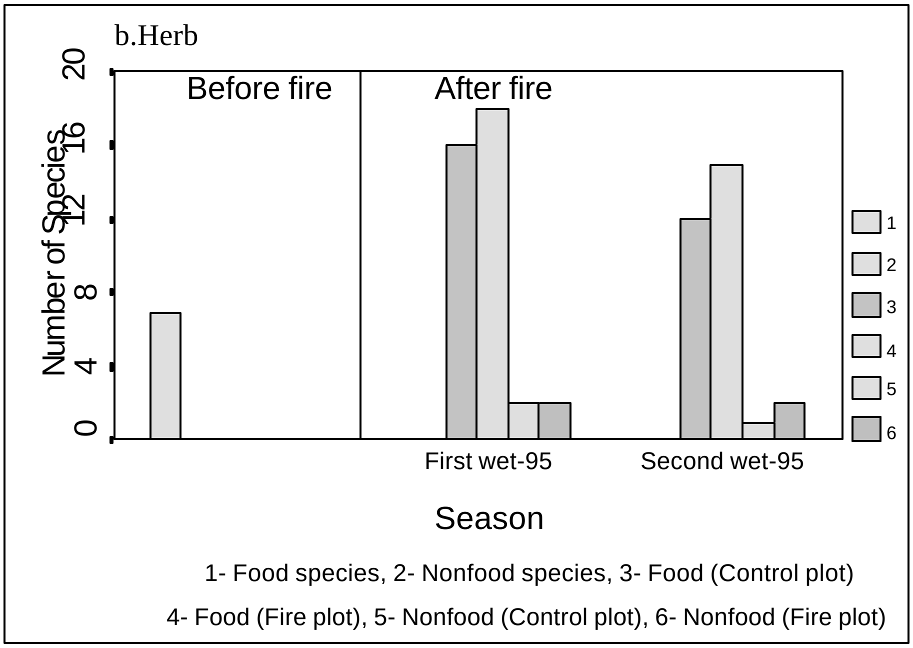
Grass

Noticeable variation in the number grass non-food species was not observed between control and burnt plots (Fig. 113a). However, number of grass food species was considerably higher in control plots. Dry biomass of food and non-food grass species were slightly higher in burnt plots (Fig. 114a).

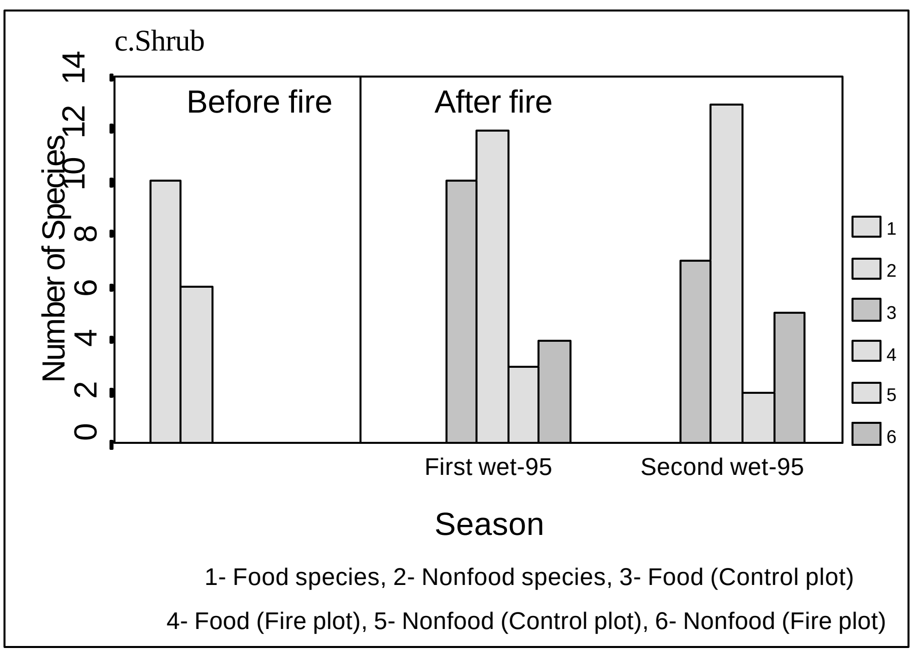
Changes in grass species composition in the plots before fire, control and after fire in different seasons are given in Tables 127 and 128.

Figure. 113. Number of plant species in moist deciduous habitat type - before and after fire Cold burn) treatment



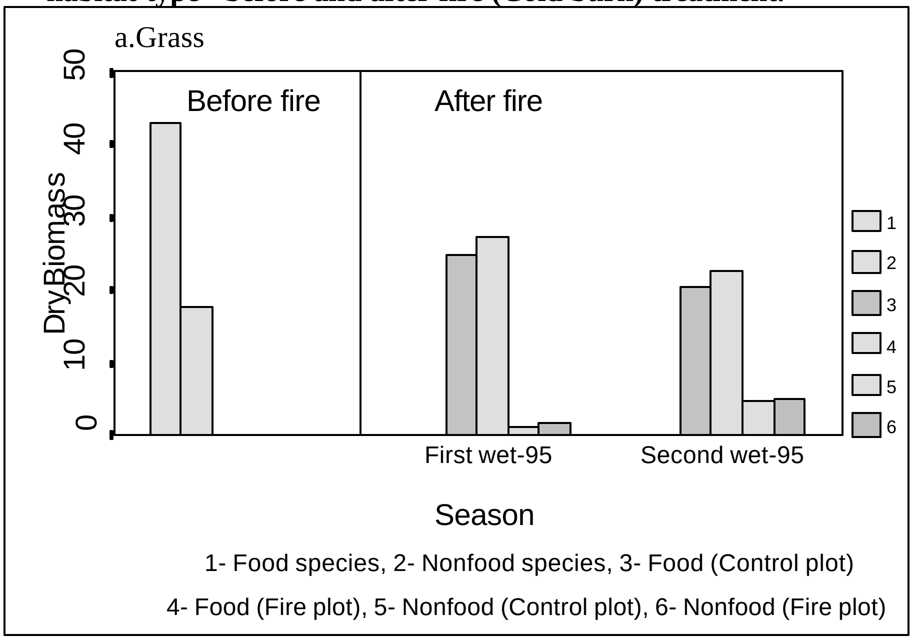


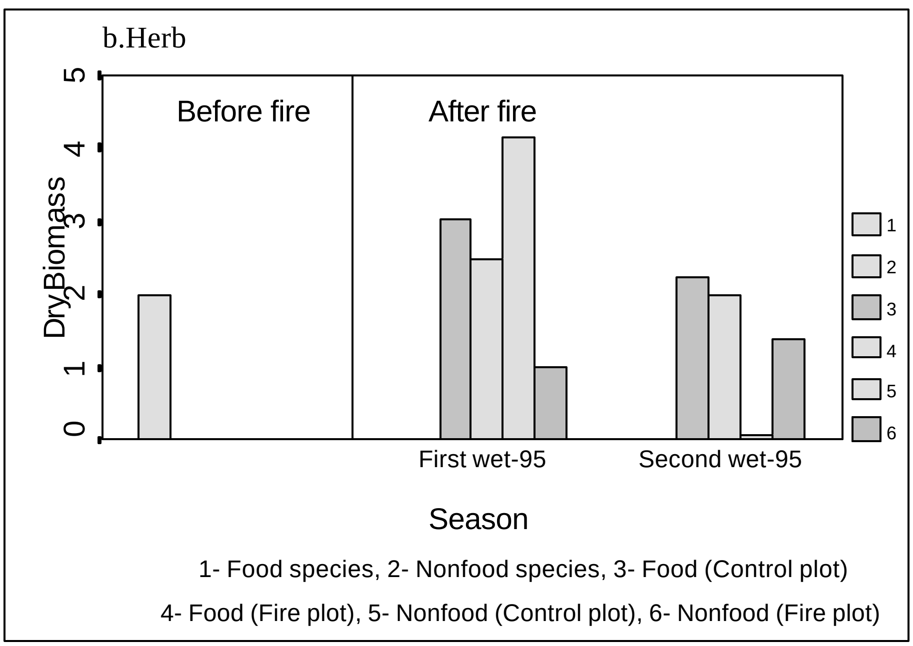
b.Herb
Before fire
After fire
Number of Species
0
4
8
12
16
20
First wet-95
Second wet-95
Season
1
2
3
4
5
6
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire plot)



c.Shrub
Before fire
After fire
Number of Species
0
2
4
6
8
10
12
14
First wet-95
Second wet-95
Season
1
2
3
4
5
6
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire plot)

Figure. 114. Aboveground plant biomass (gram dry weight/m^2) in moist deciduous habitat type - before and after fire (Cold burn) treatment.





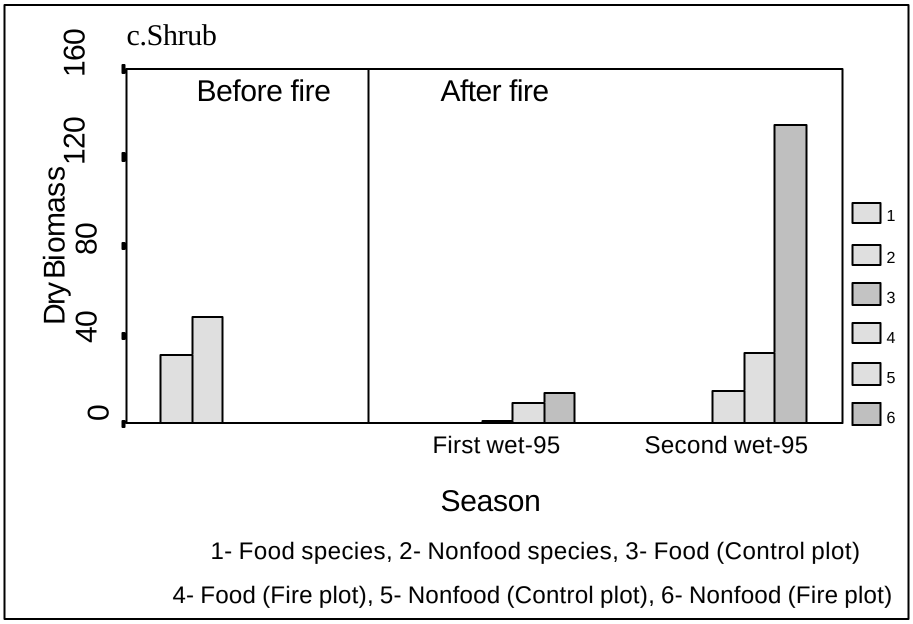


Table 127. Grass species composition in moist deciduous during first wet 1995
(Cold burn)

Before burn	Control	After burn
Brachiaria ramosa	*Brachiaria ramosa*	*Brachiaria ramosa*
Commelina benghalensis	*Commelina benghalensis*	*Commelina benghalensis*
Cyperus kurzii	*Digitaria setigera*	*Digitaria bicornis*
Digitaria setigera	*Eleusine indica*	*Digitaria griffithii*
Kyllinga monocephala	*Ischaemum indicum*	*Eleusine indica*
Oplismenus compositus	*Kyllinga monocephala*	*Kyllinga monocephala*
Tripogon ananthaswamianus	*Mariscus pictus*	*Mariscus pictus*
	Oplismenus compositus	*Oplismenus compositus*
	Ottochloa nodosa	*Ottochloa nodosa*
	Panicum notatum	*Themeda triandra*
	Panicum psilopodium	
	Paspalidium flavidum	
	Paspalum conjugatum	

Table 128. Grass species composition in moist deciduous during second wet 1995
(Cold burn)

Control	After burn
Brachiaria ramosa	*Brachiaria ramosa*
Cynodon dactylon	*Cynodon dactylon*
Cyrtococcum decurrens	*Cyrtococcum decurrens*
Digitaria setigera	*Digitaria griffithii*

Continued…

Eragrostis tenuifolia	*Ischaemum rangacharianum*
Heteropogon contortus	*Kyllinga monocephala*
Ischaemum indicum	*Oplismenus compositus*
Ischaemum rangacharianum	*Ottochloa nodosa*
Kyllinga monocephala	*Panicum psilopodium*
Mariscus pictus	*Paspalidium flavidum*
Oplismenus compositus	*Themeda triandra*
Ottochloa nodosa	
Panicum notatum	
Paspalidium flavidum	
Rotboellia cochinchinensis	

Herb

The number herb food species was higher in burnt plots compared to control plots in both seasons (Fig. 113b). However, not much variation was observed in the case of non-food herb species. Dry biomass of herb food species was lower in burnt plots than controls in both the seasons (Fig.114b) whereas dry biomass of non-food herb species was higher in control plots during first wet season, 1995 and it was higher in burnt plots during second wet seasons.

Changes in herb species composition in the plots before fire, control and after fire in different seasons are given in Tables 129 and 130.

Table 129. Herb species composition in moist deciduous during first wet 1995
(Cold burn)

Before burn	Control	After burn
Achyranthes aspera	*Acalypha racemosa*	*Acalypha racemosa*
Centerosema pubescens	*Ageratum conyzoides*	*Ageratum conyzoides*
Justicia trinervia	*Alternanthera pungens*	*Alternanthera pungens*
Micranthus oppositifolius	*Alternanthera sessilis*	*Alternanthera sessilis*
Mimosa pudica	*Biophytum reinwardtii*	*Biophytum reinwardtii*
Synedrella nodiflora	*Centerosema pubescens*	*Centerosema pubescens*
Hemidesmus indicus	*Curculigo orchioides*	*Curculigo orchioides*
	Globba ophioglossa	*Elephantopus scaber*
	Hemidesmus indicus	*Globba ophioglossa*
	Ichnocarpus frutescens	*Hemidesmus indicus*
	Justicia trinervia	*Hibiscus lobatus*
	Ludwigia hyssopifolia	*Justicia trinervia*

Continued…

	Merremia umbellata	*Merremia umbellata*
	Micranthus oppositifolius	*Micranthus oppositifolius*
	Mimosa pudica	*Mimosa pudica*
	Sida beddomei	*Mitracarpus verticillatus*
	Synedrella nodiflora	*Sida bedomi*
	Uraria hamosa	*Synedrella nodiflora*
		Uraria hamosa
		Sida bedomi

Table 130. Herb species composition in moist deciduous during second wet 1995
(Cold burn)

Control	After burn
Achyranthes aspera	*Achyranthes aspera*
Ageratum conyzoides	*Ageratum conyzoides*
Alysicarpus monolifer	*Alternanthera pungens*
Asparagus sp.	*Cardiospermum helicacabum*
Centerosema pubescens	*Centerosema pubescens*
Dipteracanthus protrata	*Curculigo orchioides*
Hemidesmus indicus	*Desmodium heterophyllum*
Justicia trinervia	*Dipteracanthus prostrata*
Micranthus oppositifolius	*Globba ophioglossa*
Mimosa pudica	*Hemidesmus indicus*
Rungia sp.	*Hibiscus lobatus*
Sida beddomei	*Justicia trinervia*
Synedrella nodiflora	*Merremia umbulata*
	Micranthus oppositifolius
	Mimosa pudica
	Sida beddomei
	Synedrella nodiflora

Table 131. Shrub species composition in moist deciduous during first wet 1995
(Cold burn)

Before burn	Control	After burn
Acacia intsia	*Bambusa arundinacea*	*Achyranthes aspera*
Asclepias crussavica	*Crotalaria striata*	*Bambusa arundinacea*
Bambusa arundinacea	*Desmodium pulchellum*	*Crotalaria striata*
Cassia occidentalis	*Desmodium trianqulare*	*Desmodium laxiflorum*
Eupatorium odoratum	*Eupatorium odoratum*	*Desmodium trianqulare*
Helicteres isora	*Helicteres isora*	*Eupatorium odoratum*
Hibiscus furcatus	*Lantana camera*	*Helicteres isora*
Lantana camara	*Ocimum gratissimum*	*Hibiscus furcatus*
Pseudarthria viscida	*Randia dumatorum*	*Ocimum gratissimum*

Continued..

Randia dumatorum	*Sida acuta*	*Randia dumatorum*
Sida rhombifolia	*Triumfetta rhomboidea*	*Sida mysorensis*
Triumfetta rhomboidea	*Urena lobata*	*Sida rhombifolia*
Urena lobata		*Triumfetta rhomboidea*
Ziziphus oenoplia		*Urena lobata*
		Ziziphus oenoplia

Table 132. Shrub species composition in moist deciduous during second wet 1995
(Cold burn)

Control	After burn
Bambusa arundinacea	*Abutilon sp.*
Crotalaria striata	*Bambusa arundinacea*
Desmodium gangeticum	*Crotalaria striata*
Desmodium laxiflorum	*Desmodium gangeticum*
Eupatorium odoratum	*Desmodium laxiflorum*
Helicteres isora	*Eupatorium odoratum*
Hibiscus lobatus	*Helicteres isora*
Randia dumatorum	*Hibiscus lobatus*
Sida rhombifolia	*Lantana camara*
Triumfetta rhomboidea	*Ocimum gratissimum*
	Pseudarthria viscida
	Randia dumatorum
	Sida cordifolia
	Sida mysorensis
	Sida rhombifolia
	Triumfetta rhomboidea
	Urena lobata
	Ziziphus oenoplia

7.3.2.2 Plantation

Grass

Number of grass food species was more in burnt plots compared to control plots in both the seasons (Fig. 115a). But, in the case of non-food grass species, the burnt plots were with more species than controls during first wet season of 1995 and it was higher in control plots during second wet season, 1995. No considerable variation was found in the dry biomass of food and non-food grass species between control and burnt plots (Fig. 116a). However, the burnt plots had slightly higher dry biomass of both food and non-food grass species in both the seasons.

Changes in grass species composition within the plots before fire, control and after fire in different seasons are given in Tables 133 and 134.

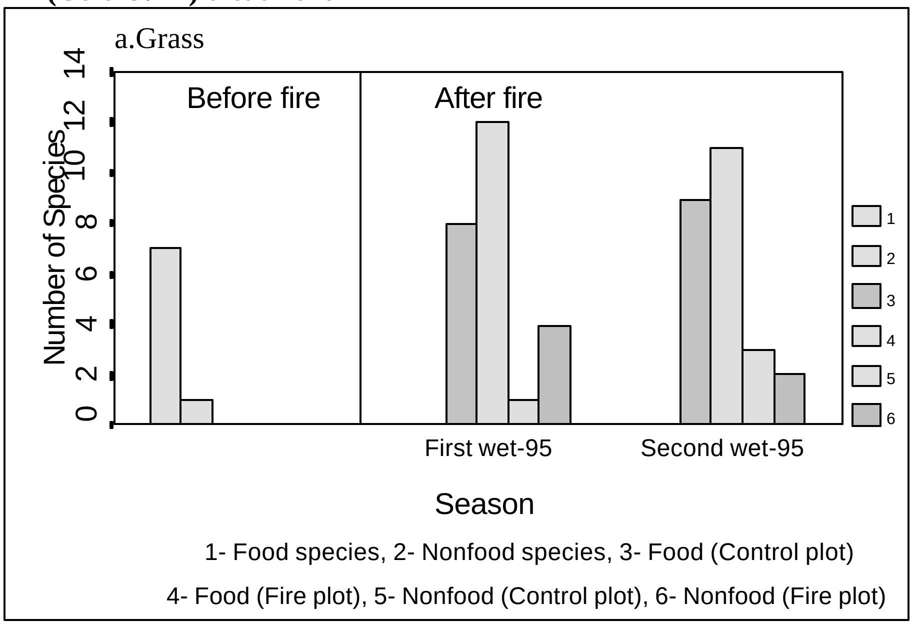
Herb

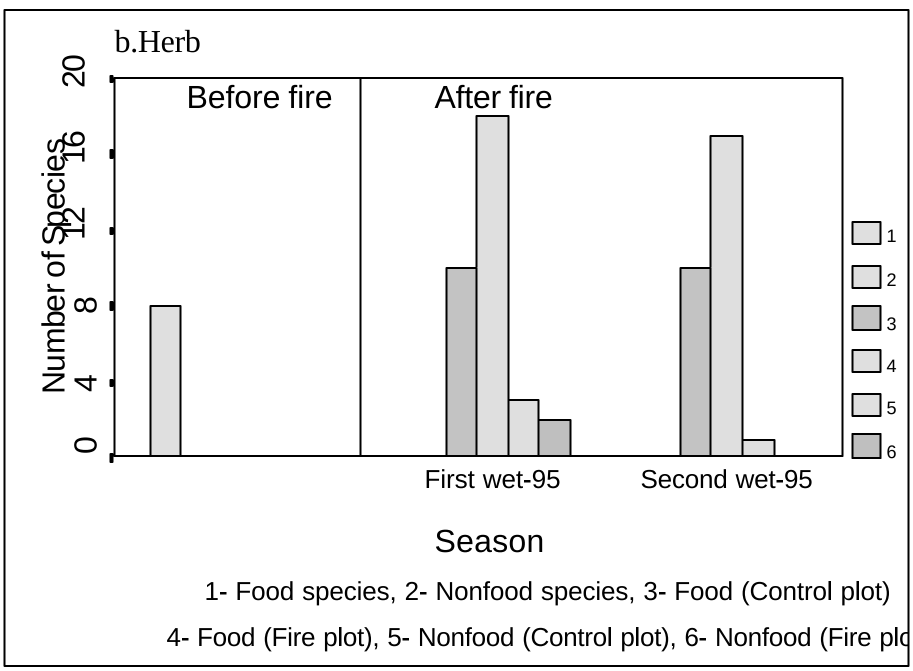
There was remarkable variation in the number herb food species between control and burnt plots (Fig. 115b). But there was not much variation in the case of non-food herb species. The absence of non-food herb species in burnt plots during second wet season, 1995 need to be mentioned. Higher dry biomass of non-food herb species was

Table 133. Grass species composition in plantation during first wet 1995
(Cold burn)

Before burn	**Control**	**After burn**
Brachiaria ramosa	*Commelina benghalensis*	*Commelina benghalensis*
Cyrtococcum decurrens	*Cyperus kurzii*	*Cynodon dactylon*
Cyperus kurzii	*Cyrtococcum decurrens*	*Cyperus kurzii*
Digitaria setigera	*Digitaria setigera*	*Cyrtococcum decurrens*
Eragrostis tenella	*Kyllinga monocephala*	*Digitaria bicornis*
Imperata cylindrica	*Oplismenus compositus*	*Digitaria setigera*
Oplismeus compositus	*Ottochloa nodosa*	*Eleusine indica*
	Panicum notatum	*Kyllinga monocephala*
		Murdannia japonica
		Oplismenus compositus
		Ottochloa nodosa
		Pseudarthria viscida
		Scleria habecarpa
		Scleria laevis
		Setaria pumila

Figure. 115. Number of plant species in plantation habitat type - before and after fire (Cold burn) treatment





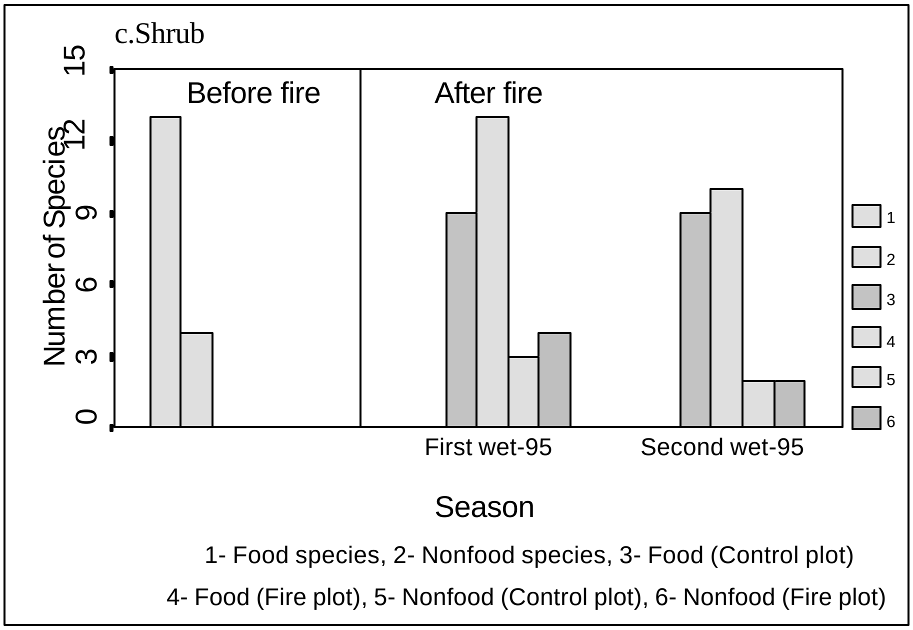
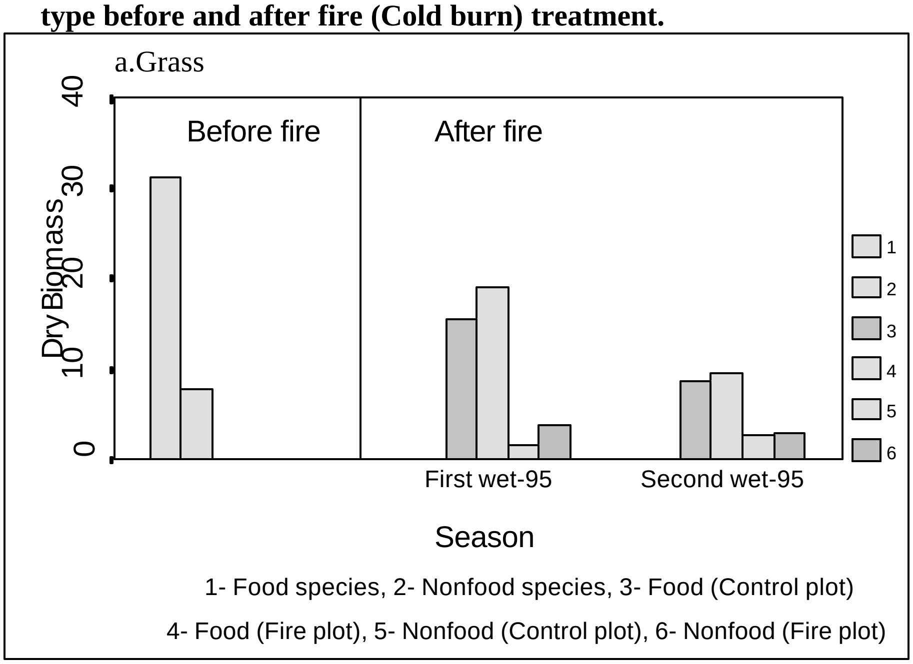
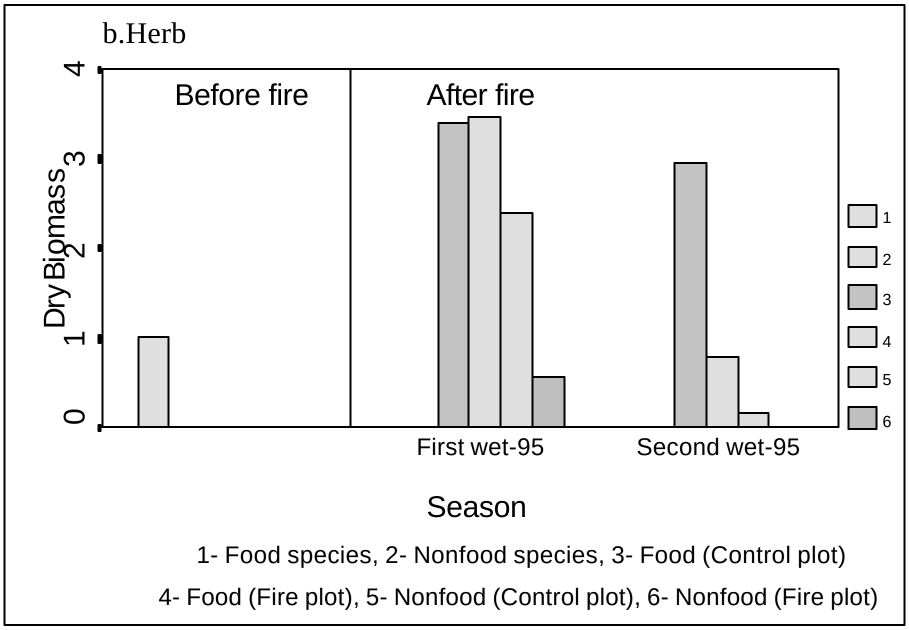


Figure. 116. Aboveground plant biomass (gram dry weight/m^2) in plantation habitat type before and after fire (Cold burn) treatment.




b.Herb
Before fire
After fire
Dry Biomass
0
1
2
3
4
1
2
3
4
5
6
First wet-95
Second wet-95
Season
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire plot)

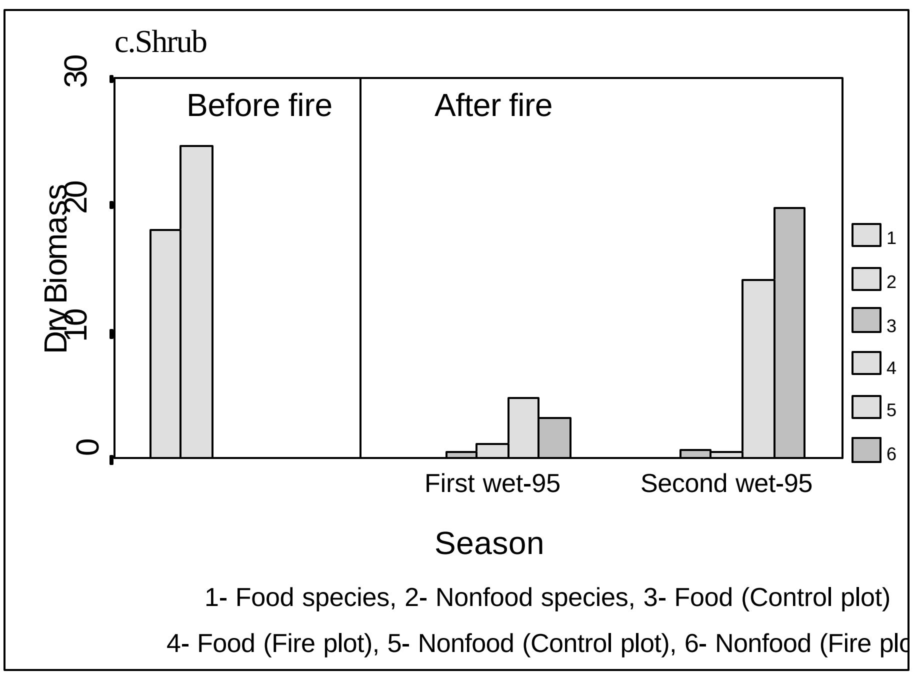

c.Shrub
Before fire
After fire
Dry Biomass
0
10
20
30
1
2
3
4
5
6
First wet-95
Second wet-95
Season
1- Food species, 2- Nonfood species, 3- Food (Control plot)
4- Food (Fire plot), 5- Nonfood (Control plot), 6- Nonfood (Fire plo

Table 134. Grass species composition in plantation during second wet 1995
(Cold burn)

Control	After burn
Bothricholoa pertusa	*Bothricholoa pertusa*
Brachiaria ramosa	*Brachiaria ramosa*
Cyperus kurzii	*Cynodon dactylon*
Cyrtococcum decurrens	*Dactyloctenium aegyptium*
Digitaria setigera	*Digitaria bicornis*
Ischaemum indicum	*Digitaria setigera*
Kyllinga monocephala	*Ischaemum indicum*
Oplismenus compositus	*Kyllinga monocephala*
Ottochloa nodosa	*Oplismenus compositus*
Panicum notatum	*Ottochloa nodosa*
Scleria habecarpa	*Panicum psilopodium*
	Paspalidium flavidum

observed in control plots than burnt plots in the both the seasons (Fig.116b). However, dry biomass of herb food species in control and burnt plots were more or less equal during first wet season, 1995 and was higher in control plots during second wet season, 1995.

Changes in herb species composition in the before fire, control and after fire in different seasons are given in Tables 135 and 136.

Shrub

Burnt plots had higher number of shrub food species than control plots (Fig. 115c). But, in the case of number of non-food species, it was higher in burnt plots during first wet season, 1995 and equal during second wet season, 1995. The shrub food species contributed very low dry biomass in both control and burnt plots (Fig. 116c). Dry biomass of non-food shrub species was more in control plots during first wet season and it was higher in burnt plots during second wet season of 1995.

Changes in shrub species composition within the plots before fire, control and after fire in different seasons are given in Tables 137 and 138.

Table 135. Herb species composition in plantation during first wet 1995
(Cold burn)

Before burn	Control	After burn
Curculigo orchioides	*Acalypha racemosa*	*Acalypha racemosa*
Centrosema pubescens	*Biophytum reinwardtii*	*Alysicarpus monilifer*
Globba marantina	*Centerosema pubescens*	*Biophytum reinwardtii*
Justicia trinervia	*Curculigo orchioides*	*Centerosema pubescens*
Hibiscus lobatus	*Dioscorea alata*	*Curculigo orchioides*
Micranthus oppositifolius	*Globba ophioglossa*	*Globba marantina*
Mimosa pudica	*Hemidesmus indicus*	*Globba ophioglossa*
Hemidesmus indicus	*Ichnocarpus frutescens*	*Hemidesmus indicus*
	Ludwigia hyssopifolia	*Hibiscus furcatus*
	Merremia umbellata	*Hibiscus lobatus*
	Micranthus oppositifolius	*Ichnocarpus frutescens*
	Mimosa pudica	*Justicia trinervia*
	Synedrella nodiflora	*Laportea interrupta*
		Ludwigia hyssopifolia
		Merremia umbellata
		Micranthus oppositifolius
		Mimosa pudica
		Phyllanthus urinaria
		Sida beddomei
		Synedrella nodiflora

Table 136. Herb species composition in plantation during second wet 1995
(Cold burn)

Control	After burn
Achyranthes aspera	*Ahyranthes aspera*
Cryptolepas buchnanii	*Alysicarpus monolifer*
Curculigo orchioides	*Centerosema pubescens*
Hemidesmus indicus	*Curculigo orchioides*
Ichnocarpus frutescens	*Hemidesmus indicus*
Justicia trinervia	*Hibiscus lobatus*
Ludwigia hyssopifolia	*Ichnocarpus frutescens*
Micranthus oppositifolius	*Justicia trinervia*
Mimosa pudica	*Ludwigia hyssopifolia*
Rungia sp.	*Micranthus oppositifolius*
Uraria hamosa	*Mimosa pudica*
	Oldenlandia nitida
	Rungia sp.
	Sida beddomei
	Synedrella nodiflora
	Thunbergia fragrans
	Uraria hamosa

Table 137. Shrub species composition in plantation during first wet 1995
(Cold burn)

Before burn	Control	After burn
Bambusa arundinacea	*Abutilon sp.*	*Abutilon sp.*
Desmodium gangeticum	*Bambusa arundinacea*	*Bambusa arundinacea*
Desmodium laxiflorum	*Desmodium trianqulare*	*Crotalaria striata*
Desmodium pulchellum	*Eupatorium odoratum*	*Desmodium laxiflorum*
Eupatorium odoratum	*Helicteres isora*	*Desmodium pulchellum*
Helicteres isora	*Hibiscus furcatus*	*Desmodium trianqulare*
Hibiscus furcatus	*Lantana camara*	*Eupatorium odoratum*
Helicteres isora	*Randia dumatorum*	*Helicteres isora*
Lantana camara	*Sida rhombifolia*	*Hibiscus furcatus*
Pseudarthria viscida	*Triumfetta rhomboidea*	*Lantana camara*
Randia dumatorum	*Urena lobata*	*Pseudarthria viscida*
Sida rhombifolia	*Ziziphus oenoplia*	*Randia dumatorum*
Triumfetta rhomboidea		*Sida mysorensis*
Urena lobata		*Sida rhombifolia*
Ziziphus oenoplia		*Triumfetta rhomboidea*
		Urena lobata
		Ziziphus oenoplia

Table 138. Shrub species composition in moist deciduous during second wet 1995
(Cold burn)

Control	After burn
Bambusa arundinacea	*Bambusa arundinacea*
Desmodium laxiflorum	*Desmodium gangeticum*
Desmodium trianqulare	*Desmodium laxiflorum*
Eupatorium odoratum	*Eupatorium odoratum*
Helicteres isora	*Flemingia strobilifera*
Pseudarthria viscida	*Helicteres isora*
Randia dumatorum	*Pseudarthria viscida*
Sida rhombifolia	*Randia dumatorum*
Triumfetta rhomboidea	*Sida rhombifolia*
Urena lobata	*Triumfetta rhomboidea*
Ziziphus oenoplia	*Urena lobata*
	Ziziphus oenoplia

7.4 Discussion

Indiscriminate burning, cutting and grazing in remnant tall grass patches in the reserved forest and tea estates have been reported to be responsible for the decline of pygmy hogs in Assam (Olivier, 1980). Deshmukh (1985) suggested burning as a good habitat management where dead grasses inhibiting further meristematic activity is removed and nutrient turn over increased. Fire is said to have an immediate effect on vegetation by changing the cover and food, on soil by loss of litter, deposition of ash and hardening of surface, and water by changed permeability increasing surface flow. Many of these effects are related and interacting. Fire ecology is thus considered to be difficult to understand and evaluate.

Fire study in Parambikulam indicates that impact of fire on vegetation in different habitat types differed according to seasons. However, effect of fire on grass species indicated an increase in number and biomass in moist deciduous and grassland habitat types during both summer and cold burn. Grass species in plantation showed a decreasing trend during summer burn but recorded a slight increase during cold burn.

Afolayan (1979) observed a higher basal cover and tillering rate for tall perennial grass when subjected to hot late burning compared to no burning. An early burning is reported to favour annual grass forbs and woody plants. But heavy grazing can reverse the process leading to a decline in the vegetation cover as a whole and accelerated growth of opportunistic and unpalatable species.

Schaller (1967) suggested that burning of forest areas was not beneficial though the grass flush on the meadows provide the major food sources in the dry season. Discontinual of burning of meadows in Kanha seems to have resulted in an increase in the number of animals to the new food source. Panwar (nd.) observed invasion of woody species to the meadow and suggested that the management needs "the evolution of pragmatic regime of periodic burning after verifying through field trials.

Laurie (1978) reported attraction of Rhinos from wide area during spring and summer as a result of post burning followed by grass regrowth in Chitwan and Kaziranga. Dinerstein (1979 a & b) observed emergence of perennial grasses in fire burnt areas even under the conditions otherwise least favourable for ungulates.

Removal of flowered bamboo in Tadoba National Park has only increased incidences of fire (Choudhury, 1986). Deb Roy (1986) advocates controlled early buring of grasslands for the benefit of the animals and habitat.

Fire has resulted in disturbed habitat condition of soil microorganisms but has held emergence of availability of grasses and herbs (Mithani *et al*. 1986). Some of the species have also been reported to be eliminated or reduced by fire. Johnsingh (1986) reported an increase in group size of chital during post fire season in dry deciduous forests of South India. He advocated burning to improve the forage availability of ungulates and suggested a complete ban if the objective is to protect fire intolerant species. Thorny species were predominant in fragmental burnt areas. Forest fire and cattle grazing enhanced the very fine roof standing crop biomass and NPP (Sundarapandian *et al*. 1996). Raman and Nagarajan (1996) reported a comparatively low VAM fungal infection on plants in burnt areas. According to Singh (1994), fire increases microbeal biomass in dry season. He suggested fire as a management tool to have better productivity and nutrient quality in dry tropical environment. Controlled burning experiments have always resulted in an increased grass biomass (Yadava and Singh, 1977). However, as observed by Panwar (nd.) heavy grazing pressure on the burnt grass areas often result in reduced production. In the experiments by Lehmkul (1989) in South Asian tall grass community, an equal or higher production were observed in early burnt plots than late burnt ones.

The Summer burning in Plantation in Parambikulam reduced biomass of grass species though the number of food species increased. Cold burning increased both biomass and number of grass species. Higher soil temperature because of increased litter fall and higher heat conductivity due to nearly nil soil moisture in plantation habitats during summer season may cause damages to roots of grass species. High temperatures have reduced production, presumably by damaging below-ground parts (Aristeguita and Medina, 1996). Lemkuhl (1989) found that the production in all early burnt plots (February) was equal to or higher than late burn (May) plots.

It was observed in Parambikulam that burning between December and January are only partial as patches of green grasses do not still burn. Rodgers (1986) also reported similar observation.

The less number of seedlings of shrubs like *Rubus alleghensis*, *Resa multiflora* and *Prunus serolinana* in early burnt (during December) areas due to the temperature bite on the immature seeds was reproted by Hartent (1991) and Hruska and Eblinger (1995). Karunakaran *et al.* (1997) reported both early and late burning to be hazardous to shrub species. Effect of fire on herb and shrub does not show any appreciable changes or benefit in Parambikulam. However, it changes species compositions.

Prabhoo (1984) reported decrease in species of soil fauna in burnt areas. Experiments in Ponmudi-Kallar region of Kerala showed an increase in surface temperature from 35^0 C to 160^0 C and the temperature 3cm below the surface raised from 33^0 C to 43^0 C. Prabhoo (1984) observed a higher density of earthworms and enchytracidae in burnt areas. In contrast, the arthropods and micro-arthropods were much higher in unburnt than burnt areas. Some of the species of micro-arthropods were found to be missing in areas after fire. Prabhoo (1983) reported further on decrease of arthopods in the burnt areas of most forest types but an increase was observed in eucalypts plantation.

It is concluded that using fire for management have to be designed according to habitat type, floral and faunal composition and physicochemical characteristics of the site. The decision to use fire for management is strictly dependent on the objective.

References

Abidin, Z.Z., M.T. Abdullah, M.A. Rahman, and E. Yusof. 1991. Large mammals in Peninsular Malaysia. In: (Ed.) Kiew, R. The State of Nature Conservation in Malaysia. Malayan Nature Society, Selangor.

Abrams, M.D. 1988. Effects of burning regime on buried seed banks and canopy coverage in a Kansas tall grass praire. *The Southwestern Naturalist*. 33(1): 65-70.

Afolayan, T.A. 1979. Change in percentage ground cover of perennial grass under different burning regims. *Vegetation*. 39(1): 35-41.

Ali, S.A. 1927. The Moghul Emperors of India as naturalists and sportsmen. *J. Bombay nat. Hist. Soc*. 31: 833-861.

Ali, S.A. and V.S. Vijayan. 1986. Keoladeo National Park Ecology study- Summary Report 1980 - 1985. Bombay Natural History Society, Bombay.

Altmann, J. 1974. Observational study of behavior: Sampling methods. *Behaviour* 49: 227-267.

Anonymous. 1987. SPSS/PC+ Trends for the IBM PC/XT/AT and PS/2. SPSS Inc. Chicago, Illinois, USA.

Anonymous. 1993. Wildlife Census - Kerala 1993. Kerala Forest Research Institute, Peechi, Thrissur, Kerala.

Aristegita, L. and E. Medina. 1966. Protection y quema de la sabina llanera. *Bol. Soc. Venez. Cienc. Nat*. 26: 129-139.

Baile, C.A. 1975. Control of food intake in ruminants. In: (Eds). McDonald I.W. and A.C.I. Warner. Digestion and Metabolism in the Ruminant University of New England Publishing Unit, Armidale.

Baker, S. 1890. Wild beasts and their ways. London.

Balakrishnan, M. and P.S. Easa. 1986. Habitat preference of larger mammals in the Parambikulam Wildlife Sanctuary, Kerala, India. *Biol. Conserv.* 37: 191-200.

Bansal, R.P. and R.C. Joshi. 1980. A note on rinderpest in gaur (*Bibos gaurus*). *Indian Vet. J.* 57: 259-260.

Barrette, C. 1991. The size of Axis deer fluid groups in Wilpattu national park, Sri Lanka. *Mammalia* 55: 207-220.

Basappanavar, C.H. 1985. Bandipur National Park - a paradise regained in tiger country. *Tiger paper* 12: 28-32.

Beekman, J.H. and H.H.T. Prins. 1989. Feeding strategies of sedentary large herbivores in East Africa with emphasis on the African buffaloes, *Syncerus caffer*. *Afr. J. Ecol.* 27: 129-147.

Beetle, A.A. 1955. The four subfamilies of the Gramineae. *Bull. Torrey bot. Club.* 82: 196-197

Beetle, A.A. 1958. *Piptochaetium* and *Phalaris* in the fossil record. *Bull. Torrey bot. Club.* 85: 179-181.

Bell, R.H.V. 1971. A grazing ecosystem in the Serengeti. *Scientific American* 225: 86-93.

Bellrose, F.C. and H.G. Anderson. 1943. Preferential ratings of duck food plants. *Illinois Nat. Hist. Surv. Bull.* 22: 417-433.

Belsare, D.K., S.C. Chandiramani and J.J. Dutta, 1984. Composition and behaviour of gaur group in Kanha National Park. *Cheetal* 26 : 28-31.

Berwick, S. 1974. The Community of Wild Ruminants in the Gir Forest Ecosystem. Ph. D. Thesis, Yale University.

Biddulph, C.H. 1936. Bison- Variation in colouration of the exposed part of the snout and tongue. *J. Bombay nat. Hist. Soc.* 39: 165.

Bines, J.A. 1976. Factors influencing the voluntary food intake in cattle. In: (Eds.) Swan .H and W.H. Broster. *Principles of Cattle Production*. Butterworth, London.

Bishop, Y.M.M., S.E. Feinberg and P.W. Holland. 1975. Discrete multivariate analysis: Theory and practice. Mass: MIT Press, Cambridge.

Blackburn, H.V. 1935. A Bull gaur *Bos gaurus* and a Tigress to death. *J. Bombay nat. Hist. Soc*. 37: 950-951.

Bligh, J. and A.M. Harthoorn. 1965. Continuous radiotelemetric records of the deep body temperature of some unrestrained African mammals under near-natural conditions. *J. Physiol.* 176: 145-162.

Blower, J. 1982. Species conservation priorities in Burma. In: (Eds.) Mittermeier, R.A. and W.R. Konstant. Species conservation priorities in the tropical forests of Southeast Asia. Occasional papers of the IUCN Species Survival Commission (SSC) number 1. IUCN, Gland, Switzerland.

Bojanus, H.L. 1827. De Uro nostrate eiusque sceleto commentatio. *Nova Acta Phys. Acad. Caes. Leopold - Carol. Nat. Curios.* 23: 413-478.

Booysen, P. de V. & N.M. Tainton (Eds) 1984. Ecological effects of fire in South African Ecosystems. *Springer Verlag*. Berlin.

Borowski, S. and S. Kossak. 1972. The natural food preferences of the European bison in seasons free of snow cover. *Acta Theriol*. 17: 151-169.

Borowski, S., Z. Krasinki and L. Milkowski . 1967. Food and role of the European bison in forest ecosystems. *Acta Theriol*. 12: 367-376.

Brander, D. A .A. 1923. Wild animals in Central India. London.

Brander, D. A. A. 1935. White bison. *J. Bombay nat. Hist. Soc*. 37: 951.

Branson, F.A. 1953. Two new factors affecting resistance of grasses to grazing. J. Range Manage. 6: 165-171.

Bray, G.A. 1974. Endocrine factors in the control of food intake. *Fed. Proc*. 33: 1140-1145.

Brink Van den, W.J. 1980. The behaviour of wisent and bison in larger enclosures. *Acta Theriol.* 25: 115-130.

Brody, S. 1945. Bioenergetics and growth. Hafner Press, New York.

Burnham, K.P., D.R. Anderson and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr*. 72: 1-202.

Cabon-Raczynska, K., M. Krasinska. and Z. Krasinski. 1983. Behaviour and daily activity rhythm of European bison in winter. *Acta Theriol*. 28: 273-299.

Cabon-Raczynska, K., M.Z. Krasinska., Z.A. Krasinski. And J.M. Wojcik. 1987. Rhythm of daily activity and behaviour of European bison in the Bialoweza forest in the period without snow cover. *Acta Theriol*. 32: 335-372.

Cameron, I. L. 1929. Body measurements of a Gaur, *Bibos gaurus*. *J. Bombay nat. Hist. Soc*. 33: 983-985.

Canh, L.X. 1995. A report on the survey for large carnivores in Tay Nguyen Plateau, South Vietnam with emphasis on tiger (*Panthera tigris*). Institute of Ecology and Biological Resources, *Hanoi and Wildlife Conservation Society*, New York.

Caraco, T. 1979a. Time budgeting and group size: A theory. *Ecology* 60: 611-617.

Caraco, T. 1979b. Time budgeting and group size: A test of theory. *Ecology* 60: 618-627.

Caughley, G. and J. Goddard. 1975. Abundance and distribution of elephants in Luangwa Valley, Zambia. *E. Afr. Wildl. J.* 13: 39-48.

Champion, H.G. and S. K. Seth. 1968. A revised survey of the forest types of India. Manger of Publications, Delhi.

Chattopadhyay, B. and T. Bhattacharya. 1986. Basic diurnal activity pattern of Black buck, *Antilope cervicapra* Linn. of Ballavpur Wildlife Sanctuary, W.B. and its Seasonal variation. *J. Bombay nat. Hist. Soc.* 83: 553-561.

Chazee, L. 1990. The mammals of Laos and the hunting practices. Unpublished mimeograph.

Choudhury, R. 1986. Fire in Bamboo area – lessons from Tadoba National Park. *Indian For.* 112(10): 900-907.

Climo, L. 1990. Wildlife survey in the Samopun Valley. Khao Yai National Park, Thailand. A report prepared for the National Park Division, Royal Forest Department and Wildlife Fund, Thailand.

Clough, G. and A. G. Hassam. 1970. A quantitative study of the daily activity of the Warthog in the Queen Elizabeth National Park, Uganda. *E. Afr. Wildl. J.* 8: 19-24.

Coe, M. 1980. A look at wildlife management in India. *Oryx* 15: 60-65.

Colman, R.L. and A. Lazenby. 1970. Proc. 11th Int. Grassld. Congress. Surface Paradise, Queensland.

Conry, P.J. 1980. The impact of development and the behavioural response of the Malaysian seladeng. In: (Ed.) Furtade, J. I. Tropical Ecology and Development, Proc. Vth. Int. Symp. of Tropical Ecology, International Society of Tropical Ecology, Kuala Lumpur. 279-286.

Conry, P.J. 1981. Habitat selection and use, movements and home range of Malayan gaur *Bos gaurus hubbacki* in Central Pahang, Malaysia. M.S. Thesis, University of Montana, Missoula.

Conry, P.J. 1989. Gaur *(Bos gaurus)* and development in Malaysia. *Biol. Conserv*. 49 : 47-65.

Cooke, H.B.S. 1968. Evolution of mammals on southern continents. Part 2. The fossil mammals fauna of Africa. *Quart. Rev. Biol.* 43: 234-264.

Cooper, J.P. 1973. In: (Eds.) Butler, G. W. and R. W. Bailey. Chemistry and Biochemistry of herbage. Vol.2. Academic press, London.

Coutinho, L.M. 1982. Ecological effect of fire on the Brazilian Cerrado. In: (Ed.) Huntly, B.J. and B.H. Walker. Ecology of Tropical Savanas. Springer-Verlag, Berlin. 273-291.

Crawley, M.J. 1983. Herbivory. The Dynamics of Animal-plant interactions. Blackwell Scientific publications, Oxford.

Crook, J.H., 1972. Sexual selection, dimorphism and social organization in the primates. In: (Ed.) Campbell, B. Sexual selection and the descent of man, 1871-1971, Aldine, Chicago, Illinois, USA.

Crook, J.H., J.E. Ellis and J. D. Goss-Custard. 1976. Mammalian social systems; structure and function. *Anim. Behav*. 24: 261-274.

Daubenmire, R. 1968. Ecology of fire in grasslands. Adv. In *Ecol. Research*. Vol. 5: 209-266. Academic Press.

Davidar, E.R.C. 1970. White Bison of Manjapatti. *J. Bombay nat. Hist. Soc*. 67: 565-569.

Deb Roy, S. 1986. Fire in wet grassland habitats of Assam. *Indian For.* 112(10): 914-917.

Debroy, S. 1991. Manas - a monograph. *Tiger paper* 18: 6-15.

Delany, M.J. and H.C.D. Happold. 1979. Ecology of African Mammals. Longmans, London.

Denham, W.W. 1971. Energy relations and some basic properties of primate social organization. *American Anthropologist* 73: 77-95

Deshmukh, I. 1985. Decomposition of grasses in Nairobi National Park. Kenya. *Decologia.* 67: 147-149.

Dinerstein, E. 1979. An ecological survey of the Rayal Karnali - Bardia Wildlife Reserve, Nepal. Part II: Habitat/ Animal interaction. *Biol. Consery.* 16: 265-300.

Dinerstein, E. 1979a. An ecological survey of the Royal Karnali – Bardia Wildlife Reserve, Nepal. I. Vegetation, modifying factors and successional relationships. *Biol. Cons*. 15: 127-150.

Dinerstein, E. 1979b. An ecological survey of the Royal Karnali – Bardia Wildlife Reserve, Nepal. II. Habitat animal interactions. *Biol. Cons*. 15: 265-299.

Dinerstein, E. 1987. Deer, Plant phenology and succession in the Lowland Forests of Nepal. In: (Ed.) Wemmer, C. M. Biology and Management of the Cervidae. Smithsonian Institution Press. Washington DC.

Dobias, R.J. 1982. The Shell Guide to the National Parks of Thailand. The Shell Company of Thailand Limited, Bangkok.

Dobias, R.J. 1985. Elephant Conservation and Protected Area Management. WWF/IUCN Project 3001, Final report. No.28.

Duckworth, J.W., R.J. Timmins, R.C.M. Thewlis, T.D. Evans and G.Q.A. Anderson. 1994. Field observations of mammals in Laos, 1992-93. *Nat. Hist. Bull. Siam Soc*. 42: 177-205.

Duncan, P. 1975. Topi and their food supply. Ph.D. Thesis, University of Nairobi, Nairobi.

Duplessis, S.S. 1972. Ecology of blesbok with special reference to productivity. *Wildl. Monogr*. 30: 1-70.

Dwivedi, G.D. and R. Shukla. 1988. The Pench bision - An Ecological and behavioural study. *Cheetal* 29 : 28-31.

Easa, P.S. 1988. Movement Pattern of Asiatic Elephant, *Elephas maximus* in Parambikulam Wildlife Sanctuary. KFRI Research Report No.54, Kerala Forest Research Institute, Peechi, Thrissur, Kerala.

Easa, P.S. 1989. Certain aspects of ecology and ethology of the Asian elephants (*Elephas maximus* Lin.). in Parambikulam Wildlife Sanctuary, South India. Ph.D. Thesis, Department of Zoology, University of Kerala, Trivandrum.

Easa, P.S. and M. Balakrishnan. 1990. Population ecology and management problem of large mammals in the Parambikulam Wildlife Sanctuary, Kerala. In: (Eds.) Daniel, J.C. and J.S. Serrao. Conservation in developing countries; problems and prospects. Proceedings of the centenary seminar of the Bombay Natural History Society, Bombay.

Eisenberg, J.F. 1966. The social organisation of mammals. *Hdb. d. Zool.* 8: 1-92.

Eisenberg, J.F. and M. Lockhart. 1972. An Ecological Reconnaissance of Wilpattu National Park, Ceylon. Smithsonian Contribution to Zoology. No. 101: 47-51.

Eltringham, S.K. 1979. The ecology and conservation of Large African Mammals, McMillan Press, London.

Estes, R.D. 1974. Social organization of the African bovidae. In: (Eds.) Geist, V. and F. Walther. The behaviour of ungulates and its relation to management. Vol. I. IUCN, Morges.

Estes, R.D. 1976. The significance of breeding synchrony in the wildebeest. *E. Afr. Wildl. J.* 14: 135-152.

Fleming, G.A. 1973. In : (Eds.) Butler, G.W. and R.W. Bailey. Chemistry and Biochemistry of herbage. Vol.1. Academic Press, London.

Foenander, M.E. 1952. Big Game of Malaya. Batchworth Press, London.

Fuller, W.A. 1960. Behaviour and social organization of the wild bison of Wood Buffalo National Park, *Canad. Arctic*. 13: 1-19.

Gaare, E., B.R Thomson and O.Kjos-Hanssen. 1975. Reindeer activity on Hard-angervidde In: “Fennoscandian tundra ecosystems”, Ecological studies Analysis and synthesis. Wielgolaski (Ed.) Springer Verlag. Berlin, Heidelberg, New York.

Gates C.C and R.J. Hudson. 1979. Effects of posture and activity on metabolic responses of Wapiti to cold. *J. Wildl. Manage*. 43: 564-567.

Gebezynska, Z. 1980. Food of the roe deer and red deer in the bialowieza primeval Forest. *Acta Theriol*. 25: 487 - 500.

Gebezynska, Z. and M. Krasinska. 1972. Food preferences and requirement of the European bison. *Acta Theriol*. 17: 105-117.

Gebezynska, Z., M. Gebczzynski and E. Martynowicz. 1991. Food eaten by the free-living European bison in bialowieza Forest. *Acta Theriol.* 36: 307-313.

Gill, J. 1967. The physiological properties of the European bison. *Acta Theriol*. 12 : 349-360.

Glading, B., H. H. Biswel and C.F. Smith. 1940. Studies on the food of the California Quail in 1937. *J. Wildl. Manage.* 4: 128-144.

Gomide, J.A., C.H. Noller, G.O. Mott, J.H. Conrad and D.L. Hill. 1969. *Agron. J*. 61: 116-120

Green, W.C.H. and A. Rothstein. 1993. A synchronous parturition in bison: Implications for the hider - follower dichotomy. *J. Mamma*. 74: 920- 925.

Grobler, J.H. 1983. Feeding habit of the Cape mountain zebra *Eques zebra zebra* Linn., 1758. *Koedoe*. 26: 159-168.

Grobler, J.H. 1981. Feeding behaviour of sable *Hippotragus niger* (Harris, 1838) in the Rhodes Matopos National Park, Zimbabwe. *South Affrican Journal of Zoology* 16: 50-58.

Groombridge, B. 1993. 1994 IUCN Red list of threatened animals. IUCN, Gland, Switzerland.

Haberman, S.J. 1978. Analysis of Qualitative Data. Vol.1. Acdamic press, London.

Hacker, J.B., R.W. Strickland, and K.E. Basford. 1985. *Aust. J. Agric. Res.* 36: 201-212

Hadley, E.B. 1970. Net productivity and burning responses of native eastern North Dakota prairie communities. *Amer. Midl. Nat.* 84: 121-135.

Herrig, D.M. and A.O. Haugen. 1970. Bull bison behaviour traits. *Proc. Iowa. Acad. Sci.* 76: 245-262

Hobbs, N.T., D.L. Baker, J.E. Ellis and D.M. Swift. 1981. *J. Wildl. Manage.* 45: 156-171.

Hoe, H. and V. Quy. 1991. Nature conservation in Vietnam: an overview. *Tiger Paper* 18: 1-9.

Hrusska, M.C. and J.E. Ebinger. 1995. Monitoring a savana restoration in east central Illionis. *Transactions of the Illionis State University Academy Science.* 88(3): 109-117.

Hulbert, L.C. 1988. Causes of fire effects in tallgrass praire. *Ecology*, 69: 46-58.

Hundley, H.G. 1951. Measurements of an Indian Bison head, *Bibos gaurus*. *J. Bombay nat. Hist. Soc*. 50: 933-934.

Hutton, A. F. 1951. Gaur attacking man. *J. Bombay nat. Hist. Soc*. 50: 166.

International Union for the conservation of Nature and Natural Resources. 1986. The IUCN Mammal Red Data Book IUCN, Gland, Switzerland.

Irby, R.L. 1982. Diurnal activity and habitat use patterns in a population of Chanler's mountain reedbuck in the Rift Valley of Kenya. *Afr. J. Ecol.* 20: 169-178.

Ishwaran, N. 1984. The ecology of the Asian elephant (*Elephas maximus* L.) in Sri Lanka. Ph. D. Thesis, Michigan State University.

Jaczewski, Z. 1958. Reproduction in the European bison, *Bison bonasus* L., in reserves. *Acta Theriol*. 1: 333-376.

Jarman, M.V. and P.J. Jarman. 1973. Daily activity of Impola. *E. Afr. Wildl. J.* 11: 75-92.

Jarman, P.J. 1974. The social organization of Antelope in relation to their ecology. *Behaviour* 48: 216-267

Jarman, P.J. and A.R.E. Sinclair. 1979. Feeding strategy and the pattern of resource - partioning in ungulates. In: (Eds.) Sinclair, A.R.E. and M.Norton - Griffiths. Serengeti. Dynamics of an ecosystem. University of Chicago Press, Chicago, USA.

Jerdon, T.C. 1984. A hand book of the mammals of India. Mittal publications, Delhi.

Johnson, C.N. 1983. Variations in group size and composition in red and western grey kangaroos *Macropus ruful* (Desmarest) and *M. fuliginosus* (Desmarest). *Aust. Wildl. Res.* 10: 25-31.

Johsingh, A.J.T. 1986. Impact of fire on wildlife ecology in two dry deciduous forests in South India. *Indian For*. 112(10): 933-938.

Jones, C.A. 1985. C_4 Grasses and Cereals. Wiely, New York. 419 pp.

Jones, D.I.H. and A.D. Wilson. 1987. Nutritive quantity of forage. In: (Eds). Hacker, J.B. and J.H. Jernouth. The nutrition of herbivores. Academic Press, London.

Karanth, K.U. 1986. Status of wildlife and habitat conservation in Karnataka. *J. Bombay nat. Hist. Soc.* 83: 166-179.

Khan, J.A., R. Chellam and A.J.T. Jhonsingh. 1995. Group size and age-sex composition of three major ungulate species in Gir Lion Sanctuary, Gujarat, India. *J. Bombay nat. Hist. Soc*. 92: 295-302.

Khan, M., S.T. Elagupillay and Z.B. Zainal. 1982. Species conservation priorities in the tropical rain forests of Peninsula Malaysia. In: (Eds.) Mittermeier, R.A. and W.R. Konstant. Species conservation priorities in the tropical forests of Southeast Asia. Occasional papers of the IUCN Species Survival Commission (SSC) 1: 9-15. IUCN, Gland, Switzerland.

Khan, M.K.M. 1973. Studies of the seladang (*Bos gaurus*) in the State of Perak. *J. Malay. Nat. Soc.* 26:163-169.

Kitchener, H.J. 1961. A bleak prospect for the seladang or Malayan gaur. In Nature conservation in Western Malaysia. *Malay. Nat. J.* (Special Issue) 197-201.

Klein, David R. 1970. Food selection by North American deer and response to over utilization of food plants species. In: (Ed.) Watson, A. Animal population in relation to their food resources. Blackwell Scientific Publications, Oxford.

Korockina, L. N. 1969. Vidovoj sostav lesnoj travianistoj rastitel'nosti v pitani zubrov belovezskoj pusci. *Belovzskaja pusca, Issledovanija* 3: 204-221.

Korockina, L. N. 1972. Sutocnyj ritm aktivnosti zubrov Belovezkoj Pusci. *Belovezskaja Pusca*. 6: 125-131.

Kozlowski, T.T. & C.E. Ahlgren (Eds). 1974. Fire & Ecosystems. Academic Press, New York.

Krasinska, M and Z.A. Krasinski. 1995. Composition, group size and spatial distribution of European bison bulls in Bialowieza Forest. *Acta Theriol.* 40: 1-21.

Krasinska, M., K. Cabon-Raczynska and Z.A. Krasinski. 1987. Strategy of habitat utilization by European bison in the Bialowieza Forest. *Acta Theriol*. 32:147-202.

Krasinski, Z.A. 1967. Free living European Bison. *Acta Theriol*. 12: 391-405.

Krasinski, Z.A. 1978. Dynamics and structure of the European Bison population in the Bialowieza Primeval Forest. *Acta Theriol.* 23: 3-48.

Krasinski, Z.A. and M. Krasinska. 1992. Free ranging European bison in Borecka Forest. *Acta Theriol*. 37: 301-317.

Krischke, N. 1984. Beitrage Zum Sozialverhalten des wisents (*Bison bonasus* L.). *Z. Saugetierkde.* 49: 43-54.

Krishnan, M. 1972. An ecological survey of the larger mammals of Peninsular India. The Indian elephant. *J Bombay nat. Hist. Soc*. 69:297-315.

Krishnan, M. 1975. India's wildlife in 1959-70 - An ecological survey of the larger mammals of Peninsular India. Bombay Natural History Society, Bombay.

Kucera, C.I. 1981. Grasslands and fire. In: Fire Regimes and Ecosystem Properties. *USDA Forest Service Gen. Tech. Rep.* WO-26. USDA Forest Service, Washington, D.C.

Kurt, F. 1974. Remarks on social structure and ecology of Ceylon elephant in the Yala National Park. In: (Eds.) Giest, V. and F. Walther. Behaviour of Ungulates and its Relation to management. IUCN Publication, New Series 24.

Kutintara, U. and S. Pongumphai. 1982. Khao Yai Ecosystem Project Final Report Vol. IV. *Wildlife*. Faculty of Forestry, University, Bangkok.

Laake, J.L., S.T. Buckland, D.R. Anderson and K.P. Burnham. 1994. Distance users guide, version 2.1. Colorado Co-operative fish and wildlife Research Unit, Colorado University, Fort Collins, U.S.A.

Lal, P. 1974. The tribal man in India, a study in the ecology of primitive communities. In: (Ed.) Mani, M.S. Ecology and Biogeography in India. Junk. Hague.

Langer, R.H.M. 1972. How grasses grow. Arnold, London.

Larter, N.C. 1988. Diet and habitat selection of an erupting wood bison population. M.S. Thesis, University of British Columbia, Vancouver.

Larter, N.C. and C.C. Gates. 1991. Diet and habitat selection of wood bison in forage quantity and quality. *Can. J. Zool.* 69: 2677-2685.

Larter, N.C. and C.C. Gates. 1994. Home Range Size of Wood Bison: Effects of Age, Sex and Forage availability. *J. Mamma.* 75:142-149.

Laurie, A., H.D. DUC and P.T. ANH. 1989. Survey for Kouprey (*Bos sauveli*) in western Daklak Province, Vietnam. The Kouprey Conservation Trust and IUCN.

Laurie, W.A. 1978. The ecology of the Greater one-horned rhinoceros. Ph.D. Thesis. Cambridge University, Cambridge.

Lehmkuhl, J.F. 1989. The ecology of a South-Asian tall grss community. Ph. D. Thesis. University of Washington.

Lekagul, B. 1952. Hunting of gaur: Life History, Behaviour and Hunting Etiquette. *The Science Society of Thailand*, Bangkok.

Lekagul, B. and J. McNeely. 1977. Mammals of Thailand. Association for the conservation of the wildlife, Bangkok.

Leuthold, B.M. and W. Leuthold. 1978. Daytime activity patterns of generuk and giraffe in Tsavo National Park, Kenya. *E. Afr. Wildl. J.* 16: 231-243.

Leuthold, W. and B.M. Leuthold. 1975. Pattern of social grouping in ungulates of Tsavo National Park, Kenya. *J. Zoo. Lond*. 175: 405-420.

Linsdale, J.N. and P.Q. Tomich. 1953. A herd of Mule deer. Berkely, University of California Press, California.

Longhurst, W.M. and Douglas, J.R. 1953. Parasite interrelationships of domestic sheep and Columbian black-tailed deer. *Trans. N. Am. Wildl. Nat. Resour. Conf.* 33: 181-92.

Lyttleton, J.W. 1973. In: (Eds.) Butler, G.W. and R.W. Bailey. Chemistry and Biochemistry of herbage. Vol.2. Academic press, London.

Ma, S.L., L.X. Han and D.Y. Lan. 1994. Bird and mammal resources and nature conservation in the Gaoligongshan region, Yunnan Province, People's Republic of China. Kuming Institute of Zoology, Kuming.

MacKinnon, J., A. Laurie, M. Nhieu, D.H. Huynh, L. Khoi and H.D. Duc. 1989. Draft Management plan for Yak Don Nature Reserve, Easup District, Daklak Province, Vietnam. WWF, Hong Kong.

Maithani, G.P., V.K. Bahuguna and P. Lal. 1986. Effect of forest fires on the ground vegetation of a moist deciduous Sal (*Shorea robusta*) forest. *Indian For*. 112(8): 646-678.

McBride, G. 1976. The study of social organization. *Behaviour* 59: 96-115.

McCullough, D.R. 1993. Variation in black-tailed deer herd composition counts. *J. Wildl. Manage*. 57: 890-897.

McCullough, D.R. 1994. What do herd composition counts tell us?. *Wildl. Soc. Bull.* 22: 295-300.

McDowell, L.R. 1985. Nutrition of grazing ruminants in warm climates. Academic Press, New York.

McHugh, T.S. 1958. Social behaviour of the American buffalo (*Bison bison bison*). *Zoologica* 43: 1-10.

McHugh, T.S. 1972. The time of the buffalo. A.A. Knopt, New York.

McKay, G.M. 1973. Behaviour and ecology of the Asiatic elephant in southeastern Ceylon, Smithsonian Contribution to Zoology, Number 125, Smithsonian Institution Press, Washington DC.

McNaughton, S.J. 1985. Ecology of a grazing ecosystem. The Serengeti. *Ecol. Monogr*. 55: 259-294.

McNaughton, S.J. 1987. Adaptation of herbivores to seasonal changes in nutrient supply. In: (Eds.) Hacker, J.B. and J.H. Ternoth. The nutrition of herbivores, Academic Press, Sydney, Australia.

McNaughton, S.J. and N.J.Georgiadis. 1986. Ecology of African grazing and browsing mammals. *Ann. Rev. Ecol. Syst.* 17: 39-65.

Meagher, M.M. 1973. The bison of Yellowstone National Park. *National Park Service Scientific Monograph Series* 1: 1-161.

Menon, A.R.R. 1991. Vegetation analysis and mapping of Parambikulam Wildlife Sanctuary. KFRI Research Report No. 79, Kerala Forest Research Institute, Peechi, Thrissur, Kerala.

Midas. 1993. Conservation Forest Area Protection, Management and Development Project. Pre-investment study. Final Report. Vol.7. Midas Agronomics Company Ltd., Bangkok.

Mishra, H.R. 1982. The ecology and behaviour of chital (*Axis axis*) in the Royal Chitwan National Park, Nepal. Ph. D. Thesis, University of Edinburgh, UK.

Mishra, H.R. and C.M. Wemmer. 1987. The comparative breeding ecology of four Cervids in Royal Chitwan Natonal Park. In: (Ed.) Wemmer, C. M. Biology and Management of the Cervidae Smithsonian Institution Press, Washington DC.

Mitchell, A.W. 1977. Preliminary observations on the daytime activity patterns of lesser kudu in Tsavo National Park, Kenya. *E. Afr. Wildl. J.* 15: 199-206.

Mitchell, B., B. W. Staines and D. Welch. 1977. Ecology of red deer. A research review relevant to their management in Scotland. Banchory Institute of Terrestrial Ecology.

Miura, S. 1981. Social behaviour of the Axis deer in dry season in Guindy sanctuary, Madras. *J. Bombay nat. Hist. Soc*. 78: 125-138.

Moorthy, B. 1989. Ecology and conservation of gaur (*Bos gaurus*) in Berijam Reserve Forest, Palani Hills. M.Sc. Thesis, A.V.C. College, Tamil Nadu.

Morris, R.C. 1930. On distinguishing between males and females and others controversial matters pertaining to the Gaur. *J. Bombay nat. Hist. Soc*. 34: 801.

Morris, R.C. 1937. Solitary Bull bison *Bibos gaurus*. *J. Bombay nat. Hist. Soc*. 39: 617.

Morris, R.C. 1938a. Behaviour of Gaur or Indian Bison. *J. Bombay nat. Hist. Soc*. 40: 325.

Morris, R.C. 1938b. On whistling of a Bison. *J. Bombay nat. Hist. Soc*. 40: 117.

Morris, R.C. 1947. Weight of Bull Bison. *J. Bombay nat. Hist. Soc*. 47: 153.

Morris, R.C. 1948a. A diseased Gaur. *J. Bombay nat. Hist. Soc*. 48: 578.

Morris, R.C. 1948b. Charge by unwounded Bison. *J. Bombay nat*. *Hist. Soc*. 48 : 578-579.

Morris, R.C. 1952. Cases of unwounded Gaur or Indian Bison, *Bibos gaurus* charging. *J. Bombay nat. Hist. Soc*. 51: 266.

Morris, R.C. 1954a. Extraordinary behaviour of a Solitary Bison (Gaur). *J. Bombay nat. Hist. Soc*. 52: 916.

Morris, R.C. 1954b. Gaur attacking man. *J. Bombay nat. Hist. Soc*. 52: 204-205.

Mustill, F.J. 1938. Behaviour of gaur or Indian Bison (*Bibos gaurus*). *J. Bombay nat. Hist. Soc*. 40 : 731-733.

Nair, P.V. and E.A. Jayson. 1988. Habitat utilization by large mammals in teak plantations and natural forests. KFRI Research report No. 56, Kerala Forest Research Institute, Peechi, Thrissur, Kerala.

Nair, P.V. and E.A. Jayson. 1990. Interaction between elephants and teak plantations in Parambikulam Wildlife Sanctuary. Proceeding of the Elephant Symposium, Trivandrum. Kerala Forest Department, Trivandrum: 58-65.

Nair, P.V., K.K. Ramachandran, V.S. Vijayan, P.S. Easa and P.V. Balakrishnan. 1985. An ecological study in Periyar Tiger Reserve with special reference to wildlife. KFRI Research Report No. 28, Kerala Forest Research Institute, Peechi, Thrissur, Kerala.

Nakhasathien, S. 1989. Chiew Larn Dam Wildlife Rescue Operation. *Oryx* 23: 146-154.

Neu, C.N., C. Randall Byers and J.M. Peek. 1974. A technique for analysis of utilization - availability data. *J. Wild. Manage.* 38 : 541-545.

Neyra, C.A. and A. Dobereiner. 1978. Nitrogen fixation in grasses. Advances on Agronomy, Academic Press.

Ngampongsai, C. 1987. Habitat use by the sambar deer (*Cervus unicolor*) in Thailand: A case study for Khao-Yai National Park. In: (Ed.) Wemmer, C.W. Biology and Management of the Cervidae, Smithsonian Institution Press, Washington DC.

Norton, B.W. 1982. In: (Ed) J.B. Hacker. Nutritional limits to Animal production from pastures. *Commw. Agric. Bureaux*: Farnham Royal, UK .

Norton-Griffiths, M. 1979. The influence of grazing, browsing and fire on the vegetation dynamics of the Serengeti. In: (Ed.) Sinclair, A.R.E. and M. Norton-Griffiths.

Serengeti- Dynamics of ecosystem. University of Chicago Press, Chicago. Pp. 310-352.

Novellie, P. and A. Winkler. 1993. A simple index of habitat suitability for Cape mountain zebras. *Koedoe* 36: 53-59.

Oliver, W.L.R. 1980. The Pigmy Hog. Special Scientific Report No.1. The Jersey Wildlife Preservation Trust. Jersey, Channel Isles.

Olivier, R. and M.Woodford. 1994. Aerial surveys for kouprey in Cambodia. IUCN Species Survival Commission. IUCN, Gland, Switzerland.

Olivier, R.C.D. 1978a. On the ecology of the Asian elephant. Ph. D. Thesis, University of Cambridge, England.

Olivier, R.C.D. 1978b. Distribution and status of the Asian elephant. *Oryx* 14: 379-424.

Ovington, J.D. 1984. Ecological Processes and National Park Management in McNeely, J.A. & Miller, K.R. (Eds). National Parks, Conservation and Development, Smithsonian Institute, Washington DC.

Owen-Smith, N. 1979. *S. Afr. J. Wildl. Res.* 9: 102-110.

Owen-Smith, N. 1982. Factors influencing the consumption of plant products by herbivores. In: (Eds) Huntley, B.J. and B.H. Walker. Ecological studies. Vol. 42 (Ecology of Tropical Savanna), Springer-Verlag, Berlin.

Owen-Smith, N. 1985. Niche separation among African ungulates. In: (Ed.) VRBA, E.S.. Species and speciation. *Transval Museum Monograph* No. 4, Transval Museum, Pretoria, South Africa.

Owen-Smith, N. 1988. Megaherbivores. Cambridge University Press, Cambridge.

Owen-Smith, N. and P.A. Novellie. 1982. What should a clever ungulate eat? *Amer. Natu.*. 119:151-178.

Paliphod, J. 1989. Effect of Mhu Ban Ruksa Pa Pracha Ruk Sat Project on natural resources in Phukheow Wildlife Sanctuary, Changwat Chaivaphum. M.S. Thesis, Kasetsart University, Bangkok. (In Thai with English abstract).

Pankspepp, J. 1974. Hypothalamic regulation of energy balance and feeding behaviour. *Fed. Proc*. 33: 1150-1165.

Panwar, H.S. (nd). Success with the Branderi Barasinga in Kanha National Park. In: IUCN Working Meeting of Survival Service Commission, Longview, Washington, USA.

Phillipson, J. 1975. Rainfall, primary production and carrying capacity of Tsavo National park (East) Kenya. *E. Afr. Wildl J.* 13: 171-201.

Piezy, R.M. 1940. On the distinction between Indian and Malayan Gaur. *J. Bombay nat. Hist. Soc*. 41: 657-658.

Pilgrim, G.E. 1939. The fossil bovidae of india. *Mem. Goel. Surv. India. Palaeont. Indica*. 26: 1-356.

Pillai, B. S. 1951. The record spread of Gaur horns, *Bibos gaurus. J. Bombay nat. Hist. Soc*. 50: 935-936.

Powell, G.V.N. 1974. Experimental analysis of the social value of flocking by starlings (*Sturnus vulgaris*) in relation to predation and foraging. *Animal behaviour* 22: 501-505.

Prabhakar, A. 1992. An ecological investigation on gaur (*Bos gaurus*) in Ulandy Range of Indira Gandhi National Park, Tamil Nadu, South India. M.Sc. Thesis, A.V.C. College, Tamil Nadu, India.

Prabhoo, N.R. 1984. Post fire ecology of tropical forests and grassland in the Western Ghats (Kerala section) with special reference to soil fauna. *Technical Report*. Dept. of Zool., University of Kerala.

Prabhoo, N.R., T.S. Rajan, V. Muraleedharan and C.G.A. Pai. 1983. Preliminary observations on the effect of fire on soil arthropoda in the forests of Kerala. In: (Eds.) Sen-Sarma, Sangal and Kulshretha. Insect inter-relations in forest and agroecosystems.

Pulliam, H.R. 1973. On the advantages of flocking. *Journal of Theoretical Biology* 38: 419-422.

Rabinowitz, A., G.B. Schaller and U. Uga. 1995. A survey to assess the status of Sumatran rhinoceros and other large mammal species in Tamanthi Wildlife Sanctuary, Myanmar. *Oryx* 29: 123-128.

Radhakrishnan, C. 1996. Survey of reptilian fauna of Parambikulam Wildlife Sanctuary, Kerala. *Cobra* 24: 7-12.

Ramachandran, K.K. 1988. Ecology and behaviour of Malabar giant squirrel, *Ratufa indica maxima*. KFRI Research Report No. 55, Kerala Forest Research Institute, Peechi, Thissur, Kerala.

Ramakrishnan, P.S. 1985. Tribal man in the humid tropics of the north east. *Man in India*. 65(1): 1-32.

Raman, N. and N. Nagarajan. 1996. Effect of forest fire on VAM fungi in a tropical forest of southern India. *Commenwealth Forestry Review*. 75(3): 247-252.

Rao, V. 1961. Annual report on wildlife preservation in West Bengal for the year 1958-59. West Bengal Government Press, Alipore.

Reid, R.L. and G.A. Jung. 1965. *J. Anim. Sci.* 24: 615-625.

Reynolds, H.W., R.D. Glaholt and A.W.L. Hawley. 1982. Bison. In: (Eds.) Chapman J.A. and C.A. Feldhamer. Wild animals of North America; Biology, Management and Economics. John Hapkins University Press, Baltimore.

Rice, C.G. 1984. The behaviour and ecology of Nilgiri tahr (*Hemitragus hylocrius* Ogliby, 1838). Dissertation, Texas A&M University.

Rice, C.G. 1986. Observations on predators and pery at Eravikulam National Park, Kerala. *J. Bombay nat. Hist. Soc*. 83: 283-305.

Riney, T. 1982. Study and management of Large mammals. Jhon Wiley and sons Ltd., New York.

Robinette, W.L., J.S. Gashwiler, J.B. Low and D.A. Jones. 1957. Differential mortality by sex and age among mule deer. *J. Wildl. Manage.* 21: 1-16.

Robinson, S.C.H. 1942. Measurements of an Indian Bison head, *Bibos gaurus. J. Bombay nat. Hist. Soc*. 42: 100-101.

Rodgers, W.A. 1979. The implications of woodland burning for wildlife management. In: (Ed.) Ajayi, S.S. and L.B. Halstead. Wildlife Management in Savannah Woodland. Taylor & Francis, London.

Rodgers, W.A. 1986. The role of fire in the management of wildlife habitats: a review. *Indian For.* 112: 845-857.

Rodgers, W.A. 1991. Techniques for Wildlife Census in India. A Field Manual. Wildlife Institute of India, New Forest, Dehra Dun.

Rodgers, W.A., S.S.R. Bennett & V.B. Sawarker. 1986. Fire and vegetation structure in sal forests. *Tropical Ecol.* 27(1): 49-61.

Rodman, P.S. 1981. Inclusive fitness and group size with a reconsideration of group sizes in lions and wolves. *Anim. Nat*. 118: 275-283.

Rozin, P. 1976. The selection of food by rats, humans and other animals. Adv. Study Behav. 6: 21-76.

Ruangchan, S. 1982. Study on sambar population and its group structure in Khao-Yai National Park. M.S. Thesis, Kasetsart University, Bangkok.

Russel, H.G. 1938. Behaviour of Gaur or Indian Bison. *J. Bombay nat. Hist. Soc*. 40: 325-326.

Russel, H.G. 1940. Behaviuor of Gaur and Elephant. *J. Bombay nat. Hist. Soc*. 41: 656-657.

Rynjah, L. 1950. The strange death of a Bison. *J. Bombay nat. Hist. Soc*. 49 :546-549.

Sadleir, R.M.F.S. 1969. The ecology of reproduction in wild and domestic animals. Methuen, London.

Salter, R.E. 1993. Wildlife in Lao PDR. A status report. IUCN, Vientiane, Lao PDR.

Salter, R.E., B. Phanthavong, S. Sawathvong, S. Souriyakan and K. Louanglath. 1990. An assessment of the current status of kouprey and other wild cattle in southern Laos. Unpublished manuscript. Forest Resources Conservation Project, Lao/Swedish Forestry Co-operation Programme and IUCN, Vientiane, Lao PDR.

Samant, J. 1990. The Dajipur Sanctuary and its potential as a national park. In: (Eds.) Daniel, J.C. and J.S. Serrao. Conservation in developing countries: problems and prospects. Proceedings of the centenary seminar of the Bombay Natural History Society. Bombay Natural History Society.

Sanderson, G.1912. Thirteen years among the wild beats of India. Edinburgh.

Santiapillai, C. and H. Suprahman. 1986. The ecology of the elephant (*Elephas maximus*. L) in the Way Kambas Game Reserve, Sumatra. WWF/IUCN 3133 Final Report, Bogor.

Santiapillai, C., M.R. Chambers and N. Ishwaran. 1984. Aspects of the ecology of the Asian elephant, *Elephas maximus* L. in the Ruhuna National Park, Sri Lanka. *Biol. Conserv*. 29: 47-61.

Sayer, J.A. 1981. A review of the Nature Conservation and policies of the Royal Forest Department, Thailand. FAO, Rome.

Schaller, G.B. 1967. The deer and the tiger: the study of wildlife in India. The University of Chicago Press, Chicago.

Schaller, G.B. and Rabinowitz. 1995. The saloa or spindlehorn bovid *Pseudoryx nghetinhensis* in Loas. *Oryx* 29: 107-114.

Scholander, P.F., R. Hock, V. Walters, F. Johnson and L. Irving. 1950. Heat regulation in some arctic and tropical mammals and birds. *Biological Bulletin.* 99: 237-258.

Sebastine, K.M. and K. Ramamurthy. 1966. Studies on the flora of Parambikulam and Aliyar submergible areas. *Bull. Bot. Surv. India.* 8: 169-182.

Shackleton, D.M. 1968. Comparative aspects of social organization of American Bison. The University of Western Ontario, London.

Shankara raman, T.R. 1997. Factors influencing seasonal and monthly changes in the group size of Chital or axis deer in southern India. *J. Biosci*. 22: 203-218.

Sharatchandra, H.C. and M. Gadgil. 1975. A year of Bandipur. *J. Bombay nat. Hist. Soc*. 72: 623-647.

Shult, M.J. 1972. American bison behavior patterns at Wind Cave National Park. Ph.D. Thesis, Iowa State University.

Sinclair, A.R.E. 1975. The resource limitation of tropic levels in tropical grassland ecosystems. *J. Anim. Ecol.* 44: 497-520.

Sinclair, A.R.E. 1985. Does interspecific competition or predation shape the African ungulate community?. *J. Anim. Ecol.* 54: 899-918.

Singh, R.S. 1994. Changes in soil nutrients following burning of dry tropical savana. *International Jornal of Wildland Fire.* 4(3): 187-194.

Sivaganesan, N. 1991. Ecology and conservation of Asian Elephants (*Elephas maximus*) with special reference to habitat utilization in Mudumalai Wildlife Sanctuary, Tamil Nadu, South India. Ph. D. Thesis. Bharathidasan University, Thiruchirapally, Tamil Nadu.

Skinner, J.D., J.H.M. Vanzyl and J.A.H. Heerden. 1973. The effect of season on reproduction in the black wildebeest and hartebeest in South Africa. *Journal of Reproduction and Fertility Supplement* 19: 101-110.

Soper, J.D. 1941. History, range, and home life of the northern bison. *Ecol. Monogr.* 11: 348-412.

Sopher, D.E. 1980. Indian cultivation and the tropical savannah environment. In: (Ed.) D.R. Harris (Ed.) Human Ecology in Savannah Environment, Academic Press, London. pp.185-208.

Southern, H.N. 1964. The handbook of British Mammals. Blackwell Scientific Publications, Oxford.

Southwell, C.J. 1984. Variability in grouping in the eastern grey kangaroo, *Macropus giganteus*. Group density and group size. *Aust. Wildl. Res.* 11: 423-435.

Spinage, C.A., C. Ryan, and M. Shedd. 1980. *Afr. J. Ecol.* 18: 19-25.

Spinage, C.A.1968. A quantitative study of the daily activity of the Uganda defossa waterbuck. *E. Afr. Wildl. J*. 6: 89-93.

Srikosamatara, S. and V. Suteethorn. 1994. Wildlife Conservation along the Thai-Lao border. *Nat. Hist. Bull. Siam. Soc*. 42: 3-21.

Srikosamatara, S. and V. Suteethorn. 1995. Population of gaur and banteng and their management in Thailand. *Nat. Hist. Siam. Soc*. 43: 55-83.

Stark, M.A. 1986. Daily movement, grazing activity and diet of savanna buffalo, *Syncerus caffer brachyceros,* in Benoue National Park, Cameroon. *Afr. J. Ecol.* 24: 255-262.

Stebbing, E. 1911. Jungle by-ways in India. London.

Stebbing, E. 1912. Game Sanctuaries and game protection in India. *Proc. Zool. Soc. London*. 23-55.

Stebbins, G.L. 1956. Cytogenetics and the evolution of the grass family. *Amer. J. Bot*. 43: 890-905.

Stewart, A. 1928. Tiger and other game. London.

Suchart, K., D. Chutinara and N. Patanaseri. 1976. Khao Yai National Park. Group of Youth Loving Nature, Bangkok.

Sugathan, R. 1981. A survey of the Ceylon frogmouth (*Batrachostomus moniliger*) habitat in the Western Ghats of India. *J. Bombay nat. Hist. Soc*. 78: 309-316.

Sukavanich, N. 1988. Before Making a Decision for the Last Shot. Today Press, Nonthaburi, Thailand.

Sukumar, R. 1985. Ecology of the Asian elephant (*Elephas maximus*) and its interaction with man in South India, Ph. D. Thesis, Indian Institute of Science, Bangalore.

Sukumar, R. 1989a. Ecology of the Asian elephant in Southern India. Movement and habitat utilization pattern. *J. Trop. Ecol.* 5: 1-18.

Sukumar, R. 1989b. The Asian elephant: Ecology and Management. Cambridge University Press, Cambridge.

Sundarapandian, S.M., S. Chandrasekaran and P.S. Swamy. 1996. Influence of distrubance on fine root biomass and productivity in two deciduous forests of Western Ghats, Tamil Nadu. *Current Scie.* 70(3): 242-246.

Supmee, A. 1986. Exploitation of natural and artificial salt licks by wildlife in Phukheow Wildlife Sanctuary. Chaiyaphum Province. M.Sc. Thesis, Kasetsart University, Bangkok.

Taber, R.D. and R.F. Dasmann. 1954. A sex difference in mortality in young Columbia black-tailed deer. *J. Wildl. Manage.* 18: 309-315.

Thouless, C. 1987. Kampuchean wildlife - survival against the odd. *Oryx* 21: 223-228.

Timmins, R. and T. Evans. 1994. A wildlife and habitat survey of Nam Theun Natuinal Biodiversity conservation area., Khammounae and Bolikhamsai Provinces, Lao PDR. A report to Protected Areas and Wildlife Division of the National Office for Nature Conservation and Watershed Management, Vientiane, Laos and Wildlife Conservation Society, New York.

Trapnell, C.G. 1959. Ecological status of woodland burning experiments in northern Rhodesia. *J. Ecol.* 47: 129-168.

Uniyal, V.K. and Easa, P.S. 1990. Elephants in Parambikulam Wildlife Sanctuary and Management Options. In: Proceedings of the Symposium on Ecology, Behaviour and Management of Elephants in Kerala, Kerala Forest Department 23-24, February, Thiruvananthapuram.

Uniyal, V.K. (Undated). The First Management Plan for Parambikulam Wildlife Sanctuary. Kerala Forest Department.

Vajner, L. 1980. Etologicka studie stada zubru evropskych *Bison bonasus* Linnaeus, 1758, v prazske ZOO. *Gazella* 2: 59-69.

Van Waggoner and M. Hinkes. 1986. Summer and fall browse utilization by an Alaskan bison herd. *J. Wildl. Manage.* 50: 322-324.

Varma, A., B.P.S. Yadav, K.T. Sampath and D.J. Roy. 1982. *Ind. J. Anim. Sci.* 52: 859-865

Vesey - Fitzgerald, D. F. 1969. Utilization of the habitat by buffalo in the Lake Manyara National Park. *E. Afr. Wildl. J.* 7: 131-145.

Vijayan, V.S. 1979. Parambikulam Wildlife Sanctuary and its adjacent areas. *J. Bombay nat. Hist. Soc.* 75: 888-900.

Vijayan, V.S., M. Balakrishnan and P.S. Easa. 1979. Periyar Tiger Reserve - A reconnaissance report. Kerala Forest Research Institute, Peechi, Thrissur, Kerala.

Walther F. R. 1973. Round-the-clock activity of Thomson's gazelle (*Gazella thomsoni* Gunther, 1884) in the Serengeti National Park. *Z. Tierpsychol*. 32: 75-105.

Watson, A. and Moss, R. 1970. Dominance, spacing behaviour and aggression in relation to population limitation in vertebreates. In: (Ed) Watson, A. Animal populations in relation to their food resources, Blackwell Scientific Publications, Oxford.

Weigum, L.E. 1972. The problems in the preservation of the Seladang in the Malaysian National Park. M.S. Thesis, Michigan State University, East Lansing.

Weir, J.S. 1971. The effects of the creation of additional water supplies in a central African National Park - Scientific management of Animal and plant for conservation. 367-385.

Wells, L.H. and H.B.S. Cooke. 1956. Fossil bovidae from the lime works quarry, makapansgat, potgietersrus. *Paleont. Afr*. 4: 1-55.

West, O. 1965. Fire in vegetation and its use in pasture management with special reference to tropical and sub-tropical Africa. Mim. Publ. No. 1, Commonw. Bur. Pasture & Crops, Hurley, U.K. 1-53.

Westoby, M. 1974. An analysis of diet selection by large generalist herbivores. *Amer. Natu*. 108: 290-304.

Wharton, C. 1968. Man, fire and wild cattle in Southeast Asia. *Proc. Tall Timbers Fire Ecol. Conf*. 8: 107-167.

Wiegert, R.G. 1962. The selection of an optimum quadrate size for sampling the standing biomass of grasses and forbs. *Ecology* 43: 125-129.

Wright, H.A. and A.W. Bailey. 1982. Fire Ecology. Wiley and Sons, New York. 501 pp.

Wright, S. 1921. Correlation and causation. *J.agric.Res*. 20 : 557-585.

Wroblewski, K. 1927. Zubr Puszezy Bialowieskiej. *Wyd. Polskie*. Poznan.

Xiang, Z. and C. Santiapillai. 1993. Specialist group reports: Asian Elephant Specialist Group. *Species* 20: 54-55.

Yadava, P.S. and J.S. Singh. 1977. Grassland Vegetation: It's Structure , Function, Utilization and Management. Today and Tomorrow's Publishers, New Delhi. 182 pp.

Yin, U.T. 1993. Wild mammals of Myanmar. Forest Department, Myanmar.