KFRI Research Report 173

STATUS, HABITAT UTILIZATION AND MOVEMENT PATTERN OF LARGER MAMMALS IN WAYANAD WILDLIFE SANCTUARY

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PEECHI, THRISSUR

September 1999 Pages: 166

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SUMMARY

Management of Protected Areas requires information on various aspects of population of animals including their distribution in relation to biotic and abiotic factors and their interactions. The present study was carried out in Wayanad Wildlife Sanctuary to collect information on population parameters, distribution, food and feeding habits of selected animals especially, the elephants in relation to environmental parameters. The study was confined to the three ranges coming under the three Forest Ranges of the Sanctuary forming the southern part, which is contiguous with Mudumalai Wildlife Sanctuary of Tamil Nadu and Bandipur Tiger Reserve of Karnataka. Southern moist mixed deciduous, southern dry mixed deciduous and west coast semi-evergreen forests are the natural vegetation met within the area. Dry deciduous forests are confined to the borders and moist deciduous forest to the interior. Parts of the natural forests have been converted into plantations of teak, eucalypts and mixed soft wood species.

A number of swamps *(vayals)* seen in the area most are situated in the midst of moist deciduous forests and plantations. The Sanctuary harbours almost all the Peninsular Indian mammals and other groups of animals. Three seasons have been identified based on the rainfall pattern in the area. Though the Sanctuary is drained by a number of streams, only a few confined to the border areas are perennials.

The southern ranges have 80 settlements mostly confined to the moist deciduous forests. Cash crops are cultivated in the dry lands and paddy, ginger, tapioca and plantains in the wet lands. Different types of protection methods are employed to deter the wild animals from crop raiding. The extent of the crop damage and the efficiency of the methods have been evaluated.

Information on group size, composition and structure was collected through direct observations. The individuals were classified into different age-sex categories. Transects were laid in the study area in proportion to habitat size. A few of these

were placed in the bordering and inside areas. Line transect (indirect) method was followed to collect information on indirect evidences of animals to get abundance indices. The data from transects were pooled to estimate elephant density in different habitats, and in the periphery and interior areas. Seasonal food availability in different habitats was estimated through clip and weigh method.

Density distribution of elephants followed a clear pattern with a high density in the periphery during dry season and with a decrease in the subsequent seasons. There were seasonal differences in the elephant density between habitats. Availability grass as food was higher in dry deciduous forests in dry season and showed a decreasing trend in the subsequent seasons. Moist deciduous and plantations showed an increasing trend from dry to second wet season in the grass availability. There was a slight annual change in the trend. About 35% to 70% of the total browse biomass was in moist deciduous and in plantation. Availability was comparatively low in dry deciduous forest. Contribution of *Helicteres isora* was found to be very high.

Density distribution of elephants in the area was mostly influenced by the food and water availability coupled with disturbance due to human activities and fire. The sex ratio of elephants was almost equal up to the sub adult II category. However, a highly skewed sex ratio was observed in all the categories above 10 years old. Overall male to female sex ratio in the population was 1:3.48. The sex ratio in the adult category was 1:40.

Seasonal difference in the density of gaur was observed as evidenced from the dung density. Density of sambar deer was lowest in dry season. Proportion of adult stags and does was almost equal. Highest density of spotted deer was observed during the first wet season.

Elephants fed on 97 plant species. There was a considerable difference between seasons and habitats in the utilisation of plant parts. Grass formed a major percentage of food in all habitats in different seasons except in the moist deciduous forests and plantations in dry season, and in plantations during the first wet season. Major conmbution to the diet was from a few among the grass species. The percentage contribution varied considerably between seasons and between habitats. There were considerable seasonal variations in the plants browsed in different habitats. Sambar deer fed on 92 plant species compared to 93 by spotted deer.

Density distribution of gaur indicated difference between areas and between seasons. Distribution of Sambar and spotted deer was also influenced by seasons but without any pattern. Gaur had a preference for deciduous forests in the periphery.

Nine settlements were selected for crop raiding studies based on the surrounding vegetation types. location of the settlements and type of protection methods employed. These settlements were visited twice in a month to collect information on crop damage. The extent and quantity of damage due to feeding and trampling were estimated by laying plots. Plots were also laid in the adjacent undamaged area to assess the loss. The economic loss due to crop damage was quantified and converted in to per unit area.

Elephants were responsible for most of the crop damages and paddy was the most affected. Trampling was responsible for damage during vegetative phase and feeding in reproductive phase. The extent of damage to crops was higher by males.

Total economic loss due to crop damage by elephant was estimated to be Rs. 9.67 lakhs in 1994 and Rs. 7.97 lakhs in 1995. The loss incurred was Rs. 2,306/ha. There was no correlation between frequency of raiding and size of the settlement. Electric fencing, though not successful against males was the most effective protection mcthod. The crop raiding behaviour of elephants in Wayanad is attributed to several factors such as difference in the quality of food species in the natural forests and in cultivated crops. degradation of habitat coupled with the behaviour of the habitual crop raiding solitary bulls.

Chapter 1

Introduction

Management strategies in Protected Areas are formulated based on an understanding of the functional relationship between the habitat conditions and the animal populations. The importance of determining preference or avoidance of a given habitat by animals has long been recognised (Bellrose and Anderson, 1943; Neu *et.al.*, 1974). Herbivores are reported to favour habitat types where nutrient intake could be maximised (Owen-Smith, 1985). Further, seasonal movements of large herbivores in response to environmental changes have also been recorded (McNaughton, 1987). Alteration in herd size and patterns of habitat utilisation are often due to climatic changes (McNaughton, 1985). Owen-smith (1988) observed considerable impact of food, shelter and water on the distribution pattern of large herbivores.

Changes in habitat preferences in relation to climatic conditions are reported also among European bison (Krasinska, *et al.*, 1987) and Wood bison (Krasinski, 1978; Larter and Gates, 1991). Changes in plant distribution and phenology affected ungulate food habits, energy budget, movement and seasonal distribution in Chitwan National Park (Dinerstein, 1979). Rhinoceros attained highest density in areas with greatest habitat diversity (Laurie, 1978). The highest number of gaur were observed in areas formed by shifting cultivation (kitchener, 1961).

Elephants are probably the best studied for distribution in relation to environmental factors. Caughley and Goddard (1975) reported aggregation of elephants on the alluvial zone as a result of flush of annual grasses during the rains in Luangwa Valley. Water was found to influence elephant distribution in Kalahari sand region (Weir, 1971). Differential use of habitats by African elephants was influenced by forage preference and availability (Leuthold and Sale, 1973; Leuthold, 1977; Western and Lindsay, 1984; Thouless, 1995a) as well as by external factors such as extreme weather conditions (Corfield, 1973), human settlements and cultivation (Laws, 1970: Lamprey, 1985) and poaching activity (Dublin and Douglas-Hamilton. 1987).

Cumming *at al.* (1990) and Said *et al.* (1995) reported that the external factors have led to the concentration of African elephants in Protected Areas. Dublin (1995 &1996) studied the factors influencing the habitat selection and group size pattern in African elephants. Seasonal distribution in relation to environmental factors such as rainfall, food and water availability and habitat utilisation of Asian elephants were studied by several investigators in South India (Sukumar, 1985; Balakrishnan and Easa, 1986: Easa, 1989a; Sivaganesan. 1991).

Far ranging large mammals such as elephants have also been the most affected due to the ever increasing demand for agricultural land to meet the requirement of growing human population. Daniel (1995) listed the priority requirements for long-term conservation of elephant and stressed the need of assessing the extent of human-elephant conflict.

Ramachandran (1990) and Gopinathan (1990a) have mentioned the migration and crop-raiding problem in Wayanad Wildlife Sanctuary. The Management Plan for Elephant Reserves in Kerala has highlighted the incidences of loss of life and crop depredation due to wild animals in general and elephants in particular (Easa. 1994). A total of Rs. 2,40,505 has been paid as compensation for crop damage and Rs. 1,25,150 for death and injury to human in Wayanad during the period between 1985 and 1993 (Veeramani and Jayson, 1995; Veeramani *et al.*, 1996). This was registered as the highest amount paid compared to the other forest divisions in Kerala. The compensation is on the increase since 1986 even after providing live wire fencing in some of the areas in the study area (Easa, 1994). These reports indicate the seventy of the problem in Kerala especially Wayanad.

Hence, the present research project was taken up to study the movement pattern of large herbivores in relation to season, food and water availability, agriculture cropping pattern and biotic disturbances in Wayanad Wildlife

Chapter 2

Study Area

Wayanad Wildlife Sanctuary is situated in the North East of Kerala and falls within the Nilgiri Biosphere Reserve (NBR). The total extent of the area is 344.44 km^2 and is divided into two discontinuous portions with revenue lands in between. The North west portion of the sanctuary has only one range viz., Tholpetty (hehveen 11" 50' and behveen 11^o 59' N and 76^o 2' and 76^o 7' E) and have an area of 77.67 km^2 This range is contiguous to Rajiv Gandhi National Park in Nagerhole in the North east, Kakkankotte Reserved Forest in the North and Brahmagiri Hills of North Wayanad Division in Kerala in the East. The Southern portion of the sanctuary, the main study area (between 11^0 35' and 11^o 49' N and 76^o 13' and behveen 76^o 27' E), comprises an area of about 266.77 km^2. It is contiguous to Mudumalai Wildlife Sanctuary (MWLS) of Tamil Nadu in the East and Bandipur Tiger Reserve (BTR) of Kamataka in the North and North east (Fig. I).

Wayanad' derives its name from the numerous swamps (locally called as *vayals)*. Francis (1994) described the political history, forest; agriculture and wildlife in Wayanad in earlier days.

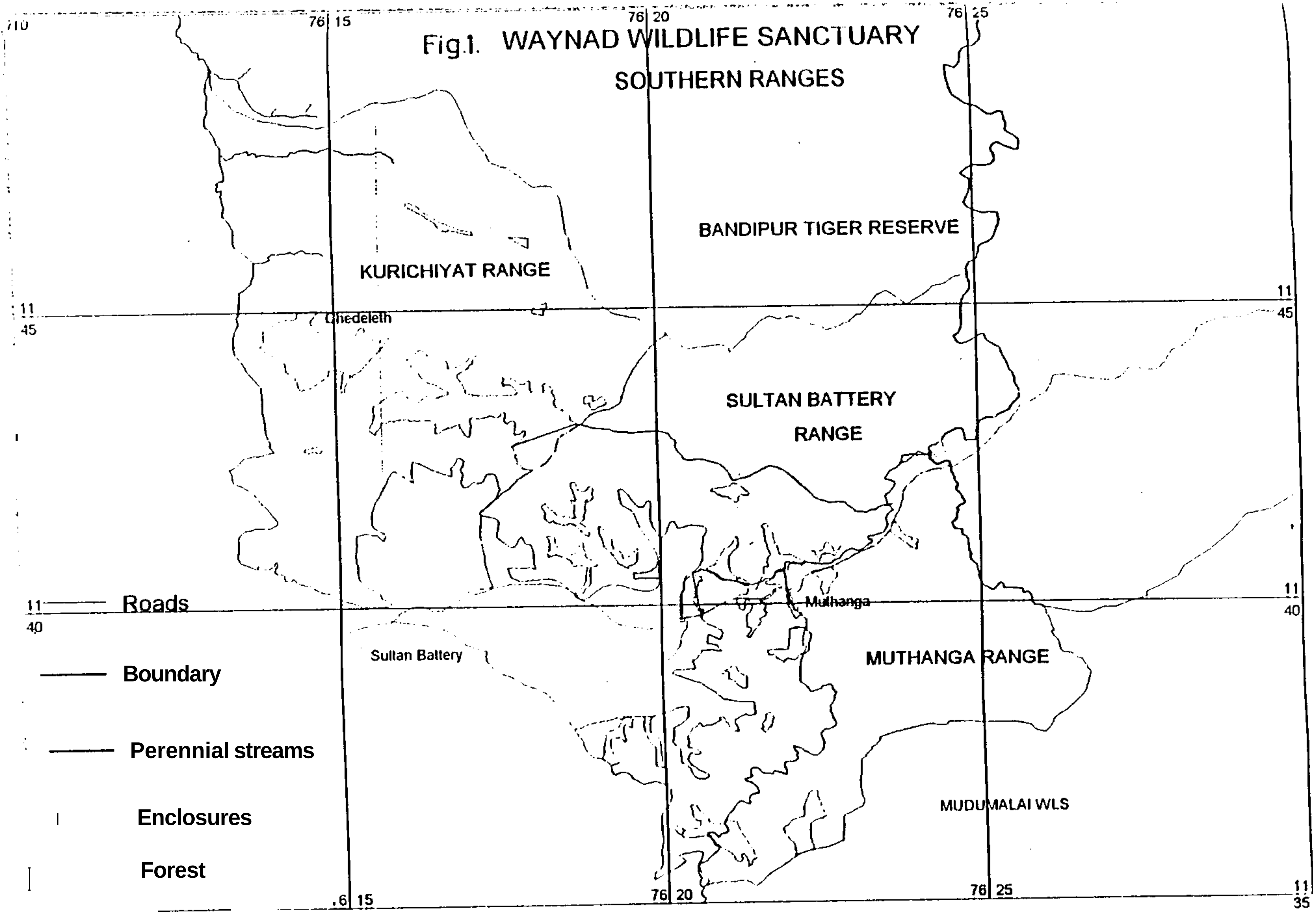
During the dawn of the century, the area was protected as Reserved Forests under the jurisdiction of Chedileth Range. Subsequently, Sulthan's Battery Range was formed in 1924. After 1958, South Wayanad was managed under Kozhikode Forest Division and North Wayanad under Wayanad Forest Division. The area was declared a Sanctuary in 1973 and brought under the Wildlife Division in 1985. Gopinathan (1990b) has given a detailed description and history of the Sanctuary.

2.1 Precipitation

The average annual rainfall ranges from 1200-1700 mm with maximum precipitation from June to September. The South West monsoon brings the greater

Fig.1. WAYNAD WILDLIFE SANCTUARY

SOUTHERN RANGES



part of the total rainfall bursts normally by first week of June preceded by a few showers in April and May. North East monsoon brings some rain in October and November. Breaks in the monsoon are not uncommon. Based on the rainfall pattern, three seasons *viz*. Dry (January-April), first wet (May-August) and second wet (September-December) could he identified (Fig. 2). The moist deciduous forests received more rainfall compared to the dry deciduous forests (Fig. 3).

2.2 Temperature and humidity

The temperature and humidity data were collected from the Agricultural Farm at Ambalavayal adjacent to Wayanad Wildlife Sanctuary. Mean atmospheric temperature varied from a monthly maximum of 31°C in March to 24°C in July and monthly minimum of 19°C in May to 14°C in December. The average relative humidity ranged between 60.4% in January and 87.6% in June.

2.3 Terrain and soil

The terrain is almost flat (less than 5°) to gentle slope (varies from 5° to 10°) in the western part. This region is a part of the Mysore plateau. The altitude varies between 850 m and 1147 m. The broad type of soil is Ferroiite and sub type is Ustic Altisol.

2.4 Water sources

The sanctuary forms a significant part of the catchment area of Kabani river which flows into Karnataka. Northern portion of Kurichat range is drained by Kannarampuzha and Kurichiat thodu flows northward and join Kabini river. Towards the south east, Manjal thodu and other streamlets join Nuguhole river to flow fiuther north east to Kamataka. Southern portion of the sanctuary is drained by Nulpuzha and Mavinahalla thodu which combine to form Nuguhole river. Manjal thodu and other small streams in the sanctuary become dry during peak summer season. Nulpuzha is the main perennial streamlet in the study area.

Fig. 2. Monthly distribution of rainfall and temperature in Wayanad Wildlife Sanctuary during 1993 - 1994

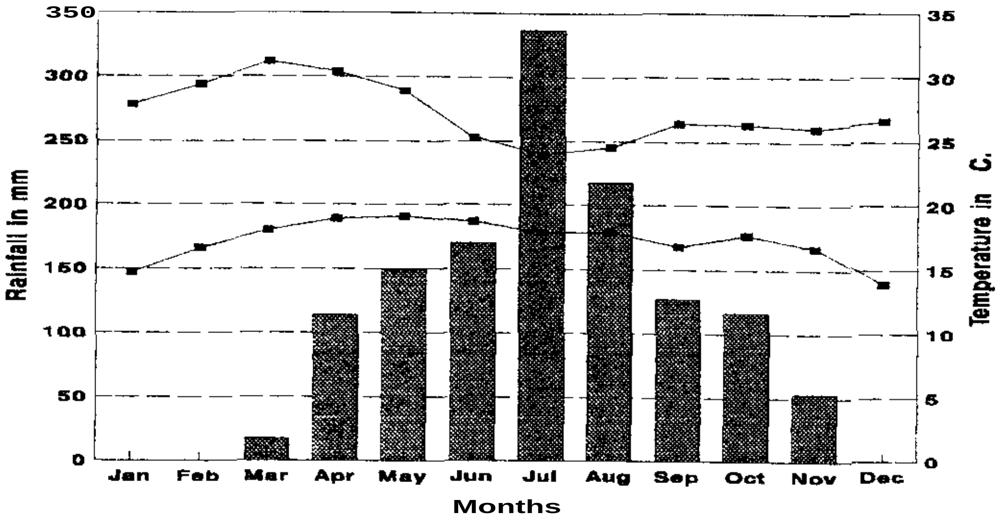
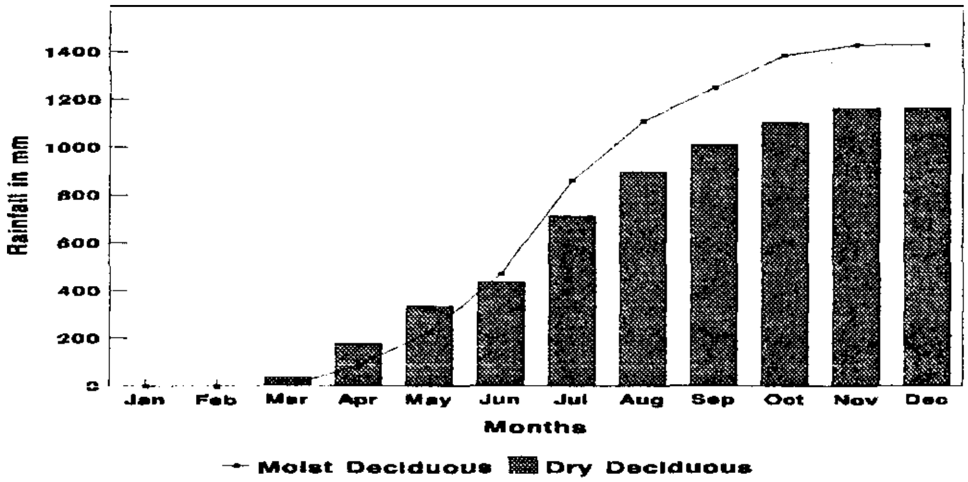


Fig. 3. Cumulative rainfall in dry and moist deciduous forests in Wayanad Wildlife Sanctuary in 1995



2.5 Vegetation Types

The forest types include mostly moist deciduous (MDF) with a few evergreen patches and riverine forests. A long belt of dry deciduous forests (DDF) exists in the areas bordering Tamil Nadu and Karnataka (Fig. 4). About one third of the sanctuary is covered by plantations of teak, eucalypts and mixed species interspersed with bamboo. The forest types could be broadly classified into Southern Moist Mixed Deciduous Forests, Southern Dry Mixed Deciduous Forests and West Coast Semi-evergreen Forests. The details are available in Gopinathan (1990 b).

Total area of the plantation in the study area is about 73.27 Km^2, which includes pepper (2.1 Km^2), eucalypts (13.55 Km^2), teak (36.53 Km^2) and mixed softwood species (21.09 Km^2). Eucalypts plantations do not have any other tree species except a few saplings of *Cassia fistula* and *Terminalia* sp. The whole plantation is occupied by *Lantana*. Tall grasses *viz., Themeda cymbaria, Themedu triandra* and *Cymbopogan flexuosus* are found in open areas in the plantations. In Teak plantations, apart from a few deciduous tree species. *Helicteres isora* occupy a large proportion of the area.

2.7 Fauna

The sanctuary is rich in fauna in diversity and abundance. Almost all the large mammals of peninsular India are observed in the area. The area has a good population of elephant *(Elephas maximus),* gaur *(Bos gaurus),* sambar *(Cervus unicolor),* spotted deer *(Axis axis),* barking deer *(Muntiacus muntjac),* mouse deer *(Tragulus meminna)* and wild boar *(Sus scrofa).* Other animals such as bonnet macaque *(Macaca radiata),* common langur *(Presbytis entellus),* sloth hear *(Melursus ursinus),* tiger *(Panthera tigris),* wild dog *(Cuon alpinus),* panther *(Panthera pardus),* jungle cat *(Felis chaus),* Indian pangolin *(Manis crassicandata),* porcupine *(Histrix indica),* Malabar giant squirrel *(Ratufa indica),* Indian hare *(Lepus. nigricollis nigricollis)* are also seen in this area. Sighting of four homed antelope *(Tetracerus quadricornis)* is rare and are restricted to areas bordering Karnataka. A total of 44 species of reptiles (Thomas *et al.*, 1997), 31 species of amphibians and 54 species of fishes (Shaji and Easa. 1997) were identified from Wayanad.

There are a good number of swamps in Mavinahalla and Rampur Reserves with perennial water sources. This sanctuary is a dry season refuge for the elephants.

2.8 Human habitations and cultivation

The most interesting feature of Wayanad Wildlife Sanctuary is the large number of settlements where cultivation is practiced. Southern Ranges have 80 settlements and Tholpetty Range 9. These settlements in Southern Ranges are confined to the moist deciduous forests (Fig. 4). The people occupy almost all the vayals with perennial water sources in the study area. A population of more than 25,000 people live in and around the Protected Area. This includes 6795 tribals and 4951 non-tribals (2587 and 1010 families respectively) inside the sanctuary alone. The main occupation is agriculture. They cultivate cash crops such as coffee, pepper and coconut followed by primary crops ***viz.,*** paddy, ginger, tapioca and plantains. Electric fencing, provided by the Forest Department protects a few of the settlements. A total of 166 Km. length of electric fencing has been erected in the study area.

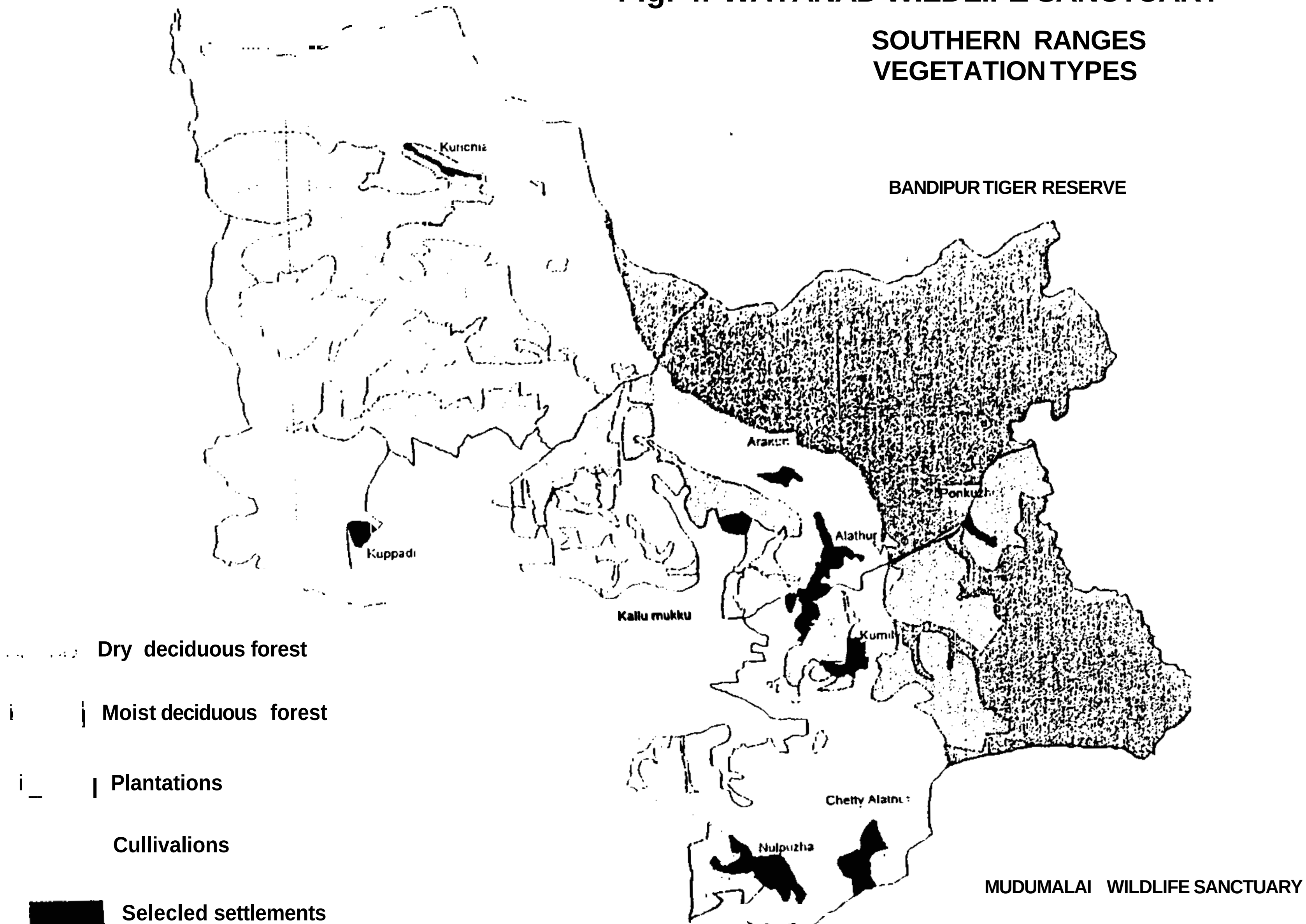
Livestock holdings are confined mostly to goats and cattles. The people residing inside the sanctuary own a total population of 4114 goats and cattle. These animals are mostly left to feed inside the sanctuary. Cattle lifting by panther and tiger are not uncommon in the study area.

2.9 The people

The main occupants of the settlements in the study area are Chetties. The principal tribes living in the forest plateau are Kurumbas, Paniyans, Kattu Naikens, Uralis and a few Kurichias (Thurston and Rangachari, 1909). Three sub-castes of Kurumbas *viz.,* Mullu Kurumba, Beta Kurumba and Jenu Kurumba live in this region. Some of the settlements have also Hindus, Christians and Muslims. The chief occupation of Chetties is the cultivation of paddy in the swamps. They also grow pepper, plantains and coffee in their homestead. *Lantana* bushes are found abandoned shifting cultivation plots.

Fig. 4. WAYANAD WILDLIFE SANCTUARY

SOUTHERN RANGES
VEGETATION TYPES



The Paniyans are an aboriginal race, owning no land, but cultivating paddy for the Chetties. They speak an aboriginal language and also a dialect of Malayalam. Among the Kurumbas, the Mullu Kurumbas are socially and economically advanced. They cultivate various crops in the adjoining wet lands. They also own cattle. They want little from the forests other than the land to cultivate. The Betta Kurumbas used to practice shifting cultivation in the virgin forest. At present, they live by extending labour to neighboring estates as well as to the Forest Department. The

Kurumbas are considered as the least civilized among the jungle tribes and subsist on the forest by collecting non-wood forest produce such as honey, roots, fruits and others.

Chapter 3

Animal Population

3.1 Introduction

Information on the population of a species in the wild is an important attribute for judging its future for conservation and management. This is especially true for a species like elephant, which is larger in size and contribute high proportion of biomass among the wild animals.

It is also essential to study the precise structure, dynamics and level of organisation of a species, since the population is linked with the environmental conditions. Social organisation of a population such as herd size, composition and structure would generate essential information on population characteristics and trend (McCullagh, 1993 & 1994).

A number of studies have reported the population estimates of Asian elephants in different parts of the Indian sub-continent (Singh, 1978; Lahiri-Choudhury, 1980). The status of elephant populations in South India have been reported by several studies (Nair *et al.,* 1977; Nair and Gadgil, 1978; Vijayan *et.al.,* 1979; Joseph, 1980; Nair *et al.,* 1980; Nair *et al.,* 1985; Sukumar, 1985; Easa, 1989a: Easa and Balakrishnan, 1995).

Herd size, composition and density of wild animals other than the elephants is poorly reported. This is true especially in the case of gaur, sambar and spotted deer. Gaur is the second mega-herbivore and is reported as a gregarious animal. The herd size and composition of gaur in Parambikulam Wildlife Sanctuary has been reported by Vairavel (1998). Schaller (1967) and Vairavel (1998) have reported a distorted sex ratio of gaur, favouring females.

Sambar, the largest deer in Southeast Asia is widely distributed (Schaller, 1967). The typical herd size of the sambar is fewer than 6 (Schaller, 1967). The recent study in Parambikulam Wildlife Sanctuary indicated that adult females dominate in the population (Easa, unpublished).

Distribution of chital has been greatly affected by the elimination of its habitat for agricultural purpose. The herd size is influenced by the availability of food and water. The herd size in Kanha National Park has been reported by Schaller (1967).

The objectives of the present study were to estimate the population of larger mammals in Wayanad Wildlife Sanctuary along with details of its structure, size and composition.

3.2 Methods

3.2.1 Density estimate

Different techniques have been used for estimation of elephant population in the wild. Ramakrishnan *et al.* (1991) has reviewed the methods in detail. Bames and Jensen (1987) suggested a method based on dung density, for use in such areas where elephant sightings are comparatively difficult. Asian Elephant Specialist Group of the World Conservation Union recognized the need to use standard techniques for estimation of elephant abundance/population and suggested the method based on dung count (Ramakrishnan *et al.,* 1991).

The dung density method of population estimation assumes an equilibrium state in the system (Jachmann and Bell, 1984) and involves measuring density of dung in a given area, defecation rate and dung decay rate. Since the defecation and decay rates depend on habitat and season, it is important to estimate these rates seasonally in different habitats (Barnes and Jensen, 1987). Barnes *(pers.comm.)* suggested collection of additional information on the habitat (humidity, temperature, soil type and canopy cover) while estimating the dung decay rate. He also stressed the importance of making preliminary dung density estimates before dung decay rate experiments to have an idea on the sample size.

The study area was divided into blocks based on the vegetation types and 11 transect of 2 km length were laid in proportion to habitat. Care was taken to have some of these transects in areas bordering the adjacent Bandipur Tiger Reserve and Mudumalai Wildlife Sanctuary and a few radiating from the settlements for correlating the density distribution with cropping pattern. These transects were followed seasonally (once in four months) taking the rainfall pattern of the study area into consideration (Chapter 2). Information on the number of animals and the details of herd size and composition were collected along with the sighting angle (using a compass) and the sighting distance (using a range finder) (Burnham *et al.*, 1980).

The methods suggested by Barnes and Jensen (1987) was used for collecting information on the indirect evidences of the elephants *viz.* the dung piles along the transect. The time of sampling and the effort taken were uniform. The analysis of the line transects (direct) data indicated very low sample size resulting in highly unreliable density estimates. Hence, only the indirect evidences were collected subsequently. A fixed width of one meter on both sides of the transects were considered for observations on indirect evidences of sambar deer and spotted deer. Indefinite width was used for elephants and gaur, measuring the perpendicular distance from the transect to the dung sighted

3.2.2 Decay rate

A total of 389 fresh dung piles (all observed defecation) were marked with numbered bamboo stakes in the three seasons in the dry and moist deciduous forests for regular monitoring. The number of samples in different seasons in both habitats were closer to or greater than 50 in most cases However, only 27 observed defecation could be monitored in dry deciduous forests in first wet season due to the constraints in availability of fresh dung.

The marked dung piles were monitored during first, third, fifth and seventh day of first week and thereafter once a week. The dung piles were categorized into six stages following Dekker *et al.* (1991). The data were collected for three seasons in 1995.

3.2.3. Structure, herd size and composition

The entire study area was covered every month on foot from January 1994 to December 1995. Size, composition and structure of the elephant herds sighted during the visits were recorded by direct observation, spending time in all habitat types proportionately. Individuals in the herd were classified into different age/sex categories following the criteria suggested by Sukumar (1985).

Gaur, sambar deer and spotted deer were classified into adults, sub-adults, juveniles and calves/fawns.

3.2.4 Elephant mortality

A thorough inspection was made on the carcasses of elephants encountered during the field trips or on getting information from others. Information on the sex and age of the animal, location and date of death (approx.) and cause of death were collected. The cause of death was confirmed with the experts.

3.3 Analyses

3.3.1 Elephant dung decay rate

The formula suggested by Sukumar *et al.* (1991) was used to estimate the mean daily rate of decomposition.Data analyses were facilitated by the computer program GAJAHA Ver.01 developed by Asian Elephant Conservation Centre, Bangalore, India.

The results were subjected to z-test for statistical significance of differences between habitats in different seasons. The climatic data for the adjacent Mudumalai Wildlife Sanctuary were collected from Varman *et al.* (1995).

3.3.2 Density estimates

The data on indirect evidences from different transects were pooled for analysis of density estimates with the help of the computer program DISTANCE (Laake *et al.*, 1994).

3.3.2.1 Estimation of elephant density from dung density

The elephant density, based on the dung density was calculated using the formula suggested by Barnes and Jensen, 1987). The defecation rate of 16.33/day, obtained from the study at Mudumalai by Watve (1992) was used in the present analysis since this could not be collected from the study area.

3.3.3 Herd size, composition and structure

Only the completely classified herds were taken for analyses of herd size and structure. Herd size, composition and proportion of different age and sex classes in the population were derived on the basis of all sightings during the study period. The solitaries were not considered for calculating mean herd size.

3.3.4 Effect of age-sex categories on herd size of elephants

In simple terms, herd size is just a sum of the numbers of individuals in the different component classes. However, herd 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 herd size was studied through regression analysis taking herd size as dependent variable and number of individuals in each age-sex category as independent variables. The regression functions included each category one at a time. In such cases, the regression functions fitted were of the following form.

$HS = \beta o + \beta_1 N$, Where,

HS = herd size

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

β_0, β_1 = are parameters

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 square root 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 herd size, a multiple linear regression equation was fitted including all the categories except the unsexed class in the model. The prominent components affecting herd size were identified through stepwise regression.

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

33.5 Changes in the mean herd size of elephants over time

The data consisted of observations on herd size for 24 months starting from January 1994. For this analysis, the months were grouped into dry (January-April), first wet (May-August) and second wet (September-December) seasons. The mean herd size for each month was computed and changes in the mean herd size over time were analysed using the following model.

$$\square_t = \mu + a\,t + \epsilon_t \qquad (2), \text{ where}$$

$\square_t$ = mean herd size at time t, μ = intercept, t = time in years

α = coeficient of the trend variable, ϵ_t = error at time t

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

$\square_{(i)} = \mu + \alpha t + P_i + \epsilon_{t(i)}$ (3)

Where $\square_{t(i)}$ = mean herd size at time *t* belonging to *i* th season.

β = effect due to *i* th season.

$\epsilon_{t(i)}$ = residual at time *t* belonging to the *t* th season.

μ, α, t = as defined earlier.

Model (3) assumes a continuous change in the mean herd size over time with seasonal fluctuations superimposed. The additivity of the seasonal 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 non-significant as shown by Durbin-Watson statistic. However, a plot of residuals against the seasons showed heteroscedasticity. The observations in the wet seasons were less variant compared to those of other seasons. 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 season. The weights (W) were

The weights (W) were $W = {}^{-\delta}$

Where = standard deviation of the residuals for each season

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+.

3.4 Results

3.4.1 Elephant

Dung decay rate

There were marked seasonal differences, within the habitats in the time taken for decomposition. However. it was following almost similar pattern within season. Overall decomposition, irrespective of seasons was comparatively faster in the moist deciduous forest. The survival curve in different seasons for the study area (irrespective of habitats) indicate marked difference in the decomposition

The decay rate was greater in moist deciduous in the first (0.2037/day) and second wet seasons (0.0615/day) (Table 1). There was no marked difference between habitats in the dry seasons. However, the overall decay rate irrespective of seasons (0.0512/day) was higher in moist deciduous forest

Table 1. Summary of Dung decay rate in Wayanad Wildlife Sanctuary.

Season	Habitat	Sample Size	Mean decay rate/day	Standard Error	Confidence Level (95%)
Dry	DDF	122	0.0192	0.0004	0.0184 - 0.0200
	MDF	42	0.0187	0.0006	0.0175 - 0.0200
	Combined	164	0.0191	0.0003	0.0184 - 0.0198
Wet-1	DDF	27	0.0754	0.0074	0.0610 - 0.0899
	MDF	87	0.2037	0.0054	0.1931 - 0.2144
	Combined	114	0.1406	0.0097	0.1215 - 0.1596
Wet-2	DDF	64	0.0360	0.0022	0.0317 - 0.0402
	MDF	47	0.0615	0.0040	0.0538 - 0.0693
	Combined	111	0.0436	0.0023	0.0391 - 0.0482
Overall	DDF	213	0.0251	0.0008	0.0235 - 0.0267
	MDF	176	0.0512	0.0041	0.0432 - 0.0592
	Combined	389	0.0335	0.0012	0.0311 - 0.0359

DDF= Dry Deciduous forests; MDF= Moist Deciduous Forests; Dry = Dry Season; Wetl= First Wet Season; Wet2 = Second Wet Season;

The seasonal difference in the decay rate was highly significant in moist deciduous forest and significant in the dry deciduous (Table 2). Differences in decay rate between habitats within the same season were significant except in dry season. The total period (number of days) of observation on the marked dung piles in each season and habitat, the number of rainy days, the amount of rainfall during these days and the respective decay rates are given in Table 3

The observation days were very high when the number of rainy days as well as the amount of rain were very less. Out of the 70 days of observation in both habitats during the dry season, only two days had rainfall in the dry deciduous forests (35.00mm). During first wet season, there were rains for 17 days out of 28 days of observation in dry deciduous forests and for 13 days out of 14 days in moist deciduous forests. In the second wet season, it rained for 7 days in each habitat out of 56 days in dry deciduous and 42 days in moist deciduous forests. The correlation between the percentage of rainy days and the dung decay rate was positive.

Table 2. Results of comparison of dung decay rate indifferent seasons and habitats

Typeof comparison	z-value
Overall DDF & Overall MDF	6.248 *
Drv and Wetl	12.519**
Dry and Wet2	10.562 **
Wet1 and Wet2	9.730*
Dry-DDF and Dry-MDF	0.693 ns
Wet1-DDF and Wet1-MDF	14.005 **
Wet2-DDF and 'Wet2-MDF	5.586 *
Dry-DDF and Wet1-DDF	7.584 *
Dry-MDF and Wetl-MDF	34.049**
Dry-DDF and Wet2-DDF	7.513 *
Dry-MDF and Wet2-MDF	10.581 **
Wetl-DDF and Wet2-DDF	5.104 *
Wetl-MDFand Wet2-MDF	21.160 **

* = P < 0.05, ** = P < 0.001, ns = non-significant

DDF = Dry deciduous forests; MDF = Moist deciduous forests Dry = Dry season; Wet-1 = First wet season; Wet-2 = Second wet season.

Table 3. Summary of observation period, rainfall and dung decay rate

Season	Habitat	Number of Observed days	Number of rainy days	Total rainfall (mm)	Dung decay rate/day
Dry	DDF	70	2	35.0	0.0192
	MDF	70	0	0.0	0.0187
Wet-1	DDF	28	17	252.4	0.0754
	MDF	14	13	268.6	0.2037
Wet-2	DDF	56	7	115.2	0.0360
	MDF	42	7	160.9	0.0615

DDF = Dry deciduous forests; MDF =Moist deciduous forests. Dry = Dry season: Wet-1 = First wet season wet season; Wet-2 = Second wet season.

3.4.2 Density estimate

There was a fluctuation in the annual density of elephants in the study area. The estimated density of elephants in the study area in 1994 was 1.02/km^2. The density estimates for 1995 and 1996 were 1.33/km^2 and 1.35/km^2 respectively.

3.4.2.1 Overall seasonal estimates

The seasonal density estimates of elephant for the area are summarised in Table 4.

Table 4. Estimate of overall elephant density in different seasons

Year	Seasons	Sample Size	Dung Density/ km^2	Percent CV	95 % CI		Elephant density/ km^2
					Upper	Lower	
1994	Dry	146	879.00	10.77	712.12	1085.00	1.03
	Wet-1	161	854.97	12.74	666.70	1096.00	1.00
	Wet-2	173	386.75	8.08	330.18	453.00	1.03
1995	Dry	344	1746.10	7.88	1496.60	2037.00	2.04
	Wet-1	126	125.12	8.91	105.11	148.90	1.08
	Wet2	167	473.91	7.74	286.15	387.30	0.89
1996	Dry	210	1183.20	9.11	990.07	1414.00	1.38
	Wet-1	105	154.13	11.71	118.75	189.51	1.33

Dry = Dry season; Wet-I = First Wet Season Wet-2 = Second Wet Season

No significant difference in the density of elephants between seasons in 1994 ($\chi2 = 0.156$; $df = 2$; $P > 0.05$). The density estimates were between 1.0/km^2 to 1.03/km^2. The dry season density in 1995 was 2.04/km2 and was significantly higher ($\chi2 = 151.09$; df=2; $P < 0.05$) than the density in the first and second wet seasons. Though the difference in the density in dry and first wet seasons in 1996 were non-significant ($\chi2 = 0.27$; $df = 1$; $P > 0.05$), the figures were higher than the density figures of the corresponding seasons of the previous years.

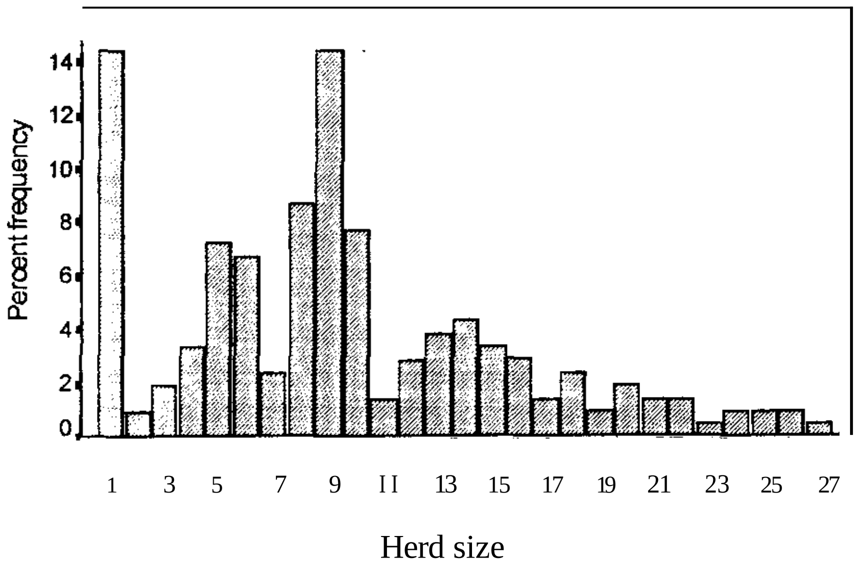
3.4.2.2 Population size from density estimates

Total number of elephants in the Southern Range (266.78 km^2) were estimated for 1994, 1995 and 1996. The estimated population size of elephants for the year 1994 was 272. This was 354 and 360 in 1995 and 1996 respectively. The annual difference in the population of elephants in the study area was found to be significant ($\chi2 = 14.85$; *df* =2; P< 0.05).

3.4.3.1 Herd size

Percentage frequency distribution of herd size in the study area is given in Figure 5. The herd size was found to range from 1 to 38 during the study period with a positively skewed distribution. Out of the 208 sightings, 14.42% were loners (most of them were solitary bulls). Most frequently observed herd size was of nine individuals (14.5%). Herd size of 8 and 10 were observed in 8.5% and 7.5% of the sightings respectively. Herd size of 5 and 6 formed 6.75% and 7.25% respectively.

Fig. 5. Percentage frequency distribution of herd size of elephants



The mean herd size of elephant in different seasons and habitats are given in Table 5. The overall mean herd size was 10.39 (n=82) in 1994 and 11.56 (n=96) in 1995. The overall seasonal mean herd size indicates a higher herd size during first wet season (12.53) followed by dry (10.51) and second wet (9.96) seasons.

Tahle 5. Mean herd size in different seasons in different years

Year	Season	Mean herd size	Standard Deviation	N (N = 178)
1994	Dry	10.26	6.577	31
	Wet-1	11.38	6.283	29
	Wet-2	9.27	2.436	22
1995	Dry	10.69	5.928	42
	Wet-1	13.69	7.879	29
	Wet-2	10.56	5.748	25
Overall	Dry	10.51	6.088	73
	Wet-1	12.53	6.597	58
	Wet-2	9.96	4.667	47

Dry = Dry season; Wet-1 = First Wet Season Wet-2 = Second Wet Season

The results of one-way ANOVA show a significant difference in the mean herd size between seasons ($P < 0.05$) and non-significant difference between years (Table 6). There was also no interaction between the seasons and years in the mean herd size.

Tahle 6. Two-way ANOVA showing the relationship of mean herd size of elephants with seasons and years

Source of variation	Sum of Squares	Df	Mean Square	F	p
Main Effects					
Season	205.32	2	102.66	2.918	*
Year	71.92	1	71.92	2.044	ns
2-way interactions					
Season x Year	28.207	2	14.10	0.401	ns
Residual	6050.47	172	35.18	-	-

* = $P < 0.05$, ns = non-significant

3.4.3.2. Herd composition and age structure

Age structure of elephants in Wayanad Wildlife Sanctuary for 1994 and 1995 are given in Table 7.

Table 7. Age structure of elephants in Wayanad Wildlife Sanctuary

Category	Age (years)	1994(No)s M	1994(No)s F	1995(No)s M	1995(No)s F	Combined (No)s M	Combined (No)s F	% M	% F
Calves*	0-1	73		89		162		8.16	
Juveniles-I	1-2	24	35	19	58	43	93	2.17	4.69
Juveniles-II	2-3	31	50	18	28	49	78	2.47	3.93
Juveniles-III	3-5	32	53	65	86	97	139	4.89	7.00
Sub-adult-I	5-7	30	34	41	40	71	74	3.58	3.73
Sub-adult-II	7-10	43	50	56	35	99	85	4.99	4.28
Sub-adult-III	10-15	12	24	15	83	27	107	1.36	5.39
Adult-I	15-20	2	109	2	117	4	226	0.20	11.39
Adult-II	20-30	1	120	4	191	5	311	0.25	15.67
Adult-III	30-40	2	99	4	111	6	210	0.30	10.58
Adult-IV	40-50	2	23	2	36	4	59	0.20	2.97
Adult	>50	1	8	1	26	2	34	0.10	1.71
Total		253	605	316	811	569	1416		

(Sampled between January, 1994 and December 1995). * Calves category could not be sexed

A total of 208 sightings consisting of 1985 individuals were analysed for age and sex classification. Out of the 208 sightings, 21 sightings were of loners and among these 42.8 % were adult bulls. The sex ratio was almost equal up to the sub-adult-II (7-10 years old) category. A highly skewed sex ratio was observed in all the categories above 10 years old.

Proportion of age-sex categories in the elephant population during the two year study period is presented in Table 8.

Table. 8. Proportion of age and sex classes of elephants

Age and sex class	Proportion
Adult Females	0.4217
Sub Adult Females	0.1335
Juvenile Females	0.1556
Adult Males	0.0105
Sub Adult Males	0.0989
Juvenile Males	0.0949
Calves	0.0813
Unknown	0.0035

Adult females formed a major portion of the population (42.17%) and were followed by juvenile females (15.56%) and sub adult females (13.35%). Sub adult males and juvenile males contributed 9.89% and 9.49% respectively. Calves (8.13%) followed this. A negligible share of individuals in the population (0.35%) in the calves category were unsexed.

3.4.3.3 Sex ratio of elephants

Sex ratio in the elephant population in the study area is summarised in Table 9. The overall male to female sex ratio in the population was 1: 3.48. A male to female ratio of I: 1.35 was observed even in the sub adult category. However, the sex ratio of adult male and adult female in the population was 1: 40

Table 9. Sex ratio of elephants

Age and sex class	Ratio
Adult Female/Adult Male	40.00
Adult Female/Sub Adult Female	3.16
Adult Female/Juvenile Female	2.71
Adult Female/Juvenile Male	4.44
Adult Female/Calf	5.19
Sub Adult Female/Sub Adult Male	1.35
Sub Adult Female/Juvenile Female	0.86
Adult Male/Sub Adult Male	0.11
Female/male	3.48

A comparison of age-sex class proportion in different elephant populations is given in Table 10. The adult male to female sex ratio in the study area is highly skewed compared to any of the Asian elephant populations.

3.4.3.4 Effect of age-sex categories on the herd size

The results of simple linear regression between herd size and different age-sex categories are presented in Table 11. The adult females accounted for 95% of the variation in herd size individually. The largest Adjusted R^2 value of adult females shows that a substantial part of variation in herd size is accountable by the adult females in the herd. The corresponding regression coefficient (β_0) was 2.192 indicating that with every addition of an adult female, at least two more individuals are added to the herd. Individually, the sub adult and juvenile females accounted for 43% and 40% of variation in the herd size respectively. Since the sample size was very less, the equation was not fit adult males. The sub adult and juvenile males accounted for 25% and 28% variation in herd size respectively. The low value of regression coefficients for sub adult males (3.6616) compared to other age-sex categories indicates a few individuals in the population. Calves contributed 11% to the variation in the herd size but the corresponding regression coefficient confirms that generally occurred in herds of large size.

Table 10. Comparison of age-sex class properties in different elephant **populations**

Area	AF:AM Sex ratio	Overall Sex ratio M/F	Sources
Wayanad WLS (S. part)	1: 40	1: 3.48	Present study
Mudumalai WLS (S.India)	1: 3.1	1: 1	Daniel et al., 1987
BR Hills, Hasanur (S India)	1: 5.1	1: 1.3	Sukumar, 1985
Nilgiris-Eastern Ghats (1982)	1: 5	-	Sukumar, 1989
Nilgiris-Eastern Ghats (1987)	1: 8.8	-	Sukumar, 1989
Periyar Tiger Reserve	1: 122	-	Chandran, 1990
Dalma WLS	1: 1.3	-	Datye, 1995b
Gal Oya (Sri Lanka)	1: 2.5	-	McKay, 1973
Lahugala (Sri Lanka)	1: 2.4	-	McKay, 1973
Ruhuna-Yala (Sri Lanka)	1: 1.9	1: 1.3	Kurt, 1974
Mahaweli regions, (Sri Lanka)	1: 1.8 1: 2.9	1: 1	Hendavitharana *et al.*, 1994
Ruhuna-Yala (Sri Lanka)	1: 2.9	-	Anonymous, 1993a
Khao Yai, Thailand	1: 2.33	-	Dobias, 1985
Way Kambas, Sumatra	1: 1.5	-	Santiapillai and Widodo, 1990

Table 11. Regression coefficient associated with simple linear regression of herd size on age/sex categories

Age/sex class	β_o	SE (β_o)	β_1	SE (β_1)	Adj. R^2	Value of δ used for transformation
AF	0.627870	0.255070	2.191877	0.052901	0.95338	0.50
SAF	4.520259	0.598375	4.330072	0.399217	0.42626	1.00
JF	2.951501	0.700634	4.552008	0.429241	0.40317	1.25
AM	Equation was not fit					
SAM	7.307172	0.945994	3.661644	0.615384	0.25790	1.25
JM	5.171946	0.995458	4.879336	0.697033	0.28572	1.00
CA	5.325090	1.579975	5.770670	1.359501	0.11654	1.25

The step-wise regression analysis for the cumulative effect of various age-sex categories on herd size is presented in Table 12 and confirms the above findings. It shows that adult females alone explained about 92% of the variation in herd size. The other age-sex categories were responsible only for meager variation in herd size. The variation in herd size due to adult males was negligible.

Table 12. Stepwise regression analysis - Cumulative effect of various age-sex categories on herd size

Age/sex class	Cumulative value of R^2	Partial regression coefficients of the final model (β)	SE (β)
AF	0.9209	0.99114	0.01481
SAM	0.9435	1.02572	0.01956
SAF	0.9590	1.06338	0.02616
JM	0.9767	0.98777	0.02369
JF	0.9868	0.96102	0.02724
CA	0.9980	1.02458	0.03217
AM	0.9984	0.94209	0.14834
Constant	-	0.01918	0.04260

SE = Standard Error

Results of coefficient of correlation matrix between herd size and different age-sex categories, and between age-sex categories are summarised in Table 13. The herd size was highly correlated positively with all age-sex categories especially with adult females and excepting adult males. Adult females were associated with all the age-sex categories except adult males. The subadult females (0.75), juvenile females (0.68) and sub adult males (0.62) were more attached with adult females than the other categories. The juvenile females were attached more with adult females (0.68) and sub adult females (0.57). The juvenile males had high association with adult females (0.57) and more or less equal extent of association with sub adult males (0.39), sub adult females (0.37) and juvenile females (0.37). The calves showed more attachment with adult females alone (0.49) and association with other age-sex categories were less.

The path-coefficient analysis for direct and indirect effects of different age-sex categories on herd size is presented in Table 14. The residual variation for the estimate was 0.01 and thus, only a negligible part of the total variation is left unexplained The maximum positive direct effect on herd size was due to adult females (0.4423) followed more or less equally by sub adult males (0.2053) and sub adult females (0.1898). There was no negative direct effects observed for any age-sex classes.

Table 13. Correlation matrix of different age-sex categories and herd size

	AF	SAF	JF	AM	SAM	JM	CA	HS
AF	I.000	**0.750****	**0.677****	**0.079**	**0.621****	**0.565****	**0.497****	**0.961****
SAF	0.750**	1.000	**0.566****	**0.021**	**0.443**	**0.372****	**0.371****	**0.798****
JF	0.677**	0.566**	1.000	**0.037**	**0.388****	**0.369****	**0.295****	**0.727****
AM	0.079	0.021	0.037	1.000	**0.032**	**0.130**	**0.274****	**0.124**
SAM	0.621	0.443**	0.388**	0.032	1.000	**0.396****	**0.253****	**0.713****
JM	0.565**	0.372**	0.369**	0.130	0.396**	1.000	**0.306****	**0.651****
CA	0.497**	0.371**	0.295**	0.274**	0.253**	0.306**	1.000	**0.555****

$* = P < 0.05$, $** = P = 0.001$

Adult females were found to have high indirect effect on the herd size through sub adult females (0.1423) and sub adult males (0.1273) indicating that variation in these categories mostly simultaneous in a herd. Similarly, sub adult females (0.3317) also had high indirect effect on the herd size through adult females. Except adult males, changes in herd size due to the changes in sub adults, juveniles and calves categories were also mostly through adult females. The adult males were mostly a stand alone group with high indirect effects on the herd size through adult females.

Table 24. Direct and indirect effects of different age-sex categories on herd size

.	AF	SAF	JF	AM	SAM	JM	CA
AF	<u>0.4423</u>	0.1423	0.1000	0.0016	0.1273	0.0881	0.0580
SAF	0.3317	<u>0.1898</u>	0.0836	0.0004	0.0909	0.0580	0.0433
JF	0.2994	O.1075	<u>0.1477</u>	0.0007	0.07%	0.0575	0.0345
AM	0.0351	0.0040	0.0054	<u>0.0203</u>	0.0066	0.0203	0.0320
SAM	0.2742	0.0840	0.0573	0.0007	<u>0.2053</u>	0.0618	0.0295
JM	0.2501	0.0706	0.0545	0.0026	0.0814	<u>0.1559</u>	0.0357
CA	0.2196	0.0703	0.0436	0.0056	0.0519	0.0477	<u>0.1168</u>

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

3.4.3.5 Changes in the mean herd size over time

The estimates of parameters in model (3) are presented in Table 15. The coefficient of the adjusted multiple determination for the model was 0.99828. There was an increasing trend for the mean herd size during the period of observation. The increase was in the order of 1.2873 per year. While estimating the effects of seasons, the second wet season was kept as a reference with no deviation from the trend line.

Table 15. Parameter estimates for different effects in the model

Effect	Coefficient (C)	SE(C)	t value	Prob. of t value
Constant	9.403538	0.451420	20.827	0.0023 *
Trend	1.287315	0.024036	53.558	0.0003 **
Dry	1,631095	0.664070	2.456	0.1334 ns
Wet-1	-1.416160	0.451421	-3.137	0.0884 ns

* = P < 0.05, ** = P < 0.001, ns = nonsignificant

3.4.4. Natality

The birth rate for the elephant population in Wayanad Wildlife Sanctuary was calculated using the mean number of calves born per year. In Asian elephants, the females are sexually mature at 15 years and first calving is usually between 15-20 years of age (Sukumar, 1985; Daniel *et al.*, 1987). A total of 162 calves and 840 adult females (>I5 years) were sampled during the study period. Based on this, the fertility rate was calculated as 0.19/adult female/year or mean calving interval of 5.19 years, The calves were recorded mostly during the wet seasons in the study area.

3.4.5 Mortality

Age specific mortality of elephants in Wayanad Wildlife Sanctuary for 1994, 1995 and 1996 are given in Table 16. A total of 46 elephants were found dead in the whole of Wayanad Wildlife Sanctuary (including Tholpetty) during the period. Among the 46 elephants, 56.5% were males and the rest females. The highest mortality of 25 elephants occurred during 1996.

Table 17 gives the age specific mortality of elephants in the study area (Southern Ranges) alone. There were 37 cases of recorded elephant deaths during the period of 3 years and 22 of these were males and 15 females. Twenty one deaths occurred during 1996 (12 males and 9 females) in the study area.

Table 16. Age specific mortality of elephants in Wayanad Wildlife Sanctuary between January 1994 and December 1996

Age/ Sex	Years							
	1994		1995		1996		Combined	
	M	F	M	F	M	F	M	F
0-1	0	0	1	1	0	2	1	3
1-2	0	0	1	1	1	2	2	3
2-5	0	0	0	0	1	1	1	1
5-7	0	0	0	0	0	0	0	0
7-10	1	1	2	1	4	2	7	4
10-15	2	1	0	0	2	0	4	1
15-20	4	2	0	0	2	0	6	2
20-30	0	0	1	1	2	1	3	2
30-40	0	0	0	0	0	2	0	2
40-50	0	0	1	0	0	1	1	1
>50	0	0	0	0	1	1	1	1
Total	7	4	6	4	13	12	26	20

Estimated average annual population of elephants in the study area for the three years period was 328 elephants (83 males and 245 females). The average mortality rate, based on 3 years of observation in Wayanad was 3.35% per year for the whole population above 2 years. As Laws (1969) pointed out, the carcasses of young animals tend to go unnoticed and additional deaths in 0-5 age class have to be inserted. Hence, the minimum mortality rate will be about 4% per year. The annual mortality was worked out to be 8.43% for males and 2.04% for females in the population

The number of elephants of 5 years and above in the population was about 219 and include 24 males and 122 females. The average mortality rate for the category was 7 males and 4 females. Hence, the mortality rate for the elephants above 5 years was worked out to be 29.17% for males and 3.28% for females.

Table 17. Age specific mortality of elephants in Southern Range alone between January 1994 and December 1996

Age/ Sex	Years							
	1994		1995		1996		Combined	
	M	F	M	F	M	F	M	F
0-1	0	0	0	0	0	2	0	2
1-2	0	0	0	1	1	0	1	1
2-5	0	0	0	0	1	1	1	1
5-7	0	0	0	0	0	0	0	0
7-10	1	1	2	1	4	2	7	4
10-15	2	1	0	0	2	0	4	1
15-20	4	2	0	0	1	0	5	2
20-30	0	0	0	1	2	1	2	2
30-40	0	0	0	0	0	1	0	1
40-50	0	0	1	0	0	1	1	1
>50	0	0	0	0	1	1	1	1
Total	7	4	3	3	12	9	22	16

The details of cause of elephant mortality in the whole of Wayanad Wild life Sanctuary are given in Table 18. Among the 26 males, around 19% were due to natural death and 46% due to disease. The mortality due to poaching and human-elephant conflict were 12% and 23% respectively. In the case of females, the cause of death was only natural and due to disease. There was no incidence of female death due to the conflict.

A very high mortality (more than 30%) in the age category of 7-10 years were recorded. About 40% of the mortality occurred in the age category of 10-15 and 15-20 years of males in the population. Percentage mortality among the categories below 5 year and above 45 year were comparatively less. On the other hand, the mortality was almost even in all the age categories in females, except that of 7-10 years, which comprises about 25%.

About 10 to 12% of female mortality occurred in 0 -1, 15-20 and 20-30 age categories. There was no record of death in 5-7-age category during the study period. However, juvenile mortality in the case of females were more (about 20%) than males (about 8%). Sub adult and adult mortality were more in males than females.

Table 18. Cause of death of elephants in Wayanad Wildlife Sanctuary between January, 1994 and December 1996

Cause of death	Males		Females	
	F	%	F	%
Natural	5	19.22	9	45.00
Disease	12	46.14	11	55.00
Poaching	3	11.54	0	0.00
Man-wildlife conflict	6	23.10	0	0.00
Total	26		20	

3.5 Density estimates of other animals

3.5.1 Gaur

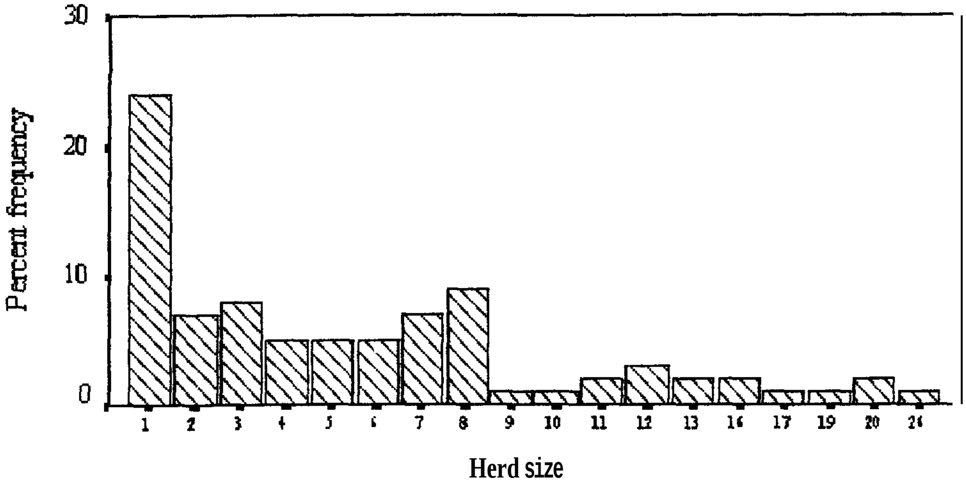
The results of estimates overall season wise dung density of gaur is presented in Table 19. There was a highly significant Qfferences observed between the years ($\chi 2$=291 .64, df=2;pf<0.001). Also a remarkable differences between seasons were observed in all the years ($\chi 2$=161.77,df=2;pf<0.001). The density was high during the dry and second wet seasons in all the years and a medium density during the first wet seasons.

Only the completely classified herds had been taken for analysis of herd size and structure. A total of 495 animals in 62 herds were recorded from Southern Ranges and herd size ranged from 1 to 26 (Fig. 6).

Table 19. Overall estimate of Gaur dung density

Year	Season	Sample size	Dung density	% CV	95%CL Lower	95%CL Upper
1994	Dry	41	564.12	8.91	465.60	662.64
	Wet 1	34	422.95	21.13	247.79	598.11
1995	Dry	54	690.41	7.62	587.30	793.53
	Wet-1	37	428.50	18.12	276.32	580.68
	Wet-2	46	582.48	19.46	360.31	804.65
1996	Dry	50	486.35	9.82	392.74	579.96

Fig .6. Percentage frequency distribution of herd size of gaur



Proportion of age-sex categories of gaur population in Southern Ranges is presented in Table 20. Adult females formed major portion of the population followed by sub adult females (Fig. 7). Adult males constituted 15.35% in the Southern Ranges. The overall male to female sex ratio in Southern Ranges was 1:3.31. Adult male to female sex ratio of 1: 3.49 and sub adult sex ratio of 1:2.82 was observed in Southern Ranges. The sex ratios of gaur in Southern Ranges are summarized in Table 21.

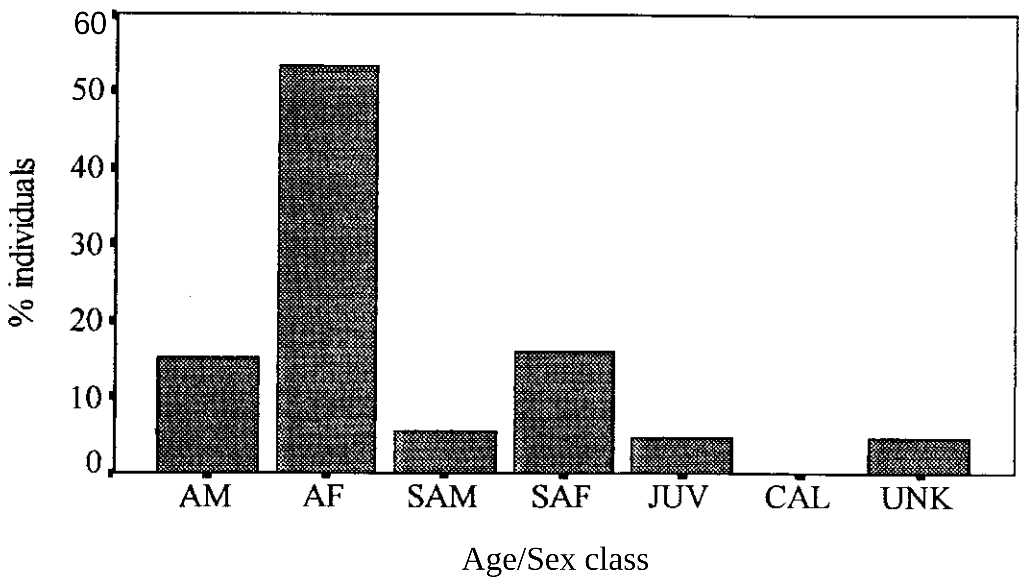
Table 20. Percentage frequency of age sex classes of gaur

Sedclass	Total	Percentage
Adult male	76	15.35
Adult female	265	53.54
Sub-adult male	28	5.66
Sub-adult female	79	15.96
Juvenile	23	4.65
Calf	0	0.00
unknown	24	4.85
Total	495	100.00

Table 21. Sex ratio of gaur

Sex/class	
Adult male : Adult female	1: 3.49
Sub-adult male : Sub-adult female	1: 2.82
Over all	1: 3.31

Fig. 7.Percentage frequency of age and sex classes of gaur



AM= Adult male, AF= Adult female, SAM= Sub adult male, SAF= sub adult female, J W = juvenile. CAL= calf, UNK= unknown

3.5.2 Sambar

Seasonal estimates of sambar pellet density in the study area are given in Table 22. The overall estimates indicate a significant difference between the seasons. In 1994, a high density was observed during the second wet seasons and medium density in the first wet seasons. A low density was observed during the dry season. There was no much significant differences observed between the first and second wet season in the pellet density during 1995. A low density was observed in the dry season. The density during the first wet season was higher than the dry season during 1996.

Group composition and sex ratio

A total of 637 animals were sighted in 231 herds in Southern Ranges. The herd size observed ranged from 1 to 11 (Fig 8). In Southern Ranges, adult females (42.86%) formed a major portion of the population followed by adult males (40.97%). The juvenile females were 7.06%, juvenile male 5.56% and fawns 2.83%

of the population (Table 23 and Fig 9). Overall sex ratio of sambar in Southern Ranges was 1: 1.07 and adult male to adult female sex ratio was 1: 1.05 (Table 24).

Table 22. Sambar deer pellet density in different seasons

Year	Season	Sample size	Pellet density/km^2	% CV	95 % CI	
					Lower	Upper
1994	Dry	79	1012	11.65	780.92	1243.08
	Wet-1	157	1538	25.65	764.79	2311.21
	Wet 2	91	2538	25.65	1262.05	3813.95
1995	Dry	96	1394.30	22.84	770.12	2018.48
	Wet-1	156	2767	28.85	1202.37	4331.63
	Wet-2	93	2627.	16.55	1774.85	3479.15
1996	Dry	90	1033.60	9.34	844.39	1222.81
	Wet-1	127	1559	23.34	845.81	2272.19

Dry = Dry season; Wet-1 = First Wet Season; Wet-2 = Second Wet Season

Table 23. Percentage frequency of age sex classes of sambar

Sex/class	Total	Percentage
Adult male	261	40.97
Adult female	273	42.86
Juvenile male	36	5.65
Juvenile female	45	7.06
Fawn	18	2.83
unknown	4	0.63
Total	637	100.00

Table 24. Sex ratio Sambar deer

Sex/class	
Adult male: Adult female	1: 1.05
Juvenile male: Juvenile female	1: 1.25
Over all	1: 1.07

3.5.3 Chital

The overall estimates of pellet density of chital are given Table 25. The overall density of pellets were distinctly varied across the seasons in all the years ($\chi 2=630.07 df=2, p<0.001$). A high density was observed during the first wet season in 1994 and 1995 and a low density during the dry season and second wet season.

During 1996, the density was more in the dry season and comparatively less in the first wet season.

Fig 8. Percentage frequency distribution of herd size of sambar

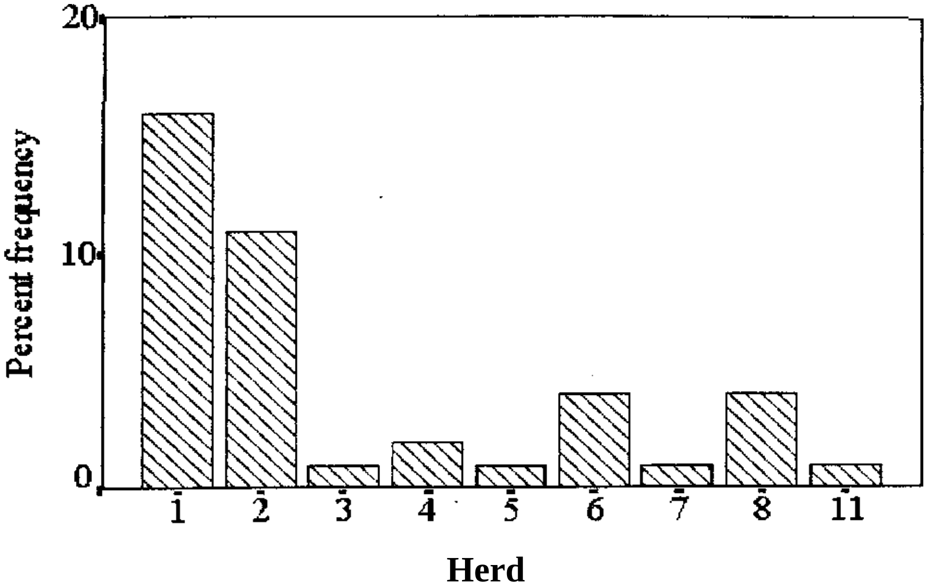
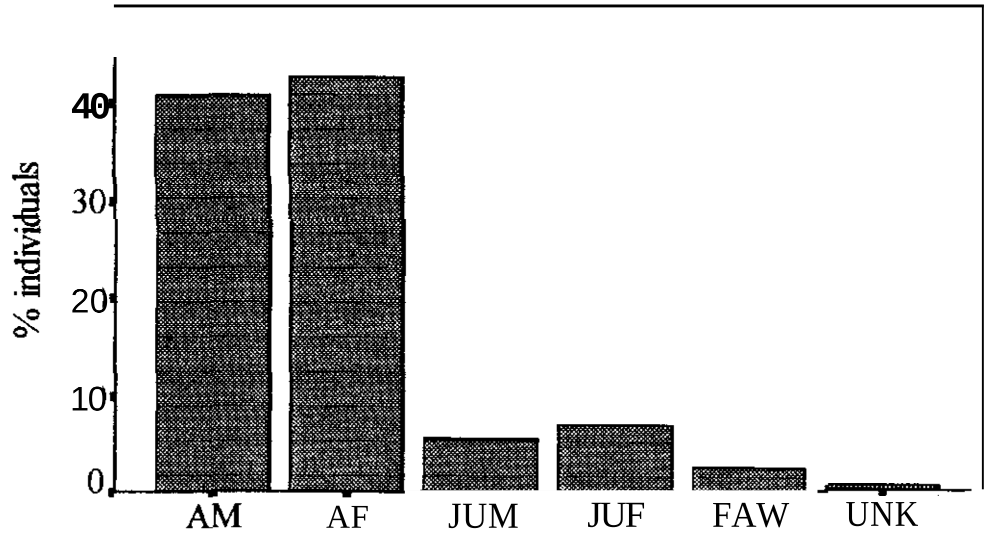


Table 25. Chital pellet density in different seasons

Year	Season	Sample size	Pellet density/km^2	% CV	95 % CI Lower	Upper
1994	Dry	40	895	27.55	411.72	1378.28
	Wet-1	77	2749	29.30	1170.30	4327.70
	Wet 2	28	628.42	26.48	320.26	954.58
1995	Dry	11	985	27.55	411.72	1378.28
	Wet-1	77	1749	29.30	744.58	2753.42
	Wet-2	62	628.40	26.40	303.24	953.56
1996	Dry	97	1287.01	31.35	496.19	2077.83
	Wet-1	68	953.06	11.24	743.10	1163.02

Dry = Dry season; Wet-1 = First Wet Season; Wet-2 = Second Wet Season

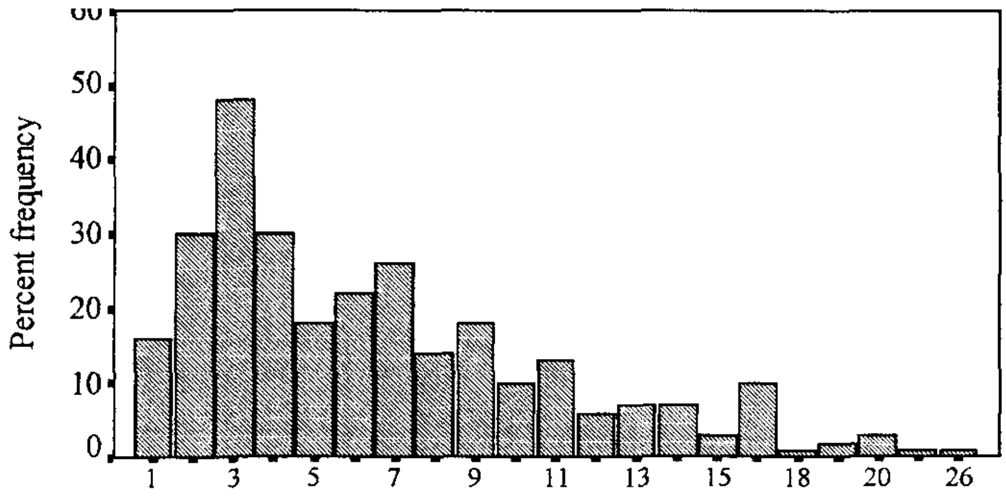
Fig. 9.Percentage frequency of age and sex classes of Sambar



AM= Adult male, AF= Adult female, JUM= Juvenile male,
JUF= Juvenile female, FAW= Fawn, UNK= Unknown

Fig. 10. Percentage frequency distribution of herd size of spotted deer

Group composition and sex ratio

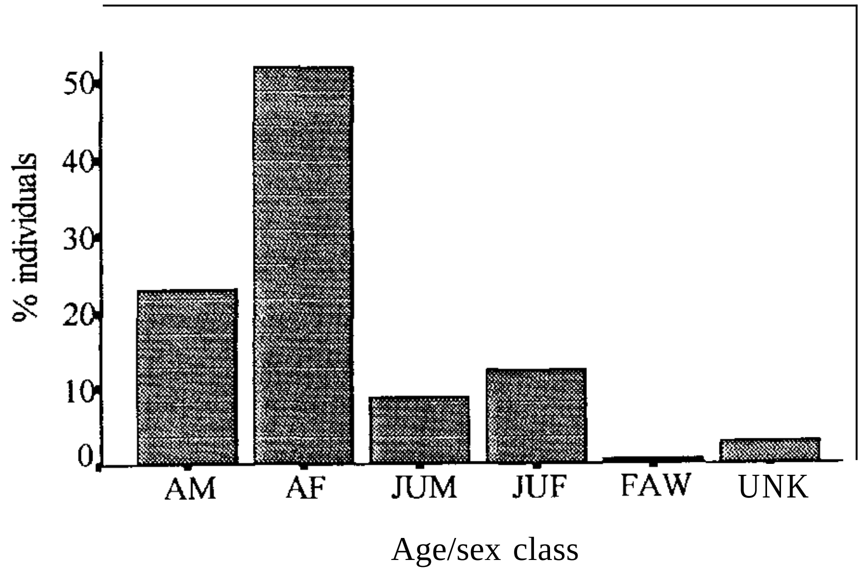


A total of 1891 animals in 286 herds were sighted in Southern Ranges during the study. Percentage frequency distribution of herd size in the Southern Ranges are given in Figure 10 and the herd size was found to range from 1 to 26.

Proportion of age-sex categories of spotted deer population in Southern Ranges are presented in Table 26. The percentage frequency distributions of various age-sex classes of spotted deer in the Ranges are given in Figure 11. Adult females formed a major portion of the population (51.98%) and adult males were about 23%.

The sex ratio of spotted deer is summarized in Table 27. The overall sex ratio was 1: 2.02, adult male to adult female was 1: 2.25 and juvenile male to juvenile female was 1: 1.41.

Fig. 11. Percentage frequency of age and sex classes of spotted deer



AM= Adult male, AF= Adult female, JUM= Juvenile male, JUF= Juvenile female, FAW= Fawn, UNK= Unknown

Table 26. Percentage frequency of age sex classes of spotted deer

Sex/class	Total	Percentage
Adult male	436	23.06
Adult female	983	51.98
Juvenile male	166	8.78
Juvenile female	234	12.37
Fawn	16	0.85
Unknown	56	2.96
Total	1891	100.00

Table 27. Sex ratio of spotted deer

Sex/class	Southern Ranges
Adult male : Adult female	1:2.25
Juvenile male : Juvenile female	1: 1.41
Over all	1:2.02

3.6 Discussion

3.6.1 Dung decay rate

Barnes and Jensen (1987) observed that the dung decay rate was related to temperature, humidity and rainfall. Varman *et al.* (1995) reported a decay rate of 0.0l0/day for dry season, 0.013 for first wet season, 0.007 for second wet season and an overall decay rate of 0.0097 per day for Mudumalai Wildlife Sanctuary. Sale *et al.* (1990) reported an overall dry season decay rate of 0.0136 in the same area and early dry season decay rate of 0.0146 per day in Parambikulam Wildlife Sanctuary.

The decay rates in Wayanad were higher than Mudumalai and Parambikulam Wildlife Sanctuaries. This could be attributed to the distribution of vegetation types in Wayanad where it is homogenous in nature compared to the heterogeneous - mosaic nature of vegetation in Parambikulam and to a certain extent in Mudumalai.

During the experimental period, the number of rainy days as well as the amount of rain significantly varied between habitats and between seasons (Table 3). The steep increase in the decay rate with the number of rainy days (Fig. 10) suggests that the seasonal differences in the decay rate in both the habitats was due to the differences in the rainfall. Higher rainfall also facilitates the activity of dung beetles and termites, accelerating the decomposition process (Coe, 1972; Kingston, 1977; Dawson and Dekker, 1992). Although, the activity of dung beetles in dry season appeared low, termite activity during the dry season could equal that of the wet season.

The higher rainfall in moist deciduous forests compared to dry deciduous forests explains the higher dung decay rate in the rainy season in the former type. It is concluded that the dung decay rate in the study area depends on the number of rainy days as well as the amount of rain received during the observation period. Since the number of rainy days and the amount of rainfall vary between seasons, between years and even between habitats, the suggestion to estimate dung decay rate simultaneously with the elephant count should be strictly adhered for a near accurate population estimate.

3.6.2 Density estimates

Density of elephants showed annual differences and ranged from 1.02/km^2 to 1.35/km^2 in the study area. This crude density is comparatively higher than reported for other areas as shown below:

Area	**Density/km^2**	**Source**
Chamaraja Nagar and Sathyamangalam	0.53	Sukumar (1985)
Periyar Tiger Reserve	1.0	Nair *et al.* (1985)
Parambikulam WLS	0.5	Easa (1989b)
Sri Lanka	0.1-0.46	Eisenberg and Lockhart (1972), Mckay (1973), Ishwaran (1984), Santhiapillai (1984)
Malaysia	0.12-0.27	Olivier (1978a)
Sabah	0.18-0.20	Andau *et al.* (1997)

However, the density estimate based on the dung density for the adjacent Mudumalai was 1.74/km^2 during 1991-1992 (Varman *et al.,* 1995). Eisenberg and Seidensticker (1976) have mentioned the possibility of elephant density ranging From 0.12 to 1/km^2 in suitable south east Asian habitats.

The seasonal difference in the density of elephants in the study area was not significant for 1994 and 1996. However, the seasonal difference in the density of 1995 was significantly higher. The dry season density of 2.04/km^2 in 1995 was much higher compared to the figures obtained throughout the study period. This has probably contributed to the higher overall density of elephants in the study area. The seasonal density values in Southern Ranges of Wayanad recorded a uniformly higher value in the dry season. Studies in Africa (Buechner *et al.,* 1963; Leuthold, 1976b; Lewis, 1987) and in Asia (Eisenberg and Lockhart 1972; Sukumar, 1985; Easa, 1989b; Sivaganesan, 1991; Desai and Baskaran, 1996) have shown the influences of food and water availability on density distribution of elephants. The seasonal distribution is also influenced by a number of proximate factors (Lamprey *et al.,* 1967; Bell, 1971; Jarman and Jarman, 1973; Western and Lindsay, 1984; Lamprey, 1985; Dublin and Douglas-Hamilton, 1987).

Varman *et al.* (1995) reported a decrease in density of elephants in the adjacent Mudumalai during dry season and an increase in the subsequent wet season. The drying up of water sources in Mudumalai and Bandipur areas along with frequent Occurrence of tire could be the factors leading to a higher density of elephants in the study area during the dry season. This could be especially true in the wake of the extensive fire in Mudumalai and Bandipur in 1995. The perennial streams in the study area - Mavinahalla, Nulpuzha and Kurichiat thodu provide much needed water source for elephants during the pinch period of dry season.

3.6.3 Herd size, composition and structure

The matriarchal social setup among the elephant have been described by several authors (Buss, 1961; Laws and Parker, 1968; Douglas-Hamilton, 1972: Olivier, 1978a; Sukumar, 1985). The present observation in Wayanad that the herds are centered around females along with sub-adults and juveniles confirms these findings.

Herd size is a measure of the ecological health and larger herd size reflects stressful condition (Laws, 1974). Eltringham (1977) have reported the possibilities of larger herd size due to the poaching pressure. The herd size frequency of the elephants in the study area showed a polymodal distribution with peaks occuring at

5, 9 and 14 with several minor peaks. Similar observations have been reported for African (Laws, 1969; Laws *et al.,* 1975) and Asian elephants (Sukumar, 1985; Daniel *et al.,* 1987; Easa, 1989b). The smaller herds frequented more in the study area could be the reflection of the forested habitats (Peak *et al.,* 1974; Leuthold, 1976b). The least frequented larger herd size could be aggregation of different family units forming extended family (Laws *et al.,* 1975) and have no long-term cohesion (Ishwaran, 1984).

All male herds (bachelor herds) were not frequented in the study area. A herd of two males was observed only once. Large sized male herds have been reported from Lake Manyara (Douglas-Hamilton, 1972), Murchison Falls (Laws *et al.,* 1975), Seronera (Croze, 1974). Mckay (1973) reported all male herds of 7 individuals in Lahugala in Sri Lanka. Sukumar (1985) observed such herds in his study area. Large sized all male herds could be an indication of the higher number of the bulls in the population (Croze, 1974). The fewer occurrences of all male herds in the population could probably be an indication of the low proportion of males in the study area. The overwhelming proportion of solitary bulls could also be pointing to the low male proportion in the population in Wayanad Wildlife Sanctuary.

The overall mean herd size of elephants was 10.39 in 1994 and 11.56 in 1995. An increasing mean herd size was observed during first wet season followed by dry season. Leuthold (1976a) have observed higher mean herd size in Tsavo National Park during wet season with a decrease during dry season and the difference was attributed to the seasonal difference in the abundance of food. Dublin (1996) reported the seasonal influence on herd size of elephants in Masai Mara, Kenya and correlated the large herd size observed in wet season to abundance of preferred food. Similar observations have been made by Sukumar (1985), Daniel *et al.,* (1987) and Easa (1989b) in Asian elephants. The present observation in Southern Ranges of Wayanad suggests the influence of food availability rather the elephant density on mean herd size.

3.6.4 Sex ratio

Downing (1980) considered sex ratio as a measure of reproductive performance of the population. Sukumar (1989) has discussed in detail the possible influence of disparate sex ratio on the fertility of the population. Most mammalian population are reported to have an adult sex ratio biased towards females. This has been attributed to the higher natural mortality of males. The dynamics of large mammal population are influenced by stochastic environmental perturbations or long term population cycles (Wu and Botkin, 1980; Croze *et al.*, 1981). Sukumar (1989) suggested that the operational adult sex ratio need not be as disparate as observed sex ratio in the population. Further, considering the non seasonality of breeding in elephants, a disparate sex ratio can still ensure mating of almost all mature females. Cowan (1950) and Clutton-Brock *et al.* (1982) have mentioned a female biased adult sex-ratios in population close to canying capacity.

Proportion of different age-sex classes in the elephant population in Wayanad indicates a shift towards the older age classes with adult, sub-adult and juvenile females contributing maximum. The calves form only 8.13% of the population indicating a low recruitment or reduced number of breeding females. These could be normally taken as a negative trend in the population growth rate. However, the conclusions arrived from the observed age distribution have been strongly criticized (Caughley, 1974 & 1977). Sukumar (1989) also showed the unreliability of such interpretation of age ratio without information on other parameters such as fertility and mortality rates, The sex ratio at stable age distribution depends on the magnitude of difference in mortality rate of male and female elephants (Sukumar, 1989).

The mortality figures for Mudumalai and Eastern Ghats have been reported to be 1.2% for adult-females and 14.5% for adult-males (Daniel *et al.*, 1987). Sukumar (1985) reported a mortality of 1.7% for females and 11.84 % for males. The present observation of 3.28% and 29.17% for females and males respectively in the study area is considerably higher. The mortality was higher during summer. The observations also indicate a higher male mortality in summer in the study area. This coincided with higher density within the area. Further, evidences from studies on cervids and sheep predict, adult or adolescent males are more likely to die during periods of food shortage than females of the same age in several dimorphic species (Robinette *et al.,* 1957; Klein, 1968; Grubb, 1974). The increased human pressure leading human-elephant conflict could also be contribution to the problems as evident from the causes of mortality.

The increased density during dry season, decreased availability of quality forage during the period and the low percentage of area available - all exert pressure on the elephant population in Wayanad. Mortality rate was high during the dry season. Sukumar (1985) attributed 20% of the female and 65% of the male mortality in South India to human beings. Daniel *et al.* (1987) reported 80.7% of the mortality due to human interference. In Wayanad, 11.54% of the mortality of males were due to poaching and 23.1% due to human-elephant conflict. In fact, these figures could be underestimates since the post mortem often fails to diagnose or pinpoint the cause of death since the carcass would be putrefied making it difficult to collect parts for laboratory examination. About 90% of the tusker carcasses examined had bullet injuries inflicted either during crop raiding or due to poaching attempts. Six out of 17 adult and sub adult tuskers observed in May, 1995 had bullet injuries.

The fertility rate of 0.19 per adult-female per year or a mean calving interval of 5.1 years have been calculated for the study area. The estimated mortality was 8.43% for males compared to 2.04% for females. The mortality was higher in the 7-10 years sub-adult category in both the males and females. Sukumar (1989) has used simulation to predict population growth rate with different calving intervals. A high male - low female mortality with 1: 28.7 male-female sex ratio and calving intervals of 5.5 years predict a growth rate of 1.08%. Sukumar (1989) have suggested a possible widening adult sex ratio for a short-term of about 5 year before narrowing down due to a higher mortality in the 7-10 and 10-15 age classes. As long as the female mortality is low, the population could still have capacity to increase or remain stable in spite of decreased fertility due to higher mortality rate (Sukumar, 1989). Considering the mortality of males in the population as high and those of females as low and with a mean calving interval of 5.19 years, the elephant population.

3.6.5 Other animals

Gaur is a gregarious animal and the group centered around the adult females (Vairavel, 1998). The proportion of solitaries in Southern Ranges was higher compared to Northern Ranges. Most of these were males. The tendency of bulls to the solitaries is considered to be a property of males of the genus Bison (Krasinski, 1978). However, observations in Parambikulam have also indicated a higher proportion of males among the solitaries. The most frequented group size of gaur in Southern Ranges was 2,3,7 and 8 and in Northern Ranges 2 and 7. However, largest herds size of 26 and 30 were observed the Southern and Northern Ranges respectively, The larger groups could be aggregations of smaller units probably due to the environmental factors in these areas.

Sambar deer is considered to form small groups (Schaller, 1967). The herd size in different ranges of Wayanad vary considerably where the solitaries dominate in the southern and northern ranges. Solitaries formed about 60% of the sites in Wilpattu National Park (Eisenberg and Lockhart 1972), 48% in Periyar (Ramachandran *et al.*, 1986) and 25% in Parambikulam (Easa, unpublished information).

The average group size of chital at Kanha was between 5 and 10, and the largest group was of about 175 animals (Schaller, 1967). The more frequented groups in Chitwan in Nepal were of 6-10 individuals and the largest group had 40 animals. (Seidensticker, 1976). The larger group sizes observed in Northern Range could be aggregations during lean period.

Schaller (1967) and Vairavel(l998) have reported distorted sex ratio of gaur, favouring females. This has been attributed to the high mortality rate among the males (Krasinski, 1978) Adult females dominate the population of sambar deer in all the ranges. Though there are variations in the proportion, the number of adult males in the southern range is almost equal to adult female. Fewer number of fawns in the northern central ranges probably indicate the slow recruitment to the population. The sex ratio of spotted deer in Chitwan was almost 1:l (Seidensticker, 1976) and about 1:1.4 in Kanha (Schaller, 1967) Schaller (1967) attributed the disparate sex ratio to the selective predation on females. This seems to be true in the case of the populations in Wayanad, especially the Northern and Southern Ranges where the populations are comparatively higher.

Considering the contiguity of Wayanad with larger extent of forests, the animal population in the area, especially the elephant population could be considered as viable without the problems of loss of genetic variation.

Chapter 4

Food and feeding

4.1 Introduction

Distribution of large herbivore, favouring habitat types is largely determined by the availability of natural resources such as food, water, minerals and shelter required for the survival of the species (Jarman and Sinclair, 1979). Food resources show marked variation between habitats and between seasons within the habitat (Philipson, 1975; Sinclair, 1975). Changes in plant distribution and phenology affect the ungulate food habits, energy budget and seasonal distribution (Dinerstein, 1979). Riney (1982) has discussed the relevance of food habit studies in wildlife management and stressed that such studies should consist of composition of the diet, its seasonal variation and parts utilised. It is also important to investigate the foraging behaviour as it has considerable relevance in the wildlife management dealing with the maintenance of habitat quality to ensure the carrying capacity. This will help to understand and interpret the crop raiding behaviour of elephants.

Though elephants are known to be a generalist feeder, there is considerable disagreement as to whether it is a browser or grazer (Sukumar and Ramesh, 1995). Studies on foraging through direct observations in Asia (Sukumar, 1985) indicate that browse also is as important as grass species in the diet component. Some of the studies (McKay, 1973; Vancuylenberg, 1977; Easa, 1989a; Sivaganesan, 1991) emphasised that elephants are predominantly grazer. These studies indicated variation in the resource utilisation depending on the vegetation and availability. The selection of the diet vary between the age and size of the animals and also are related to the energy and nutrient contents of the food species (Easa 1989a).

Studies have been reported in Asia on the food habits, the quantity fed and rate of feeding by elephants in captivity (Ananthasubramaniam, 1980) and in the wild (Krishnan, 1972; McKay, 1973; Olivier, 1978a; Sukumar, 1985 & 1989; Santiapillai and Suprahman, 1986; Daniel *et al.,* 1987; Easa, 1989a; Sivaganesan, 1995).

This chapter deals with the food and feeding habits of larger mammals especially the elephants in the Southern part of Wayanad Wildlife Sanctuary

4.2 Methods

Data on feeding of elephants in different seasons and habitats were collected by direct observation using scan sampling method (Altmann, 1974). Observation was made on foot or from an observation point for better view with a 10 x 50 binoculars. Care was taken to ensure that the target animal(s) were not disturbed. Searching was made in all habitats and observation initiated as soon as a target group was located. Data were collected on the target animals as far as possible since continuous observations were not always possible in the study area due to the dense vegetation. The period of observation was extended up to 18.00 hrs. if the animals were in the visibility. The observation hours were not strictly proportionate to the extent of vegetation types because of the seasonal variation in the density of elephants in different vegetation types.

During the 10 minutes observation in each scan sampling period, as many individuals as possible were scanned for their activity pattern. The sex and age of the individuals and the activity at the moment of observation were recorded in each scan.

The food species of sambar deer and spotted deer were identified based on direct observation and examination of feeding sites.

Activities were broadly classified into feeding, moving, resting and comfort activities. Feeding activity included feeding on grass or browse species. The 'browse species' referred here includes the herbs, shrubs, debarking, feeding on twigs and leaves of trees. Comfort activities include drinking water, feeding on salt lick, mud bath, defecation, playing and exploratory behaviour. During feeding, information on food species, height at which eaten, parts eaten and parts discarded were also noted. Identities of food species were confirmed by inspecting the feeding site after the animal(s) moved out from the area.

4.3 Analyses

Occurrence of an activity in one scan sample was considered as a record. Total frequency of each activity in different seasons and habitats were pooled separately for the purpose of analysis. Seasonal and habitat-wise feeding scores were derived From the analysis. Analysis also included the seasonal and annual proportion of grass and browse species in the dietary component of elephants in each habitat. All the analyses were carried out with the computer program SPSS ver.6.0 (Anonymous, 1987).

4.4 Results

A total of 5976 minutes of observations were made within a span of 24 months (from January, 1994 to December, 1995). Of these, 37.1% of the observation were from dry deciduous forest, 29.3% from moist deciduous and 33.6% from plantations.

4.4.1 Food species

List of food species of elephants in the study area is given in Table 28. Elephants fed a total of 97 species of plants belonging to 34 families. More than 50% of the food species belonged to Poaceae (42 species) and Cyperaceae (10 species) families.

Table 28. List of plants fed by elephants in Wayanad Wildlife Sanctuary

Cyperaceae

1. *Cyperus compressus*
C. distans
3. *C. exaltatus*
4. *C. kyllingia*
5. *C. pilosus*
6. *Fimbristylis dichotoma*
7. F. *littoralis*
8. *Kyllinga monocephala*
9. *Scleria laevis*
10. *Rhyncospora sp.*

Poaceae

11. *Arthraxon lanceolatus*
12. *Alloteropsis cimicina*

Poaceae

13. *Apluda mutica*
14. *Bambusa arundinacea*
15. *Brachiaria miliiformis*
16. *Capillipediumfil icularis*
17. *Chrysopogon aciculatus*
18. *Cymbopogonflexuosus*
19. *Cynodon arcuatus*
20. *C. dactylon*
21. *Cyrtococcumpatens*
22. *Dactyloctenium aegyptium*
23. *Digitaria ciliaris*
24, *D. longiflora*
25. *D. setigera*
26. *Echinochloa colona*
27. *Eleusine indica*
28. *Eragrostis tenella*
29. *E. tenuifolia*
30. *E. unioloides*
31. *Eriochloa procera*
32. *Heteropogon contortus*
33. *Imperata cylindrica*
34. *Ischaemum indicum*
35. *I. rangacharianum*
36. *Oplismenus compositus*
37. *Oryza meyeriana* var. *granulata*
38. *Panicum notatum*
39. *P. indicum*
40. *P. maximum*
41. *Paspal idium flavidum*
42. *P. punctatum*
43. *P. conjugatum*
44. *P. scrobiculatum*
45. *Pennisetum hohenackeri*
46. *Setaria palmifolia*
47. *S. pumila*
48. *S. intermedia*
49. *Sporobolus indicus* var. *diander*
50. *Themeda cymbaria*

Poaceae

51. *T. triandra*
52. *T. tremula*

Scrophulariaceae

53. *Scoparia dulcis*

Amaryllidaceae

54. *Curculigo orchioides*

Asclepiadaceae

55. *Hemidesmus indicus*

Euphorbiaceae

56. *Phyllanthus urinaria*

Malvaceae

57. *Sida acuta*
58. *S. mysorensis*
59. *S. rhombifolia*
60. *Thespesia lampas*
61. *Urena lobata* ssp. *sinuata*
62. *U lobata* ssp. *Lohata*

Mimosaceae

63. *Mimosa pudica*

Papilionaceae

64. *Desmodium gangeticum*
65. *D. triangulare*

Rhamnaceae

66. *Zizyphus xylopyrus*

Sterculiaceae

67. *Helicteres isora*

Tiliaceae
68. *Triumfetta rhomboidea*
69. *Grewia hirsuta*
Verbenaceae
70. *Lantana camara*
Zingiberaceae
71. *Curcuma* sp.
72. *Globba marantina*
Anacardiaceae
73. *Mangifera indica*
Bignoniaceae
74. *Stereospermum colais*
Bombacaceae
75. *Bombax ceiba*
Caesalpinaceae
76. *Bauhinia racemosa*
Combretaceae
77. *Terminalia alata*
78. *T. crenulata*
79. *T. paniculata*
Dipterocarpaceae
80. *Shorea roxburghii*
Ebenaceae
81. *Diospyros montana*
Euphorbiaceae
82. *Bridelia retusa*
83. *Emblica officinalis*
Lecythidaceae
84. *Careya arborea*
Lythraceae
85. *Lagerstroemia microcarpa*
Malvaceae
86. *Kydia calycina*
Moraceae
87. *Ficus bengalensis*
Myrtaceae
88. *Syzygium cumini*
Oleaceae
89. *Schrebera swietenioides*
Papilionaceae
90. *Dalbergia latifolia*
91. *Pterocarpus marsupium*
Rubiaceae
92. *Randia dumatorum*
Sapindaceae
93. *Schleichera oleosa*
Sterculiaceae
94. *Sterculia villosa*
Tiliaceae
95. *Grewia tiliaefolia*
Verbenaceae
96. *Gmelina arborea*
97. *Tectona grandis*

4.4.2 Seasonal variation in selection of various parts of food species

4.4.2.1 Grass

The tall grasses, dominant in the dry deciduous forest were uprooted by elephants and fed on the lower portion more frequently during the dry season (Table 29). Feeding on *Themeda cymbaria* and *T. triandra* were mostly confined to the lower portion in dry deciduous forest. Feeding on entire grass and the upper portions alone formed less than 10% only. On the contrary, the entire grass was fed more often in moist deciduous forest (89%) and the percentage of feeding on upper portion formed only 11%. Elephants were not found to feed entirely on lower portion in moist deciduous forest where tall grasses are scarce. In plantations, the dry season feeding was mostly on the entire grass (65%) and then on their upper portion (35%). Elephants did not feed tall grasses in certain places in the plantations. Feeding on entire grass clump was higher (63.33%) during dry season and upper and lower portions only 19.23% and 17.44% respectively.

Table 29. Percentage contribution of various parts of grass to elephant diet during dry season

Habitat	Parts eaten					
	Entire		Upper		Lower	
	N	%	N	%	N	%
DDF	4	5.33	3	4.00	68	90.67
MDF	145	88.95	18	11.04	0	0.00
PLN	98	64.47	54	35.53	0	0.00
	247	63.33	75	19.23	68	17.44

DDI = Drv deciduous forests: MDF = Moist deciduous forests:
PLN = Plantations

During the first wet season,·elephants preferred to feed almost equally on different parts of the grass species in dry deciduous forests (Table 30). The percentage feeding on entire, upper and lower portions did not vary much in dry deciduous forests. The entire grass clump was fed in more than 97% of the observation in moist deciduous forests and a negligible percentage was on the upper portion of the grass. Elephants preferred to feed the entire grass in plantations during first wet season. Feeding on entire grass was higher during first wet season compared to dry season.

Table 30. Percentage contribution of various parts of grass to elephant diet during first wet season

Habitat	Parts eaten					
	Entire		Upper		Lower	
	N	%	N	%	N	%
DDF	39	36.11	43	39.81	26	24.07
MDF	48	97.96	1	2.04	0	0.00
PLN	102	100.0	0	0.00	0	0.00
	189	72.97	44	16.99	26	10.04

DDF = Dry deciduous forests; MDF = Moist deciduous forests;
PLN Plantations

Feeding on entire grass was more frequented in dry deciduous forests during second wet season (Table 31). The upper portion formed 25.93% and lower portion about 5.19%. Elephants were found to feed on entire clump of grass both in moist deciduous forest and plantations.

Table 31. Percentage contribution of various parts of grass to elephant diet during second wet season

Habitat	**Parts eaten**					
	Entire		Upper		Lower	
	N	%	N	%	N	%
DDF	93	68.89	35	25.93	7	5.19
MDF	145	100.0	0	0.00	0	0.00
PLN	49	100.0	0	0.00	0	0.00
	287	87.23	35	10.64	7	2.13

DDF = Dry deciduous forests; MDF = Moist deciduous forests;
PLN = Plantations

4.4.2.2 Browse

Elephants fed the entire plants of *Curcuma* sp., *Grewia hirsuta* and *Mimosa pudica*. The partially fed browse species are summarised in Table 32. Feeding on bark alone constituted about 56% and, twigs and leaves formed a major proportion next to bark (33.3%). Small twigs formed 11.13% of the total browse diet. The twigs and leaves of *Helicteres isora* formed a major part (67.52%) followed by bark of *Teetona grandis* (16.24%) and *Grewia tiliaefolia* (11.78%). *Kydia calycina, Randia dumatorum* and *Ficus* sp. were fed only to a lesser extent. Majority of twigs were of *H. isora* (58.1%), *T. grandis* (16.19%), *K. calycina* (14.29%) and *G. tiliaefolia* (11.43%). The bark of *K. calycina, S. roxburghii* and *H. isora* formed about 70% of the total browse species debarked by elephants. Other species such as *T.grandis* and *G. tiliaefolia* were moderately debarked by elephants and formed about 26%.

Proportion of *Boauhinia racemoso, Emblica officinalis, Gmelino arborea* and *Sterculia villosa* in the elephant diet were negligible in the study area.

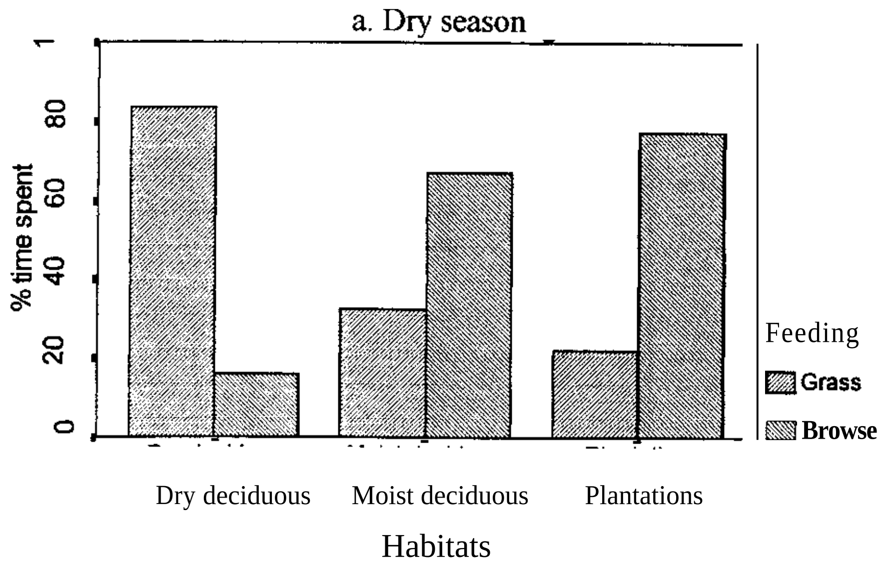
Table 32. Percentage contribution of various parts of browse species to elephant diet

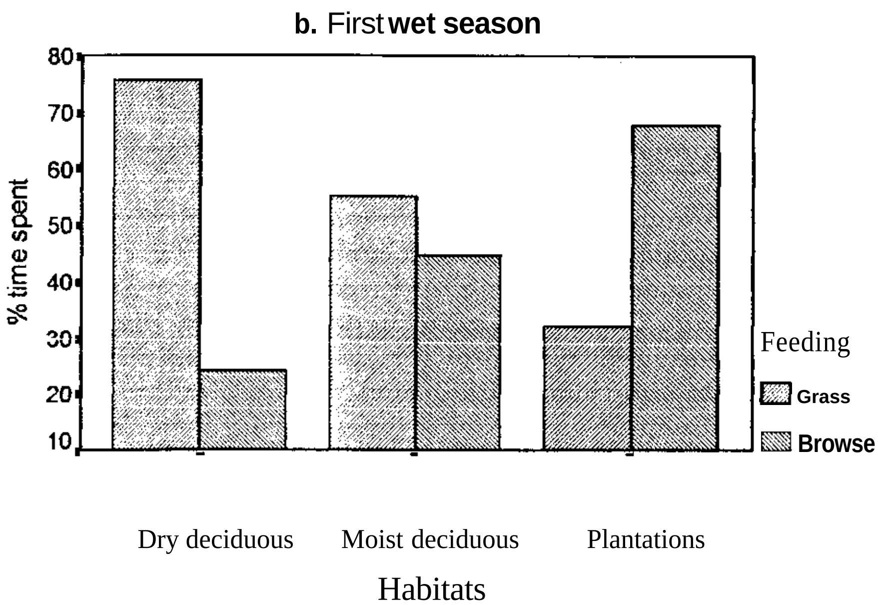
Species	Total	Parts eaten					
		Twigs & leaves		Twigs alone		Bark	
		F	%	F	%	F	%
Bauhinia racemosa	7	0	0.00	0	0.00	7	1.34
Emblica officinalis	7	0	0.00	0	0.00	7	1.34
Ficus sp.	2	2	0.64	0	0.00	0	0.00
Gmelina arborea	2	0	0.00	0	0.00	2	0.38
Grewia tiliaefolia	114	37	11.78	12	11.43	65	12.40
Helicteres isora	392	212	67.52	61	58.10	119	22.71
Kydia calycina	156	10	3.19	15	14.29	131	25.00
Randia dumatorum	7	2	0.64	0	0.00	0	0.00
Shorea roxburghii	113	0	0.00	0	0.00	113	22.56
Sterculia villosa	11	0	0.00	0	0.00	11	2.10
Tectona grandis	137	51	16.24	17	16.19	69	13.16
Total	948	314	33.30	105	11.13	524	55.57

4.4.3 Percentage contribution of grass and browse

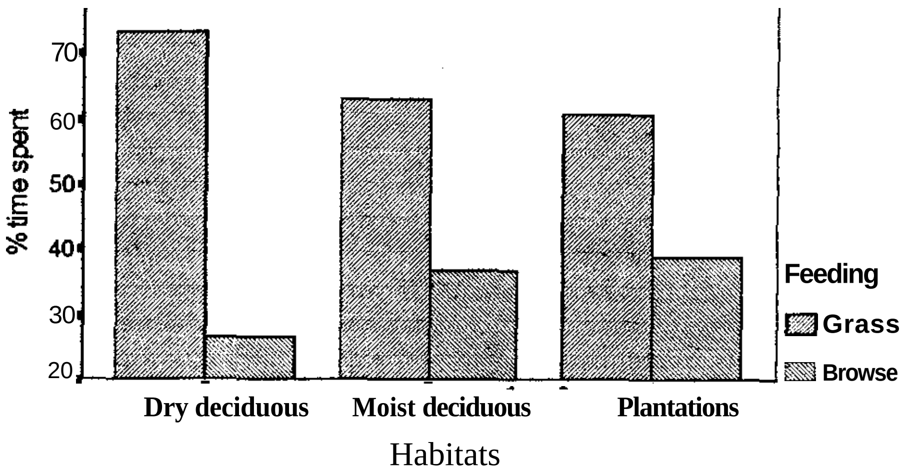
Percentage of time spent on grazing and browsing by elephants in different seasons in different habitats (percentage of grass and browse in the diet) are given in Figure 12. Grass formed the major food item throughout the year in all habitats except in dry season in moist deciduous and plantations, and first wet season in plantations. Browse was the major food item in plantations (67.9%). A marginal decrease was observed in the percentage of browse species in dry deciduous forest and moist deciduous forest during the second wet season. In plantations, the contribution of grass species increased during the second wet season.

Fig. 12. Percentage of time spent on grazing and browsing in different habitat types





c. Second wet season



4.4.4 Diet Analysis

4.4.4.1 Grass

Seasonal percentage contribution of different grass species in the dietary component of elephants in different habitats are given in Tables 33, 34 and 35. Only 12 species of grass were seen fed by elephants during direct observation, irrespective of habitats and seasons in the study area. The common grass food species in dry deciduous forests were *Themeda cymbaria, T. triandra, Heteropogun contortus, Imperata cylindrica* and *Bambusa arundinacea.* The other species such as *Cymbopogon flexuosus, Digitaria sp.* and *Apluda mutica* also formed the dietary component in the dry deciduous forest. In moist deciduous forest, *Cyrtococcum patens, Oplismenus compositus, B. arundinacea and Digitaria sp.* were found to be heavily utilised by elephants. Apart from these *T. cymbaria and T. triandra* also contributed in comparatively less proportion due to its poor availability in moist deciduous forest. Only few grass species such as *Digitaria sp. T. cymbaria, T. triandra, B. arundinacea, C. patens* and *H. contortus* were dominant in plantations and utilised by elephants.

The percentage contribution of different grass species to the elephant diet varied considerably in different seasons (Fig. 13). *T. cymbaria* formed a higher percentage of the grass species fed by elephants in dry deciduous forest in dry (75.3%) and first wet (53.5%) seasons. *T. triandra* was the most utilised (30.3%) species in the second wet season. Percentage contfibution of bamboo *(B. arundanaceae)* was less in the diet of elephants during dry season in dry deciduous forest,

Table 33. Percentage of various grass species in the diet of elephants during dry season

Species	Habitats					
	Dry deciduous		Moist deciduous		Plantations	
	F	%	F	%	F	%
Apluda mutica	5	0.9	0.0	0.0	0.0	0.0
Bambusa arundinacea	28	5.0	29	23.8	9	16.4
Cyrtococcum patens	0	0.0	31	25.4	0	0.0
Digitaria sp.	0	0.0	9	7.4	19	34.5
Heteropogon contortus	23	4.1	1	0.8	0	0.0
Imperata cylindrica	58	10.4	0	0.0	0	0.0
Oplismenus compositus	0	0.0	51	41.8	0	0.0
Themeda cymbaria	421	75.3	0	0.0	27	49.1
Themeda triandra	24	4.3	1	0.8	0	0.0
Total	559	76.0	122	16.6	55	7.5

(F- Frequency)

Table 34. Percentage of various grass species in the diet of elephants during first wet season

Species	Habitats					
	Dry Deciduous		Moist deciduous		Plantations	
	F	%	F	%	F	%
Apluda mutica	0	0.0	1	0.5	0	0.0
Bambusa arundinacea	42	8.2	69	32.1	61	44.2
Cymbopogon flexuosus	12	2.3	0	0.0	0	0.0
Cyrtococcum patens	0	0.0	37	17.2	10	7.2
Digitaria sp.	13	2.5	0	0.0	40	29.0
Heteropogon contortus	11	2.1	0	0.0	0	0.0
Imperata cylindrica	13	2.5	0	0.0	0	0.0
Themeda cymbaria	274	53.5	108	50.2	17	12.3
Themeda triandra	147	28.7	0	0.0	10	7.2
Total	512	59.2	215	24.9	**138**	**16.0**

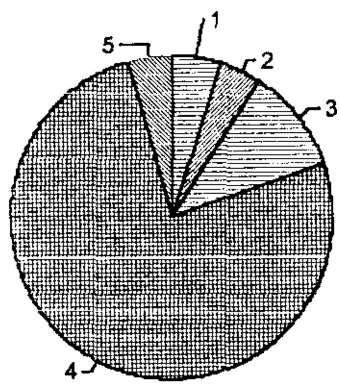
Table 35. Percentage of various grass species in the diet of elephants during second wet season

Species	Habitats					
	Dry deciduous		Moist deciduous		Plantations	
	F	%	F	%	F	%
Apluda mutica	0	0.0	2	0.6	0	0.0
Bambusa arundinacea	29	6.1	28	8.6	2	2.4
Chrysopogon sp.	32	6.7	0	0.0	1	1.2
Cyrtococcum patens	0	0.0	122	37.7	14	17.1
Digitaria sp.	12	2.5	52	16.0	29	35.4
Heteropogon contortus	123	25.7	0	0.0	25	30.5
Imperata cylindrica	27	5.6	0	0.0	0	0.0
Oplismenus compositus	0	0.0	62	19.1	0	0.0
Setaria sp.	0	0.0	42	13.0	0	0.0
Themeda cymbaria	110	23.0	0	0.0	6	7.3
Themeda triandra	145	30.3	16	4.9	5	6.1
Total	478	54.1	324	36.7	82	9.3

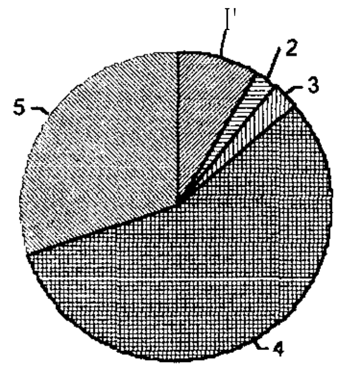
(F- Frequency)

Fig. 13. Percentage of major grass species in elephant diet in dry deciduous forests

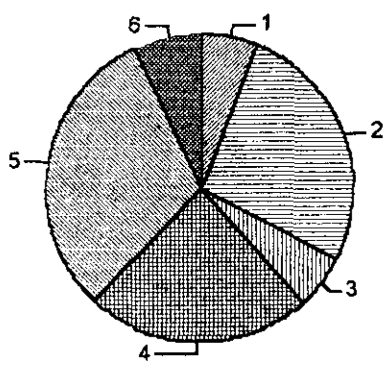
a. Dry season



b. First wet season



c. Second wet season

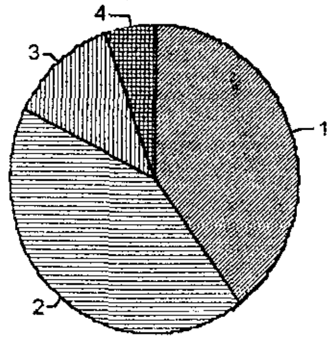


1 = *Bambusa arundinacea;* 2=*Heteropogon contortus;* 3=*lmperata cylindrica;* 4=*Themeda cymbaria;* 5=*Themeda triandra;* 6=*Crysopogon sp.*

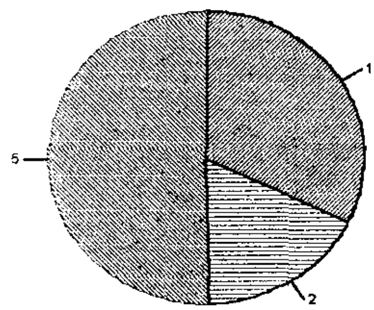
There were large seasonal variations in the number of grass species in the elephant diet and their percentage contribution in moist deciduous forests (Fig. 14). Four species, *B. arundinacea, C. patens, Digitaria sp.* and *O. compositus formed* more than 95 % of the diet during dry season. The three species, *T. cymbaria, B. arundinacea* and *C. patens* formed the first wet season grass diet in moist deciduous forests. Elephants used more of *C. patens* (37.7%) and almost equal proportion of *Digitaria* sp. and *O. compositus* (16% to 19%) during second wet season. *B. arundinacea* and *T. triandra* formed the least (1 2 %) in the diet.

Fig. 14. Percentage of major grass species in elephant diet in moist deciduous forests

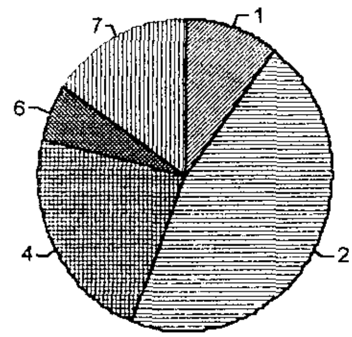
a. Dry season



b. First wet season



c. Second wet season

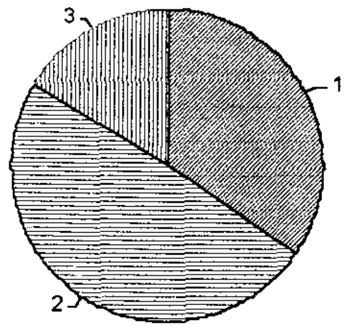


1 = *Bambusa arundinacea;* 2=*Cyrtococcum patens;* 3=*Digitaria sp.;* 4=*Oplismenus compositus;*5= *Themeda cymbaria;* 6=*Themeda triandra;*7=*Setaria sp.*

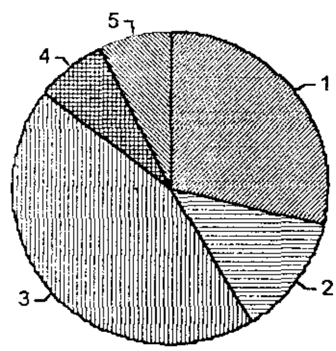
Elephants favoured 6 major grass species in plantations in which 3 species formed the major dietary component during dry season (Fig. 15). *T. cymbaria* and *Digitaria* sp. formed 49.1% and 34.5% respectively. *B. arundinacea* contributed 16.4% to the diet during dry season.

Fig. 15. Percentage of major grass species in elephant diet in plantations

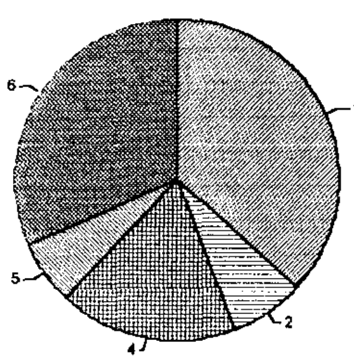
a. Dry season



b. First wet season



c. Second wet season



1=*Digitaria* sp.; 2=*Themeda cymbaria;* 3=*Bambusa arundinacea;* 4=*Cyrtococcum patens;* 5= *Themeda triandra;* 6=*Heteropogon contortus*

A marginal increase was recorded on the use of *B. arundinacea* (44.2%) during first wet season and this was not seen used during the second wet season.

Digitaria sp. and *T. cymbaria* together accounted for 42% of the diet during the first wet season. Other grass species such as *C. patens* and *T. triandra* formed only a small portion of the diet during first wet season (7.2% each). During second wet season, the major portion of diet consisted of *Digitaria* sp., *H. confortus* and *C. patens* accounting for 83% of the total grass food species in plantations.

4.4.4.2 Browse

Percentage contribution of various browse species to the diet of elephants during dry, first wet and second wet seasons are given in Tables 36, 37 and 38. A total of 14 browse species were favoured by elephants in different habitat types. Among these, *Curcuma* sp., *H. isora, K. calycina, G. tiliaefolia, S. roxburghii* and *T. grandis* were the major food species contributing more to the diet.

Table 36. Percentage of various browse species in the diet of elephants during **dry season**

Species	Habitats					
	Dry deciduous		Moist deciduous		Plantations	
	F	%	F	%	F	%
Bauhinia racemosa	2	2.7	5	3.1	0	0.0
Emblica officinalis	0	0.0	1	0.6	0	0.0
Ficus sp.	0	0.0	2	1.2	0	0.0
Gmelina arborea	2	1.2	0	0.0	0	0.0
Grewia hirsuta	2	2.7	2	1.2	0	0.0
Grewia tiliaefolia	40	53.3	11	6.7	9	5.9
Helicteres isora	0	0.0	85	52.1	42	27.6
Kydia calycina	0	0.0	27	16.6	36	23.7
Randia dumatorum	1	1.3	5	3.1	0	0.0
Shorea roxburghii	24	32.0	0	0.0	0	0.0
Tectona grandis	6	8.0	23	14.1	65	42.8
Total	77	19.7	161	41.8	152	39.5

(F- Frequency)

In dry deciduous forest, 5 browse species contributed maximum to the met of elephants in different seasons (Fig. 16). Among the browse species, *G. tiliaefolia* and *S. roxburghii* consisted of more than 90% of the total diet. *T. grandis* was utilised only to a lesser extent (8%). The other species such as *Bauhinia racemosa,* *Gmelina arborea. Grewia hirsuta* and *Randia dumatorum,* consisting of less than 5% of the total browse species were also found to be utilised by elephants in dry deciduous forest during dry season

Table 37. Percentage of various browse species in the diet of elephants during first wet season

Species	Habitats					
	Dry deciduous		Moist deciduous		Plantations	
	F	%	F	%	F	%
Curcuma sp.	0	0.0	13	26.5	0	0.0
Grewia hirsuta	7	6.5	0	0.0	0	0.0
Grewia tiliaefolia	47	43.5	0	0.0	2	2.0
Helicteres isora	0	0	12	24.5	82	80.4
Kydia calycina	9	8.3	9	18.4	18	17.6
Mimosa pudica	0	0.0	2	4.1	0	0.0
Shorea roxburghii	37	34.3	0	0.0	0	0.0
Sterculia villosa	0	0.0	7	14.3	0	0.0
Tectona grandis	8	7.4	6	12.2	0	0.0
Total	108	41.7	49	18.9	102	39.4

(F- Frequency)

Table 38. Percentage of various browse species in the diet of elephants during second wet season

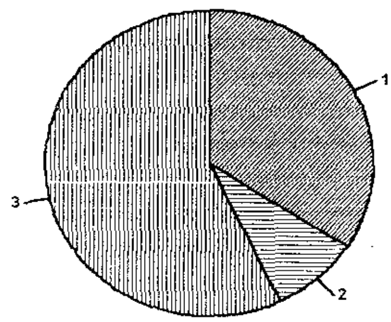
Species	Habitats					
	Dry deciduous		Moist deciduous		Plantations	
	F	%	F	%	F	%
Emblica officinalis	6	4.1	0	0.0	0	0.0
Grewia hirsuta	4	3.0	0	0.0	0	0.0
Grewia tiliaefolia	5	3.7	0	0.0	0	0.0
Helicteres isora	14	10.4	120	82.8	37	75.5
Kydia calycina	42	31.1	15	10.3	0	0.0
Randia dumatorum	1	0.7	0	0.0	0	0.0
Shorea roxburghii	52	38.5	0	0.0	0	0.0
Sterculia villosa	0	0.0	4	2.8	0	0.0
Tectona grandis	11	8.1	6	4.1	12	24.5
Total	135	41.0	145	44.1	49	14.9

(F- Frequency)

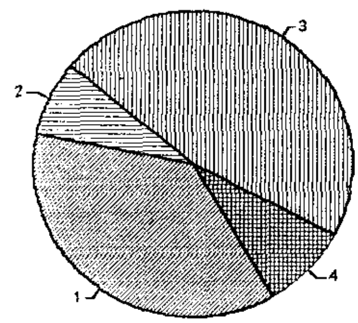
Four species formed the major browse species during the first wet season. *G. tiliaefolia* and *S. roxburghii* formed more than 75% of the total browse during the first wet season. *K. calycina* and *T grandis* also almost equally contributed to the diet (8.3% and 7.4% respectively).

Fig. 16. Percentage of major browse species in elephant diet in dry deciduous forests

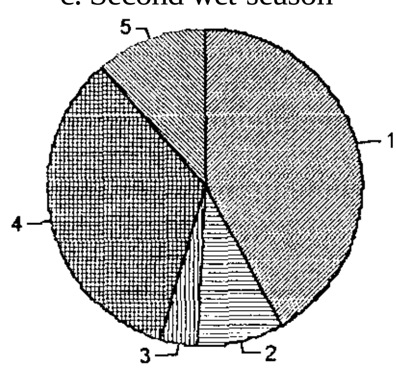
a. Dry season



b. First wet season



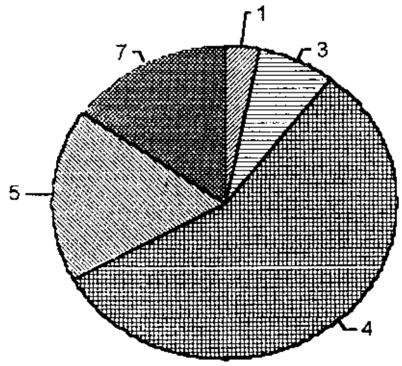
c. Second wet season



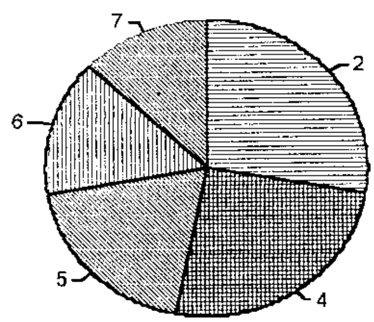
1=*Shorea roxburghii;* 2=*Tectona grandis;* 3=*Grewia tiliaefolia;* 4=*Kydia calycina;* 5=*Helicteres isora*

Fig. 17. Percentage of major browse species in elephant diet in moist deciduous forests

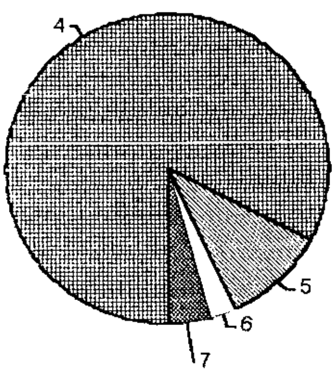
a. Dry season



b. First wet season



c. Second wet season



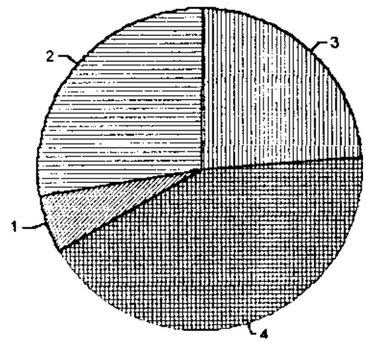
1=*Bauhinia racemosa;* 2=*Curcuma sp.;* 3=*Grewia tiliaefolia;* 4=*Helicteres isora;* 5=*Kydia calycina;* 6=*Sterculia villosa;* 7= *Tectona grandis*

Though five browse species were utilised during the second wet season, the diet in dry deciduous forest consisted primarily of *S. roxburghii* and *K. calycina* (accounting for about 70%). These were followed by *H. isora, T. grandis,* and *G. tiliaefolia* (30%).In moist deciduous forest, *H. isoru* formed the major food in the diet in dry and second wet seasons and accounted for more than 50% to 80% of the total browse (Fig. 17). Percentage contribution of *H. isora* declined to 24.5% during the first wet season. *K. calycina* and *Tectona grundis,* consisting of 16.6% and 14.1% respectively, also formed the dry season diet of elephants in moist deciduous forest. *H. isora, Curcuma* sp. and *K. calycina* contributed more to the diet in the first wet season. *Sterculia villosa* and *T. grandis* were also equally consumed by elephants during this season.

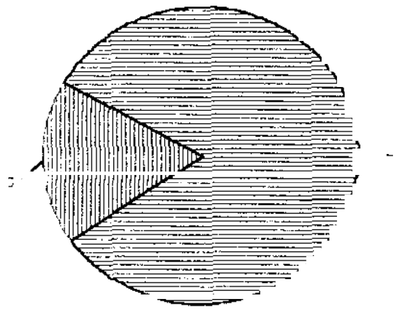
Four species were fed by elephants during dry season in plantation (Fig. 18). Of these, *H. isora, K. calycina* and. *T. grandis* were the major browse species. *G. tiliaefolia* formed only a low proportion of the diet. Only two species *viz., H. isora* and *K. calycina* formed the total browse diet of elephants in plantations during first wet season. During second wet, *H. isora* and *T. grandis* consisted a substantial proportion (75% and 25% respectively) in the total browse diet of elephants in plantations.

Fig. 18. Proportion of major browse species in elephant diet in plantations

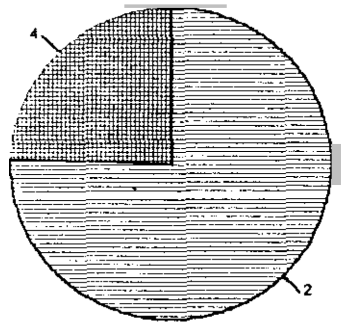
a. Dry season



b. First wet season



c. Second wet season



1=*Grewia tiliaefolia;* 2=*Helicteres isora,* 3=*Kydia calycina;* 4=*Tectona grandis*

4.4.5 Overall and seasonal activity time budget of elephants

Table 39 shows the overall and seasonal activity time budget of elephants In the study area

Table 39. Seasonal activity time budget of elephants in Wayanad WLS

Activity	Seasons						Total	
	Dry		First wet		Second wet			
	F	%	F	%	F	%	F	%
Feeding	1126	50.8	1124	64.3	1213	60.3	3463	57.9
Moving	242	10.9	316	18.1	271	13.5	829	13.9
Resting	791	35.7	181	10.4	390	19.4	1362	22.8
Others	57	2.6	127	7.3	138	6.9	322	5.4
Total	2216	37.08	1748	29.25	2012	33.67	5976	

Of the 5976 minutes of observation on herds, elephants spent more time for feeding (57.9 %) during the day time. It was followed by resting (22.8%) and moving (13.9%). During dry season, the time for feeding decreased to 50.8% and the resting time increased to 35.7%. The time spent for feeding during first wet (64.37%) and second wet seasons (60.3%) were more compared to dry season. The percentage of time for moving during dry season was less (10.9%) compared to the first wet (18.1%) and second wet (13.5%) seasons. Time spent for other activities were very less and did not vary much over the seasons. Elephants in the study area spent only 57.9% of the time for feeding and 22.8% was spent for resting.

4.5 Food species of different animals in the study area

About 92 plant species found to the food of sambar deer in the area and about 93 of spotted deer (Tables, 40 & 41). The grasses dominate among them. Though gaur were observed on different location information of food species could not be collected.

Table .40. List of plants fed by sambar deer in Wayanad

Poaceae

1. *Alloteropsis cimicina*
2. *Arthraxon lanceolatus*
3. *Arundinella purpurea*
4. *Axonopus compressus*
5. *Bambusa arundinacea*,
6. *Brachiaria miliiformis*
7. *Cupillipedium filiculamis*
8. *Centotheca lappacea*
10. *Chloris dolichostachya*
11. *Cynodon arcuatus*
12. *Cyrtococcum patens*
13. *Dactyloctenium aegyptium*
14. *Echinocloa colona*
15. *Eleusine indica*
16. *Eragrostis tenella*
17. *E. tenufolia*
18. *E. unioloides*
19. *Eriochloa procera*
20. *Heteropogon contortus*
21. *Imperata cylindrica*
22. *Leersia hexundra*
23. *Oplismenus compositus*
24. *Oryza meyeriana* ssp. *granulata*
25. *O. rufipogon*
26. *Ottochloa nodosa*
27. *Panicum maximum*
28. *P. notatum*
29. *P. trypheron*
30. *Paspalidiumflavidum*
31. *P. conjugatum*
32. *P. scrobiculatum*
33. *Sacciolepis indica*
34. *Setaria intermedia*

35. *S. palmifolia*
36. *S. pumila*
37. *Sporobolus indicus*
38. *Themeda cymbaria*
39. *T. triandra*

Acantbaceae

40. *Justicia simplex*

Amaranthaceae

41. *Achyranthus aspera*

Balasaminaceae

42. *Impatiens lenta*
43. *Impatiens sp.*

Boraginaceae

44. *Cynoglossum furcatum*

Commelinaceae

45 *Murdannia japonica*
46. *Cyanotis fasciculata*

Compositae

47. *Spilunthes radicans*
48. *Ageratum conyzoides*
49. *Elephantopus scaber*
50 *Emelia sonchifolia*
51. *Synedrella nodiflora*
52. *Tridax procumbens*
53. *Vernonia cinerea*
54. *Conryza bonariensis*
55. *Conyza stricta*
56. *Spilunthes paniculata*

Cyperaceae

57. *Mariscus pictus*
58. *Cyperus iria*
59. *C. pilosus*
60. *Fimbristylis dichotoma*

Gentianaceae

61. *Canscora diffusa*

Hypoxidaceae

62. *Curculigo orchioides*

Malvaceae

63. *Hibiscus lobatus*
64 *Sida acuta*
65. *S. alnifolia*
66. *S. rhombifolia*
67. *Thespesia lampas*
68. *Urena lobata* ssp. *Lobata*
69. *U. lobata* ssp *sinuata*

Mimosaceae

70. *Mimosa pudica*

Papilionaceae

71. *Desmodium triflorum*

Rubiaceae

72. *Mitracarpus villosus*

Hypoxidaceae

73. *Curculigo orchioides*

Papilionaceae

74. *Desmodium triquetrum*
75. *D. velutinum*
76. *D. zonatum*
77. *D. gangeticum*
78. *D. triangulare*

Rhamnaceae

79. *Zizyphus oenoplea*
80. *Z. rugosa*

Sterculiaceae

81. *Helicteres isora*

Verbenaceae

82. *Lantana camara*

Anacardiaceae

83. *Mangifera indica*

Combrctaceae

84. *Terminalia paniculata*
85. *T. tomentosa*

Euphorbiaceae

86. *Emblica officinalis*

Lecythidaceae
87. *Careya arborea*
Myrtaceae
88. *Syzygium cumini*
Oleaceae
89. *Olea dioica*
Salicaceae
90, *Salix tetrasperma*
Verbenaceae
91. *Gmelina arborea*
Tiliaceae
92. *Grewia tilifolia*
Malvaceae
93. *Kydia calycina*

Table. 41. List of plants fed by spotted deer in Wayanad

Poaceae
1. *Alloteropsis cimicina*
2. *Arthraxon lanceolatus*
3. *Axonopus compressus*
4. *Bambusa arundinacea*
5. *Brachiria miliiformis*
6. *Capillpedium filiculmis*
7. *Chloris dolichostachya*
8. *Cynodon arcuatus*
9. *Digitaria ciliaris*
10. *D. longiflora*
11. *Echinochloa colona*
12. *Eragrostis unioloides*
13. *E. tenuifolia*
14. *Eriochloa procera*
15. *Leersia hexandra*
16. *Oplismenus compositus*
17. *Oryza meyeriana* ssp. *granulata*
18. *O. rufipogon*
19. *Ottochloa nodosa*
20. *Panicum maximum*
21. *P. notatum*
22. *Paspalum conjugatum*
23. *P. scrobiculatum*
24. *Sacciolepis indica*
25. *Setaria intermedia*
26. *S. pumila*
27. *S. palmifolia*
28. *Sporobolus indicus*
29. *Themeda cymbaria*
30. *T. triandra*
31. *Arundinella purpurea*
32. *Dactyloctenium aegyptium*
33. *Digitaria setigera*
34. *Eleusine indica*
35. *Heteropogon contortus*
36. *Paspalidium flavidum*
37. *Cynodon dactylon*

Acanthaceae
38. *Justicia simplex*

Amaranthaceae
39. *A chyranthus aspera*

Boraguiceae
40. *Cynoglossum furcatum*

Commelinaceae
41. *Cyanotis fasciculata*
42. *Murdannia japonica*

Compositae
43. *Conyza stricta*
44. *C. ambigua*
45. *Acanthospermum hispidum*

46. *Ageratum conyzoides*
47. *Elephantopus scaber*
48. *Emilia sonchifolia*
49. *Synedrella nodifora*
50. *Tridax procumbens*
51. *Vernonia cinerea*
52. *Spilanthes radicans*
53. *S. paniculata*

Cyperaceae

54. *Mariscus paniceus*
55. *M. pictus*
56. *Cyperus iria*
57. *Fimbristylis dichotoma*

Hypoxidaceae

58. *Curculigo orchioides*

Malvaceae

59. *Hibiscus lobatus*
60. *Sida acuta*
61. *S. alnifolia*
62. *S. rhombifolia*
63. *Thespesia lampas*
64. *Urena lobata ssp. lobata*
65. *U. lobata ssp. sinulata*

Mimosaceae

66. *Mimosa pudica*
67. *Mitracarpus villosus*

Acanthaceae

68. *Phanlopsis imbricata*

Rubiaceae

69. *Mitracarpus villosus*

Acanthaceae

70. *Eranthemum montanum*

Papilionaceae

71. *Desmodium gangeticum*
72. *D. motorium*
73. *D. velutinum*
74. *D. zonatum*
75. *D. triquetrum*
76. *D. triangulare*
77. *D. triflorum*

Rhamnaceae

78. *Zizyphus rugosa*
79. *Z. oenoplea*

Sterculiaceae

80. *Helicteres isora*

Verbenaceae

81. *Lantana camara*

Anacardiaceae

82. *Mangifera indica*

Combrctaceae

83. *Terminalia paniculata*
84. *T. tomentosa*

Euphorbiaceae

85. *Emblica officinalis*

Lecythidaceae

86. *Careya arborea*

Myrtaceae

87. *Syzygium cumini*

Oleaceae

88. *Olea dioica*

Rutaceae

89. *Murraya exotica*

Salicaceae

90. *Salix tetrasperma*

Verbanaceae

91. *Gmelina arborea*

Tiliaceae

92. *Grewia tilifolia*

Malvaceae

93. *Kydia calycina*

4.6 Discussion

Polyphagous feeding habit of elephant has been reported from all its ranges in Africa (Bax and Sheldrick, 1963; Douglas-Hamilton, 1972; Williamson, 1975; Field and ROSS, 1976; Guy,1976b; Short, 1981) and in Asia (McKay, 1973; Olivier, 1978a; Sukumar, 1985; Santiapillai and Suprahman, 1986; Easa, 1989a; Sivaganesan, 1991). Elephants in Wayanad was observed to feed on 97 species, of which grass was the dominant one. The herbivore diet is influenced by several factors including anatomical and physiological characteristics of the animals, community structure of the plants and its structural and chemical constituents (Owen-Smith, 1982). Food intake is also influenced by body weight and digestibility of the animal (Baile, 1975; Bines, 1976). Advantages of polyphagy have been discussed by Crawley (1983). Polyphagous animals are benefited by the wide variety of plants available in the environment and can switch over to the temporarily abundant one. They also have the benefits by employing seasonal and opportunistic species preference (Westoby, 1974; Crawley, 1983). The searching effect is also reduced even in environmental scarcity. Elephants, being a non-ruminant is not benefited from the synthesis of aminoacids and vitamins by the rumen bacteria. Availability of a range of nutrients can be ensured by feeding on a variety of species supplementing the preferred ones (Olivier, 1978a).

Freeland and Janzen (1974) argued that evolution of high toxin concentrations in otherwise valuable plant food is ubiquitous and is the main source of diversification in mammalian herbivore. Mixed diets of different food species ensure a reasonable total nutrient intake. The intake rate of herbivores is influenced by a number of parameters including vegetation height (Allden and Whittaker, 1970), the ratio between green leaves and green stems (Stobbs, 1973), the bulk density (Chacon and Stobbs, 1976) and the biomass (Trudell and White, 1981; Short, 1986).

Grass was found to be the major food item throughout the year in Wayanad except in moist deciduous and plantations in certain seasons. Grass also contribute to the diet in the number of species. Grazing was a major mode of feeding in dry deciduous forest throughout the year. This was true of moist deciduous forest except during dry season. Browsing was comparatively higher in plantations except in the second wet season. The elephants in Wayanad also feed on the twigs and harks of a number of tree species. Food availability in the area (refer Chapter 5) indicate the higher grass food species availability in dry deciduous forest throughout the year. However, browse availability was higher in moist deciduous forest and plantations. Study in adjacent Mudumalai showed a clear relationship between selection of food plants and availability (Sivaganesan, 1991). Further foraging efficiency of elephants on grass is reported to be high (80%) compared to feeding on browse (50%) (McKay, 1973).

Several authors (McKay, 1973; Sukumar, 1985; Easa, 1989a: Sivaganesan, 1991) reported seasonal differences in grazing and browsing among the elephants. Herbivore feeding strategy has been to minimise toxin concentration rather than maximising nutritive value (Bryant and Kuropat, 1980). Production of secondary compounds by plants as a chemical defence also have been reported (Levin,l971; Jones, 1972; Bemays, 1981).

The anatomy of the digestive system of elephants is reported to be more sensitive to toxic plant’s secondary compounds (Olivier, 1978a). Westoby (1977) has pointed out the nutrient constraints in diet of foliage eaters because of large variation in protein and fibre contents in foliage. Studies by Sukumar (1985) have shown a low protein content in the leaves of *Thermeda cymbaria* in dry season. He had argued that a high crude protein content in the browse species was a reason for the dry season preference for browse species of elephants in his study area. According to him, elephant population living predominantly on grass diet throughout the year suffer nutritionally and may lead to a decreased fertility. However, food habit studies in Parambikulam have shown a higher rate of grazing in dry season (Easa, 1989a). The mineral content of the grass was found to be high in wet season whereas crude fibre, sodium and calcium were higher in dry season. Further, tannin content was low in grasses in dry season compared to browse including the bark. *Helrcteres* was the only browse species with no tannin content. Bax and Sheldrick (1963) observed a fall in protein content of grass in dry season.

Bamboo and *Helicteres isora* were used almost throughout in moist deciduous and plantations where they were available in good quantities. However, bamboo was not seen used in second wet season in plantations. The crude fibre content in bamboo was found to be high in all the seasons (Easa, 1989a). Further tannin was also absent both in bamboo and *Helicteres isora.*

Large non-ruminant herbivores are capable of utilising lower quality diet (Van-Soest, 1982). Hind gut fermenters such as elephant can compensate the lower digestion efficiency by increasing the food intake resulting in higher retention time. Nutrient accumulation by hind gut fermenters on low quality diets is higher than that obtained by ruminants (Bell, 1971; Rittenhouse, 1986).

Hydrogen cyanide (HCN) concentration are higher in immature tissues of plants including those of Poaceae and Leguminaceae. Excessive protein intake in dry season is also reported to be undesirable since nitrogen excretion requires more water. A loss of body weight due to less intake of protein and lack of excessive fat deposit could also help in thermoregulation (Sukumar, 1989).

Bark feeding has been reported to be in response to deficiency in essential fatty acids such as lenolic acids in other food species and found higher in bark (McCullagh, 1973). Higher contents of minerals such as manganese, iron, copper, boron (Doughall *et al.,* 1964) and calcium (Bax and Sheldrick, 1963; Easa, 1989a) in the bark have been mentioned as the reasons for bark feeding behaviour of elephants.

Sukumar (1985) and Sivaganesan (1991) have reported seasonal differences in selection of food plants' parts by elephants.

Such differences have also been observed in Africa (Bell, 1971; Fryxell *et al.,* 1988). When grasses matured, the fibre and silica contents increase and abrasive nature also shows an increase. This forces the animal to go for basal portion of the gass during dry season as observed in the study area. Moreover, the succulent nature of the basal portion and the higher proportion of soluble carbohydrates in the basal portion (Sivaganesan, 1991) also contribute to the selection of the parts.

Greenway and Vesey-Fitzgerald (1972) observed that only a few species make up a major portion of the diet of the buffalo. Beekman and Prins (1989) observed a selection of a few with increasing differences in protein contents. The animals go for low crude protein concentration species in dry season. Palatability place an important role in selection of plant parts while feeding.

Feeding on grass in dry season supplemented by a range of other species reduce toxicity. The increased grazing in dry season by elephant in the study area could be related to the increased availability of gasses and also the strategy to reduce toxic effect of other species. Bamboos are restricted to moist deciduous forests. Browsing on bamboo in moist deciduous forests in dry season also supports the view that the availability influences the selection of species in the study area.

Chapter 5

Density distribution and habitat utilisation

5.1 Introduction

Knowledge on the density and distribution pattern of animals in different seasons and habitats are important attributes in the study of wildlife for better management and long term conservation planning. The information is useful to get an idea on maximum supportable density of animals in an area, where the prime habitats are shrinking due to fragmentation and degradation by human activities.

The environment is composed of a complex of inter-dependant living and non-living elements. Some of these elements are subject to seasonal and annual changes due to the interaction of these elements themselves. Vegetation, supplying the basic requirement of herbivores responds to animal use in various ways. Changes in vegetation are normally reflected in ground cover. The trend in the changes of environment could be measured through studying the availability of habitat elements. Thus, information on food availability, water availability and food quality could yield a wealth of information on the status and trend of the animal's environment giving clues to the life of the animal. Riney (1982) has discussed in detail the methods available for animal habitat utilization studies.

Mammals, especially the gregarious ones often respond to climatic changes and the resultant change in the habitat by altering herd size and pattern of habitat utilisation (McNaughton, 1985). Ranging behaviour of wild ungulates over wide geographical areas are normally in response to the temporal abundance and quality of forage (McNaughton, 1985). Watson and Moss (1970) have given examples to support that the dispersion of animals is related to food supply. Seasonal habitat selection has been reported in several species (Fuller, 1960; Shackleton, 1968,Shult, 1972,Duncan, 1975,Oven-Smith. 1979;Krasinska,et al., 1987).

Distribution pattern of large herbivores are mostly influenced by resource availability such as food, shelter and water (Owen-smith, 1988). Various ecological parameters and climatic conditions have been reported to influence the distribution of large herbivores in Africa (Sinclair, 1975 & 1985). Caughley and Goddard (1975) reported aggregation of elephants on the alluvial zone during rains in response to flush of annual grasses in Luangwa valley. Elephant distribution in Kalahari sand region was primarily determined by water availability (Weir, 1971).

Differential use of habitats by African elephants were influenced by forage preference and availability (Leuthold and Sale, 1973; Leuthold, 1977; Western and Lindsay, 1984; Thouless, 1995a) as well as by external factors such as extreme weather conditions (Corfield, 1973), human settlements and cultivation (Laws, 1970; Lamprey, 1985) and poaching activity (Dublin and Douglas-Hamilton, 1987). Cumming *et al.* (1990) and Said *et al.* (1995) reported the influence of external factors leading to the concentration of African elephants in Protected Areas. Dublin (1995 & 1996) studied the factors influencing the habitat selection and group size pattern in African elephants.

Several studies have been conducted in Africa on the seasonal movements of elephants in relation to habitat change (Wing and Buss, 1970; Laws *et al.*, 1975; Jachmann, 1988) and other environmental factors such as rainfall, habitat and grazing conditions (Bax and Sheldrick, 1963; Leuthold and Sale, 1973; Laws *et al.*, 1975; Leuthold, 1976a; Eltringham, 1980; Merz, 1986; Jachmann, 1988). In Asia, similar studies were carried out on the distribution of mammals in Kamataka (Prasad *et al.*, 1980) and in Kerala (Vijayan *et al.*, 1979; Ramachandran *et al.*, 1986). Distribution and habitat utilisation of elephants were documented by several studies in Asian elephant ranges (Olivier, 1978a; Sukumar, 1985; Balakrishnan and Easa, 1986; Sivaganesan, 1991; Anonymous, 1995).

Weigum (1972) and Conry (1981) suggested abundance of grass, forbs and scrall browse species in agricultural estates are the most important factors influencing gaur distribution in central Pahang. Vairavel (1998) has made similar observations in the case of gaur in Parambikulam. Dinerstein (1979), studying the habitat-animal interaction in Nepal indicated that the changes in the plant distribution and phenology affected ungulate food habits, energy budget, movement and seasonal distribution. Chital responded to seasonal changes by shifting the relative time spending the different habitats (Dinerstein, 1987)

This chapter deals with the density distribution of animals in Southern part of Wayanad Wildlife Sanctuary in relation to habitat, season and food availability.

5.2 Methods

5.2.1 Density distribution

The methods followed for estimating the density of elephants in the study area is explained in detail in Chapter-3. The study area was divided into several blocks based on the vegetation types. Transects of 2 km. length were laid in proportion to habitat size. These transects were placed at random so that they fall in areas along the border as well as inside the study area.

These transects were covered in different seasons in 1994 and 1995, and the first two seasons in 1996. Information were collected on the indirect evidences (dung/pellets) of elephants (Barnes and Jensen, 1987) and other animals.

5.2.2 Food Availability

Food species of elephants in the study area were identified through direct observation and by examination of feeding sites immediately after the animal left the location (Chapter 4). The above ground biomass of food plants were estimated as follows:

The study areas were divided into grids of 2-Km^2 size on 1: 50,000 scale topo sheets. These grids were identified in the field and a transect of 500 m. length laid in each grid. Plots of 5 m^2 were laid at 100 m. interval for browse species biomass estimation and 1 m2 at 50 m. interval for grass.

The plant species within the sample plots laid for biomass estimation were cut and food species segregated (Boutton *et al.*, 1988). The food species were then weighed in the field. These were later oven dried at constant temperature till a constant weight was obtained and then weighed for dry weight. Care was taken to have such biomass plots in all vegetation types in proportion to the size. The biomass of the food species was later estimated using the formula suggested by Wiegert (1962).

The biomass data from the plots in the bordering and interior areas were pooled separately and analysed for food availability in the border and interior areas. Similarly, data for each habitat type were pooled separately and analysed for habitat-wise food availability estimation.

5.2.3 Functional relationship of elephant density with the environmental factors

A number of factors are associated with the seasonal density distribution of elephants in different habitat types. These could be broadly classified into food availability, palatability, cover, rainfall and water availability. These factors were quantified seasonally in all the habitats to find their functional relationship with the seasonal density distribution of elephants in different habitat types. The following variables were collected during the study period.

Grass (GB) and browse biomass (BB) were derived from the food availability study. From the grass plots, the grass cover (GC) was examined and percentage ratings were given based on qualitative assessment. The texture of the grass was determined based on the abrasiveness of the leaf blade and stem thickness (Jarman and Sinclair, 1979). On the basis of the texture, they were classified into soft grass (SG) and fibrous grass (FG), and quantified using percentage rating scales. The density of bamboo (DB) in different habitat types was estimated from sample plots. The percentage of young leaves (BY) and matured leaves (BM) of bamboo were also qualitatively assessed by periodical visits to the sample plots in different habitat types. Water availability (WA) was quantified using percentage ratings in different seasons across the habitats. Rainfall (RF) data were collected on monthly basis from the permanent rain gauges installed by the Forest Department and used for the analysis.

5.3. Analysis

5.3.1 Density distribution

The data from the blocks in the border area were pooled together and analysed for dung density estimates using computer program DISTANCE (Laake *et al.,* 1994). Similarly, the transect data for the interior area were pooled together and analysed for the density estimates. The transect data from different habitats were also pooled together for density estimates in different habitats. The dung density estimates were converted into elephant density using the formula suggested by Barnes and Jensen (1 987).

5.3.2 Functional relationship of elephant density with the environmental variables

Pearson's product moment correlation coefficient (r) was computed to find the influence of various environmental variables on the elephant density. A number of factors may influence the density of elephants in different habitat types, which are not directly observable. It is very difficult to determine any single factor influencing the distribution of elephants. For instance, water availability and grass growth can be expressed as a function of rainfall pattern, which attract the elephants to a particular habitat. Factor analysis, a statistical method to identify a relatively small number of significant factors that can be used to represent relationship among sets of many interrelated variables, was used in the analysis, The mathematical model for factor analysis is almost similar to multiple regression equation. Each observed variable is expressed as a linear combination of factors, which are not actually observed The model for the i^{th} standardized variable is

$$X_i = A_{i1} F_1 + A_{i2} F_2 + ... + A_{ik} F_k + U_1,$$

where the Fs are the common factors, U is the unique factor which is assumed to be non-correlated with common factors and As are the constants used to combine the k factors. The factors are inferred from the observed variables and can be estimated as linear combinations of them. The expression for the j^{th} factor F_j is

$$F_j = \Sigma W_{ji} X_i \text{ , Where}$$

W_{ji}s are factor score coefficients for the F_J th factor and p is the number of variables

Factor analysis was carried out with the program FACTOR of SPSS/PC- (Anonymous, 1987).

5.4 Results

5.4.1 Density distribution in different areas

Elephant density estimates in the bordering and inside areas are given in Table 42. Density distribution shows seasonal pattern with a high density along the border in the dry season followed by a decrease in the first wet season (Figs. 19 and 20). There was a slight increase in the density of elephants in the bordering areas in second wet season (Fig. 21). A gradual increase in density was observed from dry season to first wet season in the inside areas. However, the density decreased again in second wet season, which was significant in 1995.

Table 42. Estimated elephant density in the border and inside areas

Year	Season	Area	Sample size	Dung density /km²	%CV	95 % CI		Elephant density /km²
						Lower	Upper	
1994	Dry	Border	108	1156.20	11.95	915.55	1460.00	1.36
		Inside	38	444.42	20.13	296.66	665.70	0.51
	Wet-1	Border	71	577.76	16.07	420.13	794.50	0.68
		Inside	90	1186.20	18.96	816.61	1723.00	1.36
	Wet-2	Border	102	428.68	10.62	347.50	528.80	0.95
		Inside	71	331.47	11.87	261.83	419.60	1.25
1995	Dry	Border	223	2360.20	9.57	1957.30	2846.00	2.78
		Inside	121	1053.50	14.61	789.03	1406.00	1.21
	Wet-1	Border	59	137.85	13.02	106.37	178.60	0.64
		Inside	67	140.46	12.22	110.18	179.00	1.75
	Wet-2	Border	107	405.30	9.67	335.49	489.60	0.89
		Inside	60	256.41	12.91	198.27	331.50	0.97
1996	Dry	Border	151	1612.60	11.14	1297.10	2004.00	1.90
		Inside	59	819.89	15.56	601.67	1117.00	0.94
	Wet-1	Border	50	95.32	18.02	61.65	128.99	0.44
		Inside	55	67.08	14.42	48.12	86.04	0.88

Dry = Dry season; Wet-1 = First Wet Season; Wet-2 = Second Wet Season

Fig. 19. Density distribution of elephants in different areas during dry season

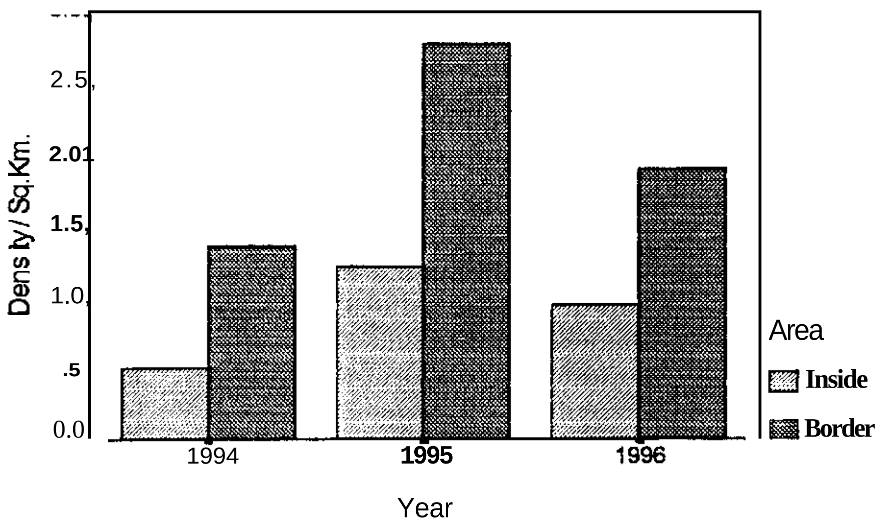


Fig. 20. Density distribution of elephants in different areas during first wet season

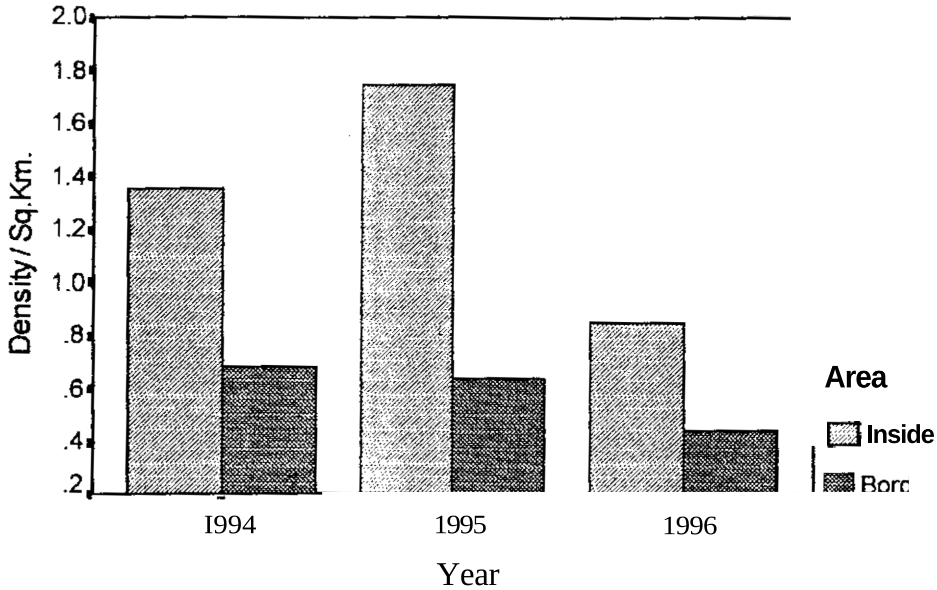
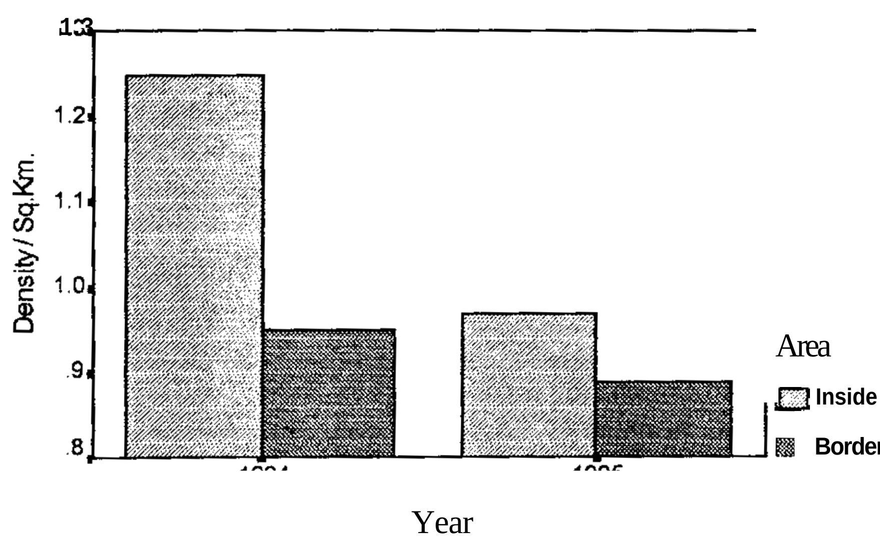


Fig. 21. Density distribution of elephants in different areas during second wet season



The two-way ANOVA revealed that the density estimates were significantly different between the areas and seasons ($P < 0.05$) (Table 43). Rut there was no significant differences in the overall density within areas and within seasons ($P > 0.05$).

Table 43. Two-way ANOVA showing the relationship of density of elephants with areas and seasons

Source of variation	Sum of squares	*df*	Mean square	F	P
Main Effects					
Area	0.016	1	0.016	0.093	Ns
Season	0.833	2	0.416	2.405	Ns
2-way interactions					
Area x Season	2.732	2	1.366	4.162	*
Residual	1.731	10	0.173		-

4.2 Habitat Utilisation

The dung density and estimated elephant density in different vegetation types in 1994 are given in Table 44.

Table 44. Estimated elephant density in different habitats in 1994

Season	Area	Sample Size	Dung Density /km²	% CV	95 % CI Lower	95 % CI Upper	Elephant density/ Km²
Dry	DDF	91	1211.30	13.04	936.00	1567.00	1.42
	MDF	42	706.18	16.44	507.71	982.20	0.81
	PLN	13	281.97	30.94	145.90	544.90	0.32
Wet-1	DDF	56	498.59	17.73	350.42	709.40	0.59
	MDF	64	1164.30	20.34	778.62	1741.00	1.33
	PLN	41	1123.10	31.97	597.75	2110.00	1.29
Wet-2	DDF	79	417.88	12.12	328.54	531.50	0.92
	MDF	70	413.22	11.95	325.87	523.90	1.56
	PLN	24	285.71	20.41	188.29	433.50	1.08

Dry = Dry season; Wet-I = First Wet Season; Wet-2 = Second Wet Season DDF = Dry deciduous Forests; MDF = Moist deciduous forests; PLN = Plantations

A dear pattern was observed in the habitat-wise density distribution of elephants in different seasons. In dry season, the density of elephants was highest in dry deciduous forests and least in plantations. An increase was observed in moist deciduous forests in the first and second wet seasons. In plantations, there was an increase in first wet season and a slight decrease in the second wet season. Table 45 gives the estimate of elephant density in different habitat types in 1995.

Table 45. Estimated elephant density in different habitats in 1995

Season	Area	Sample Size	Dung Density /km^2	Percent CV	95 % CI		Elephant density/ Km^2
					Lower	Upper	
Dry	DDF	171	2127.70	10.99	1716.50	2637.00	2.50
	MDF	102	1744.10	13.10	1346.70	2258.00	2.00
	PLN	71	1029.80	20.01	687.84	1541.00	1.18
Wet-1	DDF	47	127.03	14.59	94.87	170.00	0.59
	MDF	50	145.77	14.14	109.89	193.30	1.82
	PLN	29	136.79	18.57	93.87	199.30	1.71
Wet-2	DDF	80	303.03	11.18	242.78	378.20	0.67
	MDF	66	362.64	12.31	283.90	463.20	1.37
	PLN	21	226.29	21.82	144.49	354.40	0.85

Dry = Dry season; Wet-1 = First Wet Season; Wet-2 = Second Wet Season; DDF = Dry Deciduous Forests; MDF =Moist Deciduous Forests; PLN = Plantations

Density distribution in 1995 also followed a pattern similar to 1994 between habitats. But the distribution in moist deciduous forests and plantations showed a pattern entirely different from 1994. Density distribution in moist deciduous forests in 1995 showed a slight decrease from dry to second wet season and in plantations, an increase was recorded in the first wet season with a fall in second wet season. However, the density estimate in 1995 was considerably higher compared to 1994.The density estimate of elephants for two seasons in 1996 are given in Table 46 and followed the pattern observed in 1994.

Table 46. Estimated elephant density in different habitats in 1996

Season	Area	Sample Size	Dung Density /km^2	% CV	95 % CI		Elephant density /Km^2
					Lower	Upper	
DRY	DDF	122	1601.80	12.64	1251.50	2050.00	1.88
	MDF	64	1009.60	16.49	727.76	1400.00	1.16
	PLN	24	725.77	24.38	441.46	1193.00	0.83
WET-1	DDF	49	138.04	23.87	91.26	184.82	0.64
	MDF	47	137.15	26.47	85.27	189.03	1.71
	PLN	9	125.21	33.49	59.56	190.86	1.56

Dry = Dry season, Wet-1 = First Wet Season; Wet-2 = Second Wet Season; DDF = Dry Deciduous Forests; MDF = Moist Deciduous Forests; PLN = Plantations

The two-way ANOVA revealed a significant difference in the density between the habitats ($P < 0.05$) and non-significant difference between the seasons ($P > 0.05$). The two-way interaction between the habitat and seasons were found to be highly significant ($P < 0.05$) (Table 47).

Table 47. Two-way ANOVA showing the relationship of elephant density between the area and season

Source of variation	Sum of Squares	*df*	Mean Square	F	p
Main Effects					
Habitats	27560.953	2	13780.477	11.691	**
Seasons	1837.224	2	918.612	0.779	Ns
2-way interactions					
Habitat x Season	26026.772	4	6506.693	5.520	**
Residual	17681.031	15	1178.735	-	

** = $P < 0.001$, ns = nonsignificant

5.4.3 Food Availability

5.4.3.1 Grass availability

Table 48 shows the seasonal estimation of grass biomass in different habitats in the study area for 1994 and 1995. The ch-square test for the overall biomass of grass between years turned out to be non-significant ($\chi 2 = 3.6$; $df = I$; $P > 0.05$). However, a highly significant difference was observed between seasons, irrespective of habitats and years ($\chi 2 = 10.56$; $df = 2$; $P < 0.05$).

Seasonal estimation of grass biomass irrespective of habitats in 1994 shows a highly significant difference ($\chi 2 = 18.32$; $df = 2$; $P < 0.05$). Biomass was high in the first wet season (186 g/m^2) and low during dry and second wet seasons. During 1995, the biomass of grass in different seasons were ranging between 120 g./m^2 and 131 g./m^2, and the difference was non-significant ($\chi 2 = 0.61$; $df = 2$; $P > 0.05$).

Table 48. Availability of grass food species (g. dry weight/m^2)

Year	Habitat	Dry	%	Wet1	%	Wet2	%
1994	DDF	255.21	71.65	284.45	50.99	182.58	47.37
	MDF	95.20	26.73	188.94	33.87	147.95	38.38
	PLN	5.76	1.62	84.45	15.14	54.92	14.25
	Total	118.72	27.40	185.95	42.92	128.48	29.66
1995	DDF	220.09	55.73	216.48	56.01	218.90	61.17
	MDF	158.42	40.11	103.04	26.66	100.49	28.08
	PLN	16.42	4.16	66.96	17.33	38.48	10.75
	Total	131.64	34.66	128.83	33.92	119.29	31.41

DDF=Dry deciduous forests; MDF=Moist deciduous forests; PLN=Plantations

Dry deciduous forests had the highest mean grass availability throughout in both 1994 and 1995 followed by moist deciduous and plantations (Table 48).

The two-way ANOVA revealed a highly significant difference in the biomass of grass between habitats within the season and no significant difference between seasons within the habitats (Table 49). No interaction was observed in the grass biomass between the habitats and seasons ($P > 0.05$).

Table 49. Two-way ANOVA showing the relationship of grass with seasons and habitat

Source of Variation	**Sum of Squares**	***df***	**Mean square**	**F**	**p**
Main Effects					
Habitat	102897.294	2	51448.647	43.093	**
Season	4321.972	2	2160.986	1.810	ns
2-Way Interactions					
Habitat x Season	3099.442	4	774.861	0.649	ns
Residual	10745.158	9	1193.906		-

**= P <0.001, ns = nonsignificant

5.4.3.2 Browse availability

The mean biomass of all browse species in the study area is given in Table 50. The Chi-square test indicates a significant difference in the overall browse availability between seasons irrespective of habitats ($\chi 2 = 10.24$; df= 2; $P < 0.05$). The two-way ANOVA (Table 51) indicates a highly significant difference in the availability of browse biomass between habitats ($P < 0.001$) and no difference between seasons ($P > 0.05$). There was also no interaction between seasons and habitats, The browse biomass in dry deciduous forests was ranging between 285 g./m^2 and 481 g./m^2 during 1994 and 1995. In moist deciduous forests, the total biomass was more than dry deciduous forests and ranged between 1350 g./m^2 and 1740 g./m^2. The availability of browse species in plantations were almost equal to the availability in moist deciduous forests.

Percentage availability of browse species in different seasons and habitats for 1994 and 1995 (Table 50) indicate that 35 to 70% of the total biomass of browse species available were in moist deciduous and plantations. The availability in dry deciduous forests was comparatively low (10 to 20%).

Table 50. Availability of browse food species (g. dry weight/m^2)

Year	Habi tat	Dry	%	Wet1	%	Wet2	%
1994	DDF	386.24	12.24	284.45	8.44	480.89	15.97
	MDF	1350.10	42.77	1740.89	51.64	1489.59	49.47
	PLN	1420.40	45.00	1345.97	39.92	1040.86	34.56
	Total	1052.25	19.38	3371.31	62.11	1003.78	18.49
1995	DDF	436.15	14.75	334.83	11.14	390.99	12.05
	MDF	1420.20	48.02	1348.56	44.88	1424.78	43.91
	PLN	1101.14	37.23	1321.26	43.97	1428.91	44.04
	Total	985.83	32.12	1001.55	32.63	1081.56	35.24

DDF=Dry deciduous forests; MDF=Moist deciduous forests; PLN=Plantations

Table 51. Two-way ANOVA showing the relationship of browse spceies with seasons and habitats

Source of Variation	Sum of Squares	*df*	Mean Square	F	P
Main Effects					
Habitat	3975133.420	2	1987566.710	83.342	*
Season	5721.811	2	2860.906	0.120	ns
2-Way Interactions					
Habitat x Season	48223.480	4	12055.870	0.506	ns
Residual	214634.336	9	23848.260		

*=p <0.05, ns = nonsignificant

5.4.3.3 Availability of browse exclodiog *Helicteres isora*

Contribution of *Helicteres isora* to overall browse biomass was found to be very high. Hence an attempt was made to estimate the browse biomass after excluding *H. isora*. The biomass of browse species, excluding *H. isora* was ranging between 150 g./m^2 and 310 g./m^2 (Table 52). In moist deciduous forests, the availability was more than those in dry deciduous forests (between 250/g./m^2 to 295 g./m^2). Availability of browse species was very low in the plantation and ranged between 35 g./m^2 and 100 g./m^2.

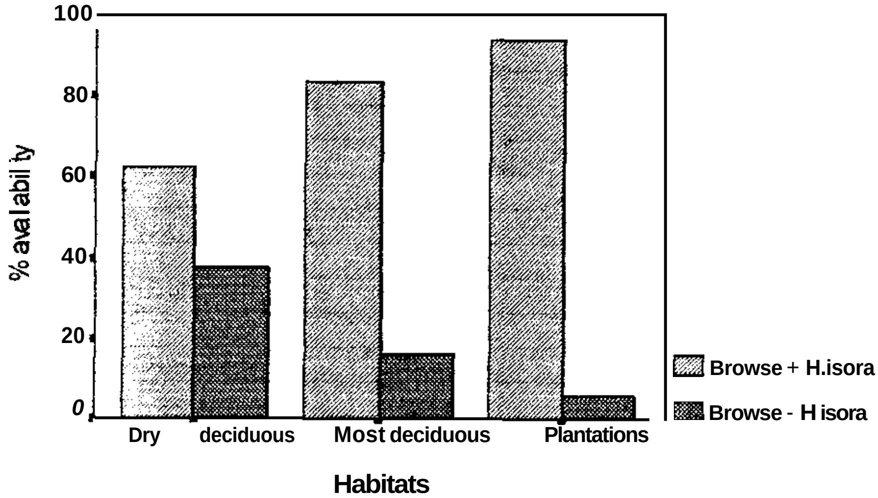
Table 52 Availability of browse food species excluding *Helicteres isora* (g. dry weight/m^2)

Year	Habitat	Dry	%	Wet1	%	Wet2	%
1994	DDF	245.74	38.94	268.00	42.12	149.40	29.86
	MDF	295.78	46.87	289.54	45.51	256.58	51.29
	PLN	89.50	14.18	78.68	12.37	94.32	18.85
	Total	210.34	35.70	212.07	35.99	166.77	28.30
1995	DDF	227.63	37.98	190.42	33.02	310.88	48.36
	MDF	270.77	45.17	288.68	50.06	296.54	46.13
	PLN	101.02	16.85	97.56	16.92	35.48	5.52
	Total	199.81	32.95	192.22	31.70	214.30	35.343

DDF=Dry deciduous forests; MDF=Moist deciduous forests PLN=Plantations

There was no marked difference between the two estimates in dry deciduous forest. But the variation was considerable in moist deciduous forest and plantations (Fig. 22).

Fig. 22. Percentage availability of browse species with and without *Helicteres isora*



5.4.3.4 Availability of total biomass

Estimation of seasonal and habitat-wise total biomass of all food species (including grass and browse species) in the study area during 1994 and 1995 are given in Table 53. The total biomass varied between 275 g./m^2 and 332 g./m^2 in dry deciduous forests and between 723 g./m^2 and 965 g./m^2 in moist deciduous forests. In plantations, the availability was moderate and varied between 548 g./m^2 and 715 g./m^2.

Table 53. Availability of total food species (grass and browse species) (g. dry weight/m^2)

Year	Habitat	Dry	%	Wet1	%	Wet2	%
1994	DDF	320.73	18.26	284.45	14.48	331.74	19.53
	MDF	722.65	41.14	964.92	49.12	818.77	48.21
	PLN	713.08	40.60	715.21	36.41	547.89	32.26
	Total	585.49	32.41	654.86	36.25	566.13	31.33
1995	DDF	328.12	19.58	275.66	16.26	304.95	16.93
	MDF	789.31	47.09	725.80	42.81	762.64	42.34
	PLN	558.78	33.34	694.11	40.94	733.70	40.73
	Total	558.74	32.40	565.19	32.77	600.43	34.820

DDF=Dry deciduous forests, MDF=Moist deciduous forests; PLN=Plantations

The two-way ANOVA (Table 54) revealed a non-significant variation between seasons and a highly significant difference between habitats ($P < 0.001$).

Table 54. Two-way ANOVA showing the relationship in the availability of food(grass and browse) with seasons and habitats

Source of Variation	Sum of squares	*df*	Mean Squares	F	P
Main Effects					
Habitat	766183.741		383091.871	55.432	*
Season	4554.731	2	2277 .366	.330	ns
2-W ay Interactions					
Habitat X Season	11764. 8011	4	2941. 200	.426	ns
Residual	62198. 809				

*=P<0.05, ns = non- significant

Percentage availability of food species (grass and browse) in different habitat types are shown in Table 53 for 1994 and 1995 respectively. There was not much variation between moist deciduous forests and plantations during the first and second wet seasons, but there was a slight variation during dry season. Total biomass was comparatively less (10 to 20 %) in dry deciduous forests during the study period.

5.4.3.5 Food availability in different areas

The estimated biomass of grass in the border areas and inside areas for 1994 and 1995 are given in Table 55. A higher biomass of grass, ranging between 212 g./m^2 and 366 g./m^2 was recorded from the border areas throughout the year in 1994. Biomass in the inside areas were comparatively less (143 g./m^2 to 192 g./m^2) in all seasons. The range of availability in the inside areas were between 122 g./m^2 and 165 g./m2 during 1995. The percentage availability of grass in the bordering areas was comparatively higher throughout (55 to 65 %).

Table 55. Availability of grass biomass in different areas (g. dry weight/m^2)

Year		Seasons		
	Areas	Dry	Wet-1	Wet-2
1994	Border	212.90	365.74	211.81
	Inside	143.27	192.10	173.64
1995	Border	229.64	247.73	236.48
	Inside	165.30	138.75	121.39

Analysis of variance (ANOVA) revealed a significant difference between the areas (P < 0.05) and non-significant difference between seasons (P > 0.05). There was interaction between the seasons and areas (Table 56).

Table 56. Two-way ANOVA showing the relationship of grass biomass with areas and seasons

Source of Variation	sum of squares	*df*	Mean square	F	P
Main Effects					
Area	27060.752	3	27060.752	15.555	*
Season	6482.649	2	3241.325	1.863	ns
2-Way Interactions					
Area x season	3266.911	2	1633.456	0.939	ns
Residual	10438.401	6	1739.734	-	-

*=P < 0.05, ns = non significant

Estimated biomass of browse species in different areas (Table 57) indicates a higher proportion of biomass in the bordering areas in all the seasons in both the years. In bordering areas, the biomass ranged from 348 g. /m^2 to 985 g. /m^2 and in the inside areas, it was from 2100 g./m^{2}to 2657 g./m^2.

Table 57. Mean biomass of browse in different areas (g. dry weight/m^2):

Year		seasons		
	Areas	Dry	Wet-1	Wet-2
1994	Border	585.95	984.74	846.58
	Inside	2570.79	2386.57	2164.76
1995	Border	856.94	347.58	784.85
	Inside	2100.55	2657.07	2459.83

Analysis of variance (ANOVA) revealed a significant difference between the areas (P < 0.05) and non-significant difference between seasons (P > 0.05). There was no interaction between the seasons and areas (Table 58).

Analysis for areas nearer to (CS) and away from settlements (AS) recorded a large variation in the biomass of grass (Table 59). The grass.biomass was always higher in areas away from settlements.

Table 58. Two-way ANOVA showing the relationship of browse biomass with areas and seasons

Source of Variation	Sum of squares	*df*	Mean Square	F	P
Main Effects					
Area	6799485.365	1	6799485.365	32.365	**
Season	204110.717	2	102055.358	0.486	ns
2-Way Interactions					
Area x Season	239160.217	2	119580.109	0.569	ns
Residual	1260506.626	6	210084.438		

**=P<0.001, ns = nonsignificant

Table 59. Mean biomass of grass in different areas (g. dry weight/m²)

Year		Seasons		
	Area	**Dry**	**Wet-1**	**Wet-2**
1994	CS	65.96	109.38	86.44
	AS	290.21	448.46	299.01
1995	CS	104.73	174.34	120.67
	AS	290.21	212.14	237.20

CS = close to settlement; AS = away from settlements

Percentage grass availability in areas close to the settlements were only 25 to 30 % of the total availability and 70 to 75 % in the areas away from the settlement .

The two-way ANOVA revealed a significant difference between the areas (P < 0.05) but not between seasons (Table 60). There was also no interaction between the areas and seasons.

Table 60. Analysis of variance (ANOVA) showing the relationship of grass availability with seasons and habitats

Source of Variation	Sum of squares	*df*	Mean Square	F	P
Main Effects					
Area	103734.067	1	103734.067	18.701	*
Season	6482.649	2	3241.325	0.584	ns
2-Way Interactions					
Areas X Seasons	821.937	2	410.969	0.074	ns
Residual	33281.113	6	5546.852	-	-

*=P < 0.05, ns = nonsignificant

Table 61 shows the browse availability in areas closer to and away from the settlements in the study area during 1994 and 1995. Though the ANOVA showed no significant difference between areas and seasons (Table 62), the percentage availability was more during the first and second wet seasons in areas closer to the settlements, and less during the dry season Availability of browse was ranging between 1210 g./m^2 and 2397 g./m^2 in areas closer to settlements and between 974 g./m^2 and 1785 g./m^2 in areas away from settlements.

Table 61. Biomass of browse in different areas (g. dry weight m^2)

Year		Seasons		
	Areas	Dry	Wet-1	Wet-2
1994	CS	1371.89	2397.22	1932.50
	AS	1784.85	974.09	1078.84
1995	CS	1211.01	1515.51	1704.78
	AS	1746.48	1489.14	1539.90

CS = close to settlement; AS = away from settlements

Table 62. Analysis of variance (ANOVA) showing the relationship of browse availability with seasons and habitats

Source of Variation	sum of squares	df	Mean Square	F	p
Main Effects					
Area	192434.546	1	192434.546	1.730	ns
Season	8582.717	2	4291.358	0.039	ns
2-Way Interactions					
Areas x Seasons	817063.816	2	408531.908	3.674	ns
Residual	667238.190	6	111206.365	-	-

ns=nonsignificant

5.4.3.6 Relationship of elephant density with the environmental variables in various seasons

During dry season, the elephant density had a significant positive correlation ($P<0.05$) with grass biomass and water availability (Table 63). Apart from the correlation between elephant density and other habitat variables, there were few variables which had correlation with some of the habitat characteristics. Grass biomass had a positive correlation with grass cover and water availability whereas it had a negative correlation with browse biomass and bamboo availability. Grass cover was significantly positively correlated with water availability ($P<0.001$) and rainfall ($P<0.05$). Browse biomass had a negative correlation with water availability and rainfall, and positive correlation with bamboo availability. Water availability and rainfall had a negative correlation with bamboo availability. Water availability was positively correlated with rainfall.

During the first wet season, the elephant density had a significant correlation with most of the factors (Table 64). Young leaves of bamboo and grass, browse biomass, density of bamboo and rainfall had positive correlation with elephant density. Density of elephants was negatively correlated with biomass, cover and fibrous texture of grass, matured leaves of bamboo and water availability. Apart from these, the grass cover, fibrous texture of grass, matured leaves of bamboo and water availability were positively correlated with grass biomass. Young leaves of grass, browse biomass, density of bamboo, young leaves of bamboo and rainfall had negative correlation with grass biomass.

Elephant density was highly positively correlated with soft texture grass and negatively correlated with the fibre textured grass (Table 65). A significant positive correlation observed between the elephant density and browse biomass, density of bamboo and young leaves of bamboo during the second wet season. Density of elephants was negatively correlated with the matured leaves of bamboo. On the other hand, grass biomass was positively correlated with grass cover and negatively correlated with browse biomass and density of bamboo. Grass cover had a negative correlation with browse biomass and density of bamboo. Bamboo young leaves had a negative correlation with water availability. Browse biomass had a highly positive correlation with density of bamboo and young leaves of bamboo and negative correlation with matured leaves of bamboo.

The correlation matrix for 10 variables is shown in Table 66. The results show that more than half of the coefficients are greater than 0.3 and almost one third are more than 0.5 in absolute value. All variables have large correlation with at least one of the other variables in the set indicating that the variables are related to each other at greater extent. For instance, the grass biomass was positively correlated with grass cover indicating that the higher grass biomass in dry deciduous forest was due to the grass cover.

The fibrous grass structure was highly negatively correlated with the soft grass. In moist deciduous forest, soft textured grass was available during the first wet season whereas during the dry season the grass was fibrous in dry deciduous forest. Negative correlation of browse biomass with the grass cover, grass biomass and fibrous texture of grass indicates that the browse availability is more in the absence of grass. Density of bamboo in the dry deciduous forest was less which is reflected from its negative correlation with grass cover and biomass which is dominated in the dry deciduous forest. There was a highly significant positive correlation between the bamboo young leaves and soft textured grass. This explains that both the factors were dominant in moist deciduous forest during first wet season. Water availability was significantly correlated with grass cover and biomass whereas negatively correlated with density of bamboo and browse biomass. A highly significant correlation was observed between rainfall and soft textured grass, young leaves of bamboo, grass cover and water availability.

Table 67 summarises the results of Principal Component Analysis for all the factors. The total variance explained by each factor is listed in the column labelled *Eigenvalue.* The linear combination formed by the first factor has a variance of 4.96, which is 49.6% of the total variance of 10 variables. Factor 2 has a variance of 3.75 (37.5%). Almost 87% of the total variance is attributable to the first two factors.

Figure 23, the *Scree* plot of the total variance associated with each factor typically indicate a distinct break between the steep slope of the large factors and the gradual trailing off of the rest of the factors. From the plot, it again appears that a two-factor model should be sufficient for explaining the elephant density.

All the variables that have large loading (coefficients) for the same factors were sorted and grouped by *rotated factor matrix* (Table 68). The first factor was highly correlated positively with young leaves of bamboo, young leaves of grass and rainfall. It was negatively correlated with fibrous structure of grass and matured leaves of bamboo. In the same way, Factor 2 was highly correlated positively with grass cover: grass biomass and water availability, whereas negatively correlated with density of bamboo and browse biomass.

Thus, the results of factor analysis indcate that the first factor consists of positively correlated variables *viz..* soft textured grass, bamboo young leaves and rainfall and negatively correlated variables *viz.,* fibrous grass and matured leaves of bamboo, explained nearly 50% of the variation in the overall elephant density. Factor 2 consists of 3 positively correlated variables *viz..* grass cover, grass biomass and water availability and 2 negatively correlated variable *viz.,* density of bamboo and biomass of browse species in the study area. Though the factor 2 is explaining less than the first factor, it is also equally important in determining the elephant density. It is important to note that all the independent environmental variables are interrelated with each other and together accounted for 87%, which determines the elephant density in the study area.

Table 63. Correlation matrix of relationships of dry season elephant density with environmental factors

	ED	GB	GC	SG	FG	BB	DB	BY	BM	WA	RF
ED	1.00										
GB	0.72*	1.00									
GC	0.61	0.92*	1.00								
SG	0.05	0.05	-0.31	1.00							
FG	-0.05	-0.05	0.30	-1.00**	1.00						
BB	-0.55	-0.76*	-0.93*	0.59	-0.59	1.00					
DB	-0.49	-0.72*	-0.91*	0.65	-0.65	0.97**	1.00				
BY	0.09	-0.26	-0.57	0.86*	-0.86*	0.72*	0.81*	1.00			
BM	-0.09	0.26	0.57	-0.86*	0.86*	-0.72*	-0.81*	-1.00**	1.00		
WA	0.71*	0.92*	0.97**	-0.32	0.32	-0.91*	-0.92*	-0.55	0.55	1.00	
RF	0.42	0.67	0.87*	-0.48	0.48	-0.82*	-0.88*	-0.68	0.68	-0.82*	1.00

Table 64. Correlation matrix of relationships of first wet season elephant density with environmental factors

	ED	GB	GC	SG	FG	BB	DB	BY	BM	WA	RF
ED	1.00										
GB	-0.86*	1.00									
GC	-0.47	0.75*	1.00								
SG	0.91*	-0.81*	-0.48	1.00							
FG	-0.91*	0.81*	0.48	-1.00**	1.00						
BB	0.84*	-0.69	-0.51	0.96**	-0.96**	1.00					
DB	0.92*	-0.75*	-0.46	0.98**	-0.98**	0.98**	1.00				
BY	0.79*	-0.88*	-0.83*	0.88*	-0.88*	0.88*	0.84*	1.00			
BM	-0.79*	0.88*	0.83*	-0.88*	0.88*	-0.88*	-0.84*	-1.00**	1.00		
WA	-0.60	0.83*	0.95*	-0.53	0.53	-0.53	-0.50	-0.85*	0.85*	1.00	
RF	0.81*	-0.63	-0.60	0.78*	-0.78*	0.88*	0.89*	0.78*	-0.78*	-0.59	1.00

Table 65. Correlation matrix of relationships of second wet season elephant density with environmental factors

	ED	GB	GC	SG	FG	BB	DB	BY	BM	WA	RF
ED	1.00										
GB	-0.21	1.00									
GC	-0.46	0.82*	1.00								
SG	0.95**	-0.37	-0.54	1.00							
FG	-0.95**	0.37	0.54	-1.00**	1.00						
BB	0.71*	-0.71*	-0.76*	0.84*	-0.84*	1.00					
DB	0.77*	-0.72*	-0.81*	0.91*	-0.91*	0.97**	1.00				
BY	0.81*	-0.62	-0.62	0.93*	-0.93*	0.96**	0.95**	1.00			
BM	-0.81*	0.62	0.62	-0.93*	0.93*	-0.96**	-0.95**	-1.00**	1.00		
WA	-0.21	0.89	0.61	-0.44	0.44	-0.78*	-0.73*	-0.72*	0.72*	1.00	
RF	0.56	-0.26	-0.49	0.36	-0.36	0.26	0.32	0.26	-0.26	0.10	1.00

ED = Elephant Density; GB = Grass biomass; GC = Grass cover; SG = Soft Grass; FG = Fibrous grass; BB = Browse biomass; DB = Density of bamboo; BY = Bamboo young leaves; BM = Bamboo matured leaves; WA = Water availability; RF = Rainfall

Table 66. Correlation matrix of relationship between the environmental variables

	GB	GC	SG	FG	BB	DB	BY	BM	WA	RF
GB	1.00									
GC	**0.85**	1.00								
SG	0.27	0.26	1.00							
FG	-0.18	-0.21	-0.86	1.00						
BB	-0.54	-0.55	0.41	-0.52	1.00					
DB	-0.54	-0.56	0.45	-0.53	0.98	I.00				
BY	0.17	0.24	0.92	-0.85	0.37	0.39	1.00			
BM	-0.07	-0.08	-0.81	0.86	-0.43	-0.41	-0.91	1.00		
WA	0.81	0.75	0.36	-0.36	-0.48	-0.51	0.32	-0.32	1.00	
RF	0.34	0.48	0.72	-0.73	-0.03	-0.03	0.84	-0.81	0.64	1.00

GB = Grass biomass; GC = Grass cover; SG = Soft Grass; FG = Fibrous grass; BB = Browse biomass; DB = Density of bamboo; BY = Bamboo young leaves; BM = Bamboo matured leaves; WA = Water availability; RF = Rainfall

Table 67. Results of Principal-Components Analysis (PCA)

Variable	Factor	Eigen Value	%Var.	Cum %
GB	1	4.95760	49.6	49.6
GC	2	3.74514	37.5	87.0
SG	3	0.59389	5.9	93.0
FG	4	0.28162	2.8	95.8
BB	5	0.18594	1.9	97.6
DB	6	0.11779	1.2	98.8
BY	7	0.05821	0.6	99.4
BM	8	0.02664	0.3	99.7
WA	9	0.02270	0.2	99.9
RF	10	0.01047	0.1	100.0

GB = Grass biomass; GC = Grass cover; SG = Soft Grass; FG = Fibrous grass; BB = Browse biomass; DB = Density of bamboo; BY = Bamboo young leaves; BM = Bamboo matured leaves; WA = Water availability; RF = Rainfall

Fig. 23. Scree plot showing the total variance associated with each factor

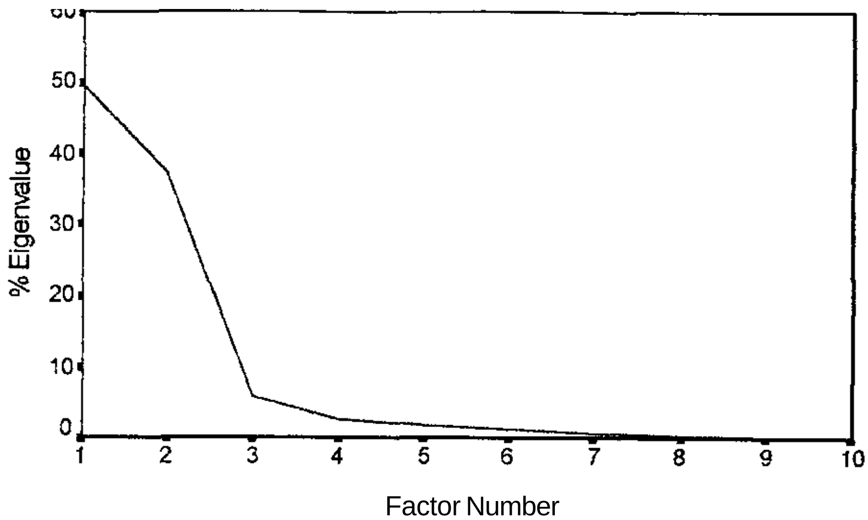


Table 68. Rotated Varimax Factor Loadings (Rotated Factor matrix)

	Factor 1	Factor 2
BY	0.95596	0.03735
FG	-0.95255	0.03486
SG	0.93746	0.04369
BM	-0.93080	0.04293
RF	0.81870	0.40750
GC	0.21540	0.88144
GB	0.18191	0.87402
WA	0.37839	0.84351
DB	0.48435	-0.82752
BB	**0.47336**	**-0.82167**

5.5 GAUR

5.5.1 Estimation of Area wise dung density

The results of area wise density distribution for all the yeas are summarised in Table 69,70 and 71. The dung density was significantly differed between the areas and between the seasons. The density was always higher on the periphery and comparatively less in the interior area

Table 69. Overall estimate of Gaur density by dung count method in different areas during 1994

Year	Season	Area	Sample size	Dung density/ km^2	% CV	95 % CI	
						Lower	Upper
1994	Dry	PER	25	755.09	20.50	511.69	1058.49
		INS	16	483.15	28.69	211.46	754.84
	Wet-1	PER	22	665.15	21.34	386.94	943.36
		INS	12	329.63	28.15	147.76	51..50
	Wet-2	PER	26	810.15	23.12	443.03	1177.27
		INS	13	443.47	29.80	184.45	702.49

Dry = Dry season: Wet-1 = First Wet Season; Wet-2 = Second Wet Season INS-Inside , PER-Periphery

Table 70. Estimates of Gaur density by dung count method in different areas during 1995

Season	Area	Sample size	Dung density/ km^2	% CV	95 % CI	
					Lower	Upper
Dry	PER	31	869.14	22.14	491.98	1246.30
	INS	23	511.92	26.21	248.94	774.86
Wet-1	PER	25	683.70	20.58	407.92	959.48
	INS	12	302.36	29.19	129.37	475.35
Wet-2	PER	31	722.12	20.21	436.07	1008.16
	INS	15	345.03	26.81	163.73	526.34

Dry = Dry season: Wet-1 = First Wet Season; Wet-2 = Second Wet Season INS-Inside , PER-Periphery

Table 71. Estimates of Gaur density by dung count method in different areas during 1996

Season	Area	Sample size	Dung density /km^2	Percent CV	95 % CI	
					Lower	Upper
Dry	PER	33	609.89	18.65	386.95	832.83
	INS	17	367.47	24.99	157.48	547.46
Wet-1	PER	25	524.74	20.20	316.98	732.50
	INS	18	229.45	23.11	125.52	333.39

Dry = Dry season; Wet- 1 = First Wet Season; Wet-2 = Second Wet Season INS-hide , PER-Periphery

5.5.2 Habitat wise distribution

The results of dung density estimate in different habitats across the season in 1994 are given in Table 72. The statistical tests for the comparison between the seasons 'show a high significance ($\chi 2$=35.33,df=2 p<0.001). There was a high density in the dry deciduous forests and medium density in the moist deciduous forests observed in all the seasons. During the first wet seasons, the density in the plantations was more or less equal to moist deciduous forests. During dry and second wet seasons the density was very low in the plantations.

Table72. Estimates of Gaur density by dung count method in different habitats during 1994

Season	Area	Sample Size	Dung Density /km^2	Percent CV	95 % CI	
					Lower	Upper
Dry	DDF	19	645.21	21.14	377.88	912.54
	MDF	12	484.07	27.60	222.21	745.93
	PLN	10	310.54	29.11	133.36	487.82
Wet-1	DDF	15	528.12	26.32	255.68	888.56
	MDF	9	256.05	29.90	118.41	453.69
	PLN	10	324.22	22.49	181.30	467.14
Wet-2	DDF	17	610.39	27.01	257.25	933.53
	MDF	11	381.94	30.03	157.13	606.75
	PLN	11	285.12	25.27	143.88	426.36

Dry = Dry season; Wet-1 = First Wet Season; Wet-2 = Second Wet Season

DDF =Dry deciduous Forests; MDF = Moist deciduous forests; PLN = Plantations

The estimate of dung density during 1995 is presented in Table 73. During 1995, the same pattern of previous year was observed during dry and first wet seasons. During second wet season and almost equal density was observed both in moist deciduous frosts and plantations. Tests between the habitats showed a remarkable significance in the dung density (x2=68.45, df=2, p<0.001)

The density estimates during 1996 are given in Table 74. A highly significant difference were observed in the dung density between the habitats and between the seasons ($x2=291.64, df=l, p<0.001$). There was no change in the pattern of habitat utilisation

Table 73. Estimates of Gaur density by dung count method in different habitats during 1995

Season	Area	Sample Size	Dung Density/ km^2	% CV	95 % CI	
					Lower	Upper
Dry	DDF	24	708.11	20.93	417.62	998.60
	MDF	17	502.70	22.16	254.36	721.04
	PLN	13	332.84	27.35	154.42	511.26
Wet-1	DDF	17	508.19	24.99	259.28	757.10
	MDF	8	311.32	32.91	110.51	512.13
	PLN	12	345.54	25.90	170.13	520.95
Wet-2	DDF	20	590.06	28.10	265.08	915.04
	MDF	14	294.40	25.94	144.72	444.08
	PLN	12	310	27.72	141.55	478.45

Dry = Dry season; Wet-1 = First Wet Season, Wet-2 = Second Wet Season DDF = Dry deciduous Forests; MDF = Moist deciduous forests; PLN = Plantations

Table 74. Estimates of Gaur density by dung count method in different habitats during 1996

Season	Area	Sample Size	Dung Density/km^2	% CV	95 % CI	
					Lower	Upper
Dry	DDF	25	556.35	20.43	33.3.57	779.13
	MDF	11	432.48	22.75	239.64	625.32
	PLN	14	291.10	28.93	126.04	456.16
Wet-1	DDF	17	600.12	24.23	315.12	885.12
	MDF	12	216.28	26.27	104.92	327.64
	PLN	14	231.91	24.44	120.82	343

5.6 SAMBAR

5.6.1 Distribution in different areas

The estimates of pellet density in different areas are given Table 75

Table 75. Estimated Sambar density by pellet count method in different Areas

Year	Season	Area	Sample size	Pellet density/km^2	% CV	95 % CI Lower	Upper
1994	Dry	PER	30	1375.05	28.03	619.61	2130.49
		INS	49	2707.23	21.03	1591.42	3823.05
	Wet-1	PER	74	1885.50	16.55	1273.88	2497.12
		INS	83	1657.86	17.83	1078.49	2237.23
	Wet-2	PER	30	1389.53	21.02	817.05	1962
		INS	61	2255.34	15.19	1583.87	2926.81
1995	Dry	PER	37	1575.75	21.08	924.70	2226.80
		INS	59	1842.95	22.94	1014.31	2671.58
	Wet-1	PER	67	1903	23.20	1037.76	2768.33
		INS	89	1948.71	20.97	1147.77	2749.66
	Wet-2	PER	34	1665.50	17.60	1090.97	2240.03
		INS	59	2344.20	26.09	1145.46	3542.94
1996	Dry	PER	44	1658.63	20.54	990.89	2326.36
		INS	46	1726.14	28.30	767.40	2678.88
	Wet-1	PER	71	1167.02	27.56	858.59	2875.44
		INS	56	2186.26	25.23	1105.26	3267.26

A significantly more density .was observed on the periphery during the dry season and second wet season during the year 1994. There was no significant difference was observed between the areas during the first wet season. During 1995, and 1996, a very less or more significant difference were observed between the areas in all the seasons.

5.6.2 Distribution in different habitats

The habitat wise density distribution patterns of sambar pellets are given in Tables 76,77 &78. The density in different habitats varied significantly in different seasons during 1994. During the dry seasons, a more density in the dry deciduous forests and a medium density in the moist deciduous forests were observed. A low density was also observed in the plantations during the second wet season. The density in the moist deciduous forests was more that of the dry deciduous forests and plantations during the first wet seasons and second wet seasons in 1994. The same distribution was observed during 1995. There was a change in the dry season density distribution pattern during 1996. A more density was observed in the moist deciduous forests than the dry deciduous forests and plantations.

Table 76. Estimates of Sambar density by pellet count method in different habitats during 1994

Season	Area	Sample Size	Pellet Density/km^2	% CV	95 % CI Lower	Upper
Dry	DDF	28	1957	31.20	771.91	3202.09
	MDF	7	1500	31.60	570.96	2429.04
	PLN	44	792	31	310.78	1273.22
Wet-1	DDF	49	1206	24	638.70	1773.30
	MDF	58	1560.35	26	765.20	2355.50
	PLN	50	926	28.70	405.11	1446.89
Wet-2	DDF	24	1659	30.70	660.75	2657.25
	MDF	40	2150	46.30	198.92	4101.08
	PLN	27	1141	48.70	51.89	2230.11

Dry = Dry season; Wet-I = First Wet Season, Wet-2 = Second Wet Season
DDF = Dry deciduous Forests; MDF = Moist deciduous forests; PLN = Plantations

Table 77. Estimates of Sambar density by pellet count method in different habitats during 1995

Season	Area	Sample Size	Pellet Density/km^2	% CV	95 % CI Lower	Upper
Dry	DDF	36	1779	29.10	764.33	2793.67
	MDF	20	1549	37.20	419.59	2678.41
	PLN	40	895.20	25.30	451.29	1339.11
Wet-1	DDF	48	1435	27.20	669.97	2200.03
	MDF	57	1789	18.20	1150.83	2427.17
	PLN	51	1255	21.90	716.30	1793.70
Wet-2	DDF	33	2248	21.60	1296.29	3199.71
	MDF	34	2739	37.20	741.94	4736.06
	PLN	26	1230	39.60	275.32	2184.68

Table 78. Estimates of Sambar density by pellet count method in different habitats during 1996

Season	Area	Sample Size	Pellet Density/km^2	% CV	95 % CI Lower	Upper
Dry	DDF	41	1008.20	28.98	435.53	1580.87
	MDF	20	1521.	29.20	650.50	2391.50
	PLN	29	813.90	28.15	364.84	1262.96
Wet-1	DDF	49	1227	21.60	707.54	1746.46
	MDF	61	1581.06	23	868.32	2293.80
	PLN	17	747.90	46.40	67.73	1428.07

5.7 Chital

5.7.1 Distribution in different areas

The area wise estimate of pellet density in different years is presented in Table 79. There was a significant difference observed in the density between the areas (x2=406.90,df=l,p<0.001) in all the seasons and years. The density was always higher in the periphery than inside areas, in all the seasons during 1994. The same pattern was followed during the dry and the first wet season of 1995, except the second wet season. There was no significant differences were observed between the areas in the second wet seasons (x2=.35,df=l,p<0.001). During 1995, the density was slightly more in the interior areas than the periphery. During the first wet season the density pattern was followed the previous years.

Table 79. Estimated Chitai density by pellet counts method in different Areas during 1994-96

Year	Season	Area	Sample size	Pellet density/km²	% CV	95 % CI	
						Lower	Upper
1994	Dry	PER	22	1750.30	21.60	1009.29	2491.31
		INS	18	854	25.60	425.50	1252.50
	Wet-1	PER	52	1565	19.40	696.92	2161.08
		INS	25	1190	23.50	641.89	1138.11
	Wet-2	PER	18	1165.80	21.20	681.39	1650.21
		INS	10	847	28.90	367.23	1326.77
1995	Dry	PER	53	773.45	21.55	446.76	1100.14
		INS	58	584.84	25.89	288.07	888.61
	Wet-1	PER	24	1083.25	23.13	592.16	1574.34
		INS	53	692.83	25.29	349.41	1036.25
	Wet-2	PER	30	579.38	30.35	234.73	924.03
		INS	32	574.26	24.13	302.66	845.86
1996	Dry	PER	49	1112.22	35.90	329.62	1894.82
		INS	48	1355.42	48.48	67.49	2643.35
	Wet-1	PER	37	1303.07	21.84	745.27	1860.87
		INS	31	373.62	19.73	413.13	934.11

Dry = Dry season; Wet-1 = First Wet Season; Wet-2 = Second Wet Season

5.7.2 Distribution in different habitats

A similar pattern of density distribution different habitats was observed in all the seasons and in all the years (Table 80, 81 & 82). Within seasons, there is a significant difference observed ($\chi2$=1356. 1 l,df=2,p<0.001). The density is high in the dry deciduous forests and medium in the moist deciduous forests were observed during the study period. A low density was also observed in the plantations.

Table 80. Estimate of Chital density by pellet count method in different habitats during 1994

Season	Area	Sample Size	Pellet Density/km^2	% CV	95 % CI	
					Lower	Upper
Dry	DDF	12	1300	29	561.08	2038.92
	MDF	21	750	30.60	300.18	1199.82
	PLN	7	295.60	39.10	69.06	522.14
Wet-1	DDF	25	1866	23	1024.81	2707.19
	MDF	24	984	28.80	428.55	1539.45
	PLN	28	391	23.90	207.84	574.16
Wet-2	DDF	14	1010	36	297.34	1722.66
	MDF	8	500	48.40	25.68	974.32
	PLN	6	352.80	29.40	149.50	556.10

Table 81. Estimate of Chital density by pellet counts method in different habitats during 1995

Season	Area	Sample Size	Pellet Density/km^2	% CV	95 % CI	
					Lower	Upper
Dry	DDF	52	750	22.54	418.66	1081.34
	MDF	37	1300	30.60	520.31	2079.69
	PLN	22	295.60	29.10	127	464.20
Wet-1	DDF	32	8866	33	3131.47	14600.53
	MDF	24	2284	38.80	547.06	4020.94
	PLN	21	3391	33.90	1137.88	5644.12
Wet-2	DDF	29	1150	36	338.56	1961.44
	MDF	18	640	48.40	32.87	1247.13
	PLN	15	385.80	39.40	87.87	683.73

Table 82. Estimate of Chital density by pellet counts method in different habitats during 1996

Season	Area	Sample Size	Pellet Density/km^2	% CV	95 % CI Lower	Upper
Dry	DDF	44	1869.40	22.80	1034	2704.80
	MDF	41	945.87	34.82	300.34	1591.40
	PLN	12	425.07	30.42	169.80	680.34
Wet-1	DDF	38	1986.80	12.40	1503.93	2469.67
	MDF	18	768.10	22.41	430.72	1105.48
	PLN	12	876.26	27.98	395.71	1356.81

Dry = Dry season; Wet-1 = First Wet Season; Wet-2 = Second Wet Season
DDF = Dry deciduous Forests; MDF = Moist deciduous forests; PLN = Plantations

5.8 Discussion

Wild animals try to achieve the presumed goal of fitness maximization by maintaining intake and avoiding environment stresses. This could be attained by selection of landscapes through migrations, home range placements or nomadism at behavioural frequencies of a few times in a year. Ranging behaviour of wild ungulates over wide geographical areas are normally in response to the temporal abundance and quality of forages (McNaughton, 1987). Watson and Moss (1970) have given examples to support that the dispersion of animals are related to food supply. Seasonal habitat selection has been reported in several species (Fuller, 1960; Shackleton, 1968; Shult, 1972; Duncan, 1975; Owen-Smith, 1979; Krasinska *el al.* 1987).

Density distribution of gaur indicate a preference for the deciduous forest in the periphery which is adjacent to the Protected Areas of Tamil Nadu and Karnataka. Interestingly, the results indicate sparse use of inside areas by gaur where settlements are located.

The density distribution of sambar deer and chital, as evident from the density of pellets in different areas does not seem to follow any type of pattern. However, there is a general tendency for increased concentration in the first wet and second wet seasons. The habitat requirements of the species vary considerably. The availability of food plants, places for resting, wallowing and drinking differs in abundance and distribution pattern according to the climatic changes. The types of variation are clearly evident in tropical dry deciduous forest. Moreover, cervids in general are reported to be highly sensitive to water deprivation (Berwick, 1974). The density distribution has also been observed to be influenced by environmental factors in Parambikulam (Easa unpublished information). Observations in the study area though do not agree completely with the reports from elsewhere, seem to indicate a pattern where the environmental factors also play a role.

A number of studies on elephants in Africa (Watson and Bell, 1969; Williamson, 1975; Tchamba, 1993; Dublin, 1996) and Asia (McKay, 1973; Santiapillai *et al.*, 1984; Sukumar, 1985; Easa, 1989a; Sivaganesan, 1991) have also reported changes in distributional pattern in response to environmental changes leading to a shift in water and food availability. Elephant distribution has also been reported to be influenced by external factors such as extreme weather condition (Corfield, 1973), human settlements and cultivation (Lamprey *et al.*, 1967; Western and Lindsay, 1984) and poaching activity (Dublin and Douglas-Hamilton, 1987).

The present study in Wayanad clearly showed a seasonal pattern in the distribution of elephants in different areas and habitats. These changes in the seasonal distribution were associated with several factors especially the food and water availability. Higher concentration of elephants had been observed in the bordering areas where dry deciduous forest was utilised to the maximum. Food availability study also indicated higher grass biomass in dry deciduous forests throughout the year. Further, the perennial water sources in the study area are restricted to the border areas. Though, a few perennial water sources do occur in the interior areas, these are not freely approachable due to the habitation and related human activities. Sukumar (1985) and Sivaganesan (1991) had also made similar shift in habitat utilisation in relation to food and water availability. Desai and Baskaran (1996) stressed the importance of water in the range use strategy of elephants in deciduous forest dominated areas

The present study has shown the importance of grass in the diet of elephants. Though, the browse biomass was high in the interior areas of moist deciduous forests and plantations, the availability of water plays a crucial role in distribution of elephants in Wayanad. Elephants have used the low crude protein but rich in forage biomass areas in dry season in Amboseli (Western and Lindsay, 1985). Studies in Mara by Dublin (1996) have pointed out that the elephant density during dry season was largely determined by water availability followed by food availability.

The increased density in moist deciduous and plantation dominated interior areas in the first wet season coincides with the fresh growth of grass and large scale water availability. The highly significant increase in the grass biomass in moist deciduous forest and plantation in the first and second wet seasons also supports the finding. The correlation coefficient shows a positive correlation between elephant density and bamboo young leaves, its availability and soft textured gass during first wet season. A similar correlation was also observed between the elephant density and, grass and water availability in dry season, explaining largely the influence of these two factors in the density distribution of elephants in the study area.

Fire seems to play a major role in the distribution of elephants along with food and water availability. Density of elephants in 1995 was the highest during the study period. The dry season density of 2.78/km^2 in dry deciduous forests during 1995 was quite unusual than expected. The extensive fire in the adjacent Mudumalai and Bandipur could have triggered a mass movements of elephants to the study area where fire, though occurred, and were only in patches during the late dry and early first wet seasons. A decrease was observed in the density of elephants from the dry to first wet season throughout the study period. However, the reduction in 1995 was drastic (2.78/km^2 to 0.64/km2) compared to 1994 (1.36/km^2 to 0.68/km^2) and 1996 (1.90/km^2 to 0.44/km^2). The fresh grass growth subsequent to the fire in the adjacent area would have definitely attracted a part of elephants leaving the rest to move to the interior of the study area. The impact of fire in the adjacent area and the resultant high density has also led to a comparatively higher density in the inside area also in 1995.

Habitats surrounding the settlements are degraded as shown From the low grass biomass throughout as a result of cattle grazing, though the rainfall was higher in these moist deciduous dominated areas compared to dry deciduous forest (refer Chapter 2). The dual impact of human settlements on elephant habitats has been discussed by Desai and Baskaran (1996). It could he due to habitat loss through conversion for human use or avoidance of human use areas by elephants in the normal home range. Moist deciduous and plantation areas in the interior of the study area had been increasingly used in first wet season followed by a decrease in second wet season. The trend in the border areas, where dry deciduous forest is dominant, was just the reverse. This seasonal movement could be explained by the optimal foraging theory developed to explain movements of foraging animals (Pyke, 1983). The higher density during dry season forced the animal to go for quantity compromising the quality. In the following wet seasons, the strategy seemed to be changing to attain higher quality food intake. Changes in density within wet seasons could he due to a decreasing rate of food intake as a result of depletion in quantity or decline in quality because of continuous use of the patches as explained in the marginal value theorem of Charnov (1976)

The elephants in the study area showed seasonal movement and shift in habitat utilisation in relation to food and water availability, and also the occurrence of fire in the adjacent areas. Wayanad thus is a dry season refuge for the elephants.

Chapter 6
Crop raiding

6.1 Introduction

Declaration of Protected Areas and the subsequent regulation led to the denial of access to the resources that were enjoyed by the local people. Fragmentation and depredation resulting from the dependence by the people in the enclosures and fringes have contributed to the increased incidence of human-wildlife conflict. Information on various aspects of crop raiding would help in formulating suitable mitigation measures and policy decisions.

Crop raiding by animals is one of the worst manifestations of the human-animal conflict and man-elephant conflict has been the major topic of study throughout considering the extent of damage caused due to the characteristic features of the animal. Elephants, generally being a shy animal, avoiding human beings and loving the privacy in the forest, often come into conflict with human during crop depredation. Since time immemorial, the crop raiding and occasional man-killing existed throughout their range in Asia and Africa at varying extent (Sukumar, 1985). People have been killing or injuring elephants in defence of their life and propert0y. Such cases were few in the past but now a days it became very serious in all the areas wherever cultivation occurs in the elephant habitats. These habitats continue to be exposed to further fragmentation leading to an increase in the level of conflict between animals and man. Also the elephants, being larger in size and range over large areas to meet their requirement of food, water and shelter have also an increased probability of crop raiding and manslaughter in human settlement. The reason for this trend could possibly be due to the growing human population with increasing demand for land for agriculture and development thereby reducing its present natural habitat into smaller islands (Balasubramanian *et al.,* 1995).

Crop raiding by elephants has been reported from almost all elephant ranges in Asia as well as Africa, where elephants survive in fragmented and disturbed habitats. Numerous studies have reported crop depredation, livestock death, injuries and damage to properties due to elephants in Africa (Thouless, 1994; Barnes, *et al.*, 1995; Kiiru, 1995; Ngure, 1995; Tchamba, 1995). In Asia, studies have been limited to identifying the problem of crop raiding by elephants (McKay, 1973; Olivier, 1978a; Fernando, 1990; Desai and Krishnamurthy, 1992) or looked at the economic implications and suggested management strategies (Mishra, 1971; Allaway, 1979; Blair *et al.*, 1979; Caufield, 1984; Sukumar, 1985; Santiapillai and Ramono, 1993; Santiapillai and Silva, 1994; Balasubramanian *et al.*, 1995; Datye and Bhagwat, 1995b). Crop raiding and man-wildlife conflict has been documented in Kerala by Veeramani and Jayson (1995) and Veeramani *et al.* (1996). Gopinathan (1990a) has mentioned the crop raiding problem in Wayanad Wildlife Sanctuary.

Information on man-elephant conflict and effectiveness of different kinds of protection methods to deter elephants has been well documented in Africa (Thouless, 1994 & 1995b; Hoare, 1995; Thouless and Sakwa, 1995; Osbom and Rasmussen, 1995; Osbom, 1996). In Asia, studies by Seidensticker (1984), Kumar and Desai (1992), Sukumar (1985, 1988 & 1990), Bist (1996), Santiapillai (1996) and Sale (1997) suggested control measures to overcome the problem of crop raiding.

Man-slaughter and circumstance of the encounters were discussed in detail by Sukumar (1989) in Southern Eastern Ghats. A report by Datye and Bhagawat (1995) indicate a total of 134 human deaths caused by elephants in South Bihar and 74 deaths in South West Bengal between 1980 and 1991. About 500 people have been killed by the elephants in Assam in the past decade and during 1993, one makhna killed about 50 people in Assam (Hussain, 1993). This kind of man-elephant interaction often led to public outcry against the elephant conservation.

This chapter deals with the extent of crop damage especially by elephants, and effectiveness of protection methods in Wayanad Wildlife Sanctuary.

6.2 Methods

Data on crop raiding were collected over a period of two years (between January 1994 and December 1995).

6.2.1 Settlement selection for studying crop raiding

The sanctuary has 80 settlements (Fig. 1). These are of different legal status such as revenue, leased, patta and forest lands. The settlements are located within the forests and the surrounding vegetation types vary according to the location. A number of protection methods are employed in these settlements. The details of the settlements are given in Chapter 2.

Nine settlements were selected in Southern Ranges of Wayanad Wildlife Sanctuary based on the vegetation types in the surrounding area, location of the settlement and types of protection methods employed. These settlements were distributed in three Ranges viz., Kurichiat, Sulthan's Battery and Muthanga (Fig.4.) Details of the settlements selected for intensive study are given in Table 83.

6.2.2 Protection methods

Crop protection methods employed in the field during raiding were recorded and classified as follows:

A. Ordinary Fencing and Guarding (OF+GU): The fields are properly fenced using different materials like bamboo, barbed Wires, thorns, hedgerows, etc. This type of protection includes guarding at night by people from machans (platforms on trees) or guard shed on ground with elephant proof trenches around. Fire and sound making devices like tins, drums, etc. are also used.

B. Special Protection (SP): This is similar to the ordinary fencing but used along with several other elephant scaring devices. Trip wires with explosive crackers are the major special scaring devices. This method is employed only during the reproductive phase of paddy in the Southern Range. Guarding at night is avoided.

C. Electric Fencing (EF): Electric fences were installed by the Forest Department around some of the settlements in the study area using energizers which generate very short pulses of high voltage current and the animal coming in contact with such wires get a strong shock but are not harmed. Some of these were maintained properly by the people themselves and some were not maintained, hence the effect varied.

Table 83. Status of the selected settlements with respect to its location, surrounding habitat and protection methods employed each year

Name of the settlements	Location	Surrounding habitat	Protection method during 1994	1995
1. Alathur	ENC	MD+TP	OF+GU	EF
2. Arakungi	ENC	MD	OF+GU	OF+GU
3. Chetty Alathur	ENC	MD	OF+GU	OF+GU
4. Kallumukku	PER	TP	EF	EF
5. Kumuzhi	ENC	EP+TP	EF	EF *
6. Kuppady	PER	SE	EF	EF **
7. Kurichiat	ENC	MD	EF	EF
8. Nulpuzha	ENC	MD+TP	OF+GU	EF
9. Ponkuzhi	ENC	EP	OF+GU	OF+GU

* Electric fencing was not functioning; ** The height of the fence was increased ENC = Enclosure; PER = Periphery; MD = Moist Deciduous; TP = Teak Plantation; EP = Eucalyptus Plantation; SE = Semi Evergreen; OF+GU = Ordinary. Fencing and Guarding; EF = Electric Fencing

6.2.3 Status of land in the selected settlements

Legal status and extent of wet and dry lands in selected settlements are given in Table 84. About 14.9 % of the total land in the selected settlement are leased areas and the rest (85.1 %) are public land under the control of the revenue department (referred as revenue land). Except Kumuzhi, Chetty Alathur and Kuppady, all the selected settlements have a sizable portion of leased land under cultivation.

Table 84. Legal status of the land in the selected settlements for crop raiding

Settlements	Total land ha	Lease (ha) Wet	Lease (ha) Dry	Revenue (ha) Wet	Revenue (ha) Dry
1. Alathur	59.8489	0.8502	0.7287	41.3335	16.9365
2. Arakunji	14.9798	12.1053	2.8745	Nil	Nil
3. Chetty Alathur	61.0041	Nil	Nil	29.6901	31.3140
4. Kallumukku	50.2024	5.0607	0.4858	37.5129	7.1430
5. Kumuzhi	54.8053	Nil	Nil	45.2878	9.5175
6. Kuppady	30.0000	Nil	Nil	15.0000	15.0000
7. Kurichiat	26.8948	23.1134	3.7814	Nil	Nil
8. Nulpuzha	140.4416	9.1174	1.2550	71.2025	58.8667
9. Ponkuzhi	15.9126	6.4777	1.8219	5.1250	2.4880
Total	454.0895	56.7247	10.9473	245.1518	141.2657

6.2.4 Cultivation in selected settlements

Total area and the percentage area under different crops in each of the selected settlements are given in Table 85. About 66.5% of the total land in the selected settlements were under seasonal crops and the remaining under perennial crops (referred as wet and dry lands respectively).

Seasonal crops:

The study area had the maximum rainfall during southwest monsoon and planting of seasonal crops began at the onset of the monsoon in May and harvest was completed by November or December. Among the seasonal crops, paddy the staple food crop of the people was gown to a larger extent (88%) in all the selected settlements. Paddy was sown during the middle of May or first week of June depending on the pre-monsoon rains and the onset of monsoon. By mid or late September, the paddy comes to flowering stage and the harvest was between November and December, and sometimes it may be extended to first and second week of January, depending upon the planting season.

The seasonal crops such as ginger and plantains constituted about 6.5% and 4.5% respectively. These were cultivated in the wet land. Tapioca was also cultivated to a lesser extent (1%) in the study area.

Table 85. Total area under different crops cultivated in the selected settlements (ha.)

	Settlements									
Name of the crop	Ponkuzhi	Kumuzhi	Alathur	Arakungi	Kallum ukku	Chetty Alathur	Nulpuzha	Kuppady	Kuri-chiat	Total
WET CROPS (Seasonal)										
Paddy	8.5210	42.009 0	39.3236	10.4153	35.0806	25.9670	69.1715	15.0000	20.0871	265.5751
	(73.4)	(92.8)	(93.2)	(86.0)	(82.4)	(87.5)	(86.1)	(100.0)	(86.9)	(88.0)
Ginger	2.4992	2.6176	2.8601	1.4552	2.1670	2.0516	3.5742	Nil	2.4474	19.6723
	(21.5)	(5.8)	(6.8)	(12.0)	(5.1)	(6.9)	(4.4)	(0)	(10.6)	(6.5)
Plantain	Nil	Nil	Nil	Nil	5.3260	1.3242	6.5380	Nil	10.4617	13.6499
	(0)	(0)	(0)	(0)	(12.5)	(4.5)	(8.1)	(0)	(2.0)	(4.5)
Tapioca	0.5824	0.6612	Nil	0.2348	Nil	0.3474	1.0361	Nil	0.1171	2.9790
	(5.0)	(1.5)	(0)	(1.9)	(0)	(1.2)	(1.3)	(0)	(0.5)	(1.0)
Subtotal	11.6026	45.2878	42.1837	12.1053	42.5736	29.6902	80.3198	15.0000	23.1133	301.8763
	(72.9)	(82.6)	(70.5)	(80.8)	(84.8)	(48.7)	(57.2)	(50.0)	85.9	(66.5)
DRY CROPS (Perennial)										
Coffee	Nil	0.2655	0.4293	Nil	Nil	2.5208	2.1403	Nil	Nil	5.3559
	(0)	(2.8)	(2.4)	(0)	(0)	(8.1)	(3.6)	(0)	(0)	(3.5)
Arecanut	Nil	Nil	Nil	Nil	Nil	0.6952	Nil	Nil	Nil	0.6952
	(0)	(0)	(0)	(0)	(0)	(2.2)	(0)	(0)	(0)	(0.5)
Pepper	Nil	0.3369	0.9168	Nil	Nil	1.2933	2.9159	Nil	Nil	5.4629
	(0)	(3.5)	(5.2)	(0)	(0)	(4.1)	(4.8)	(0)	(0)	(3.6)
Mixed crops	4.3099	8.9150	16.3191	2.8745	7.6288	26.8048	55.0655	15.0000	3.7814	140.6990
	(100.0)	(93.7)	(92.4)	(100.0)	(15.2)	(85.6)	(91.6)	(100.0)	(100.0)	(92.4)
Sub total	4.3099	9.5174	17.6652	2.8745	7.6288	31.3141	60.1217	15.0000	3.7814	152.213
	(27.1)	(17.4)	(29.5)	(19.2)	(15.2)	(51.3)	(42.8)	(50.0)	(14.1)	(33.5)
Total	15.9125	54.8052	59.8489	14.9798	50.2024	61.0043	140.4415	30.0000	26.8947	454.0893

Figures in parenthesis denotes percentages

Perennial crops:

Dry land constituted about 33.5% of the total in the selected settlements. The cash crops such as coffee and pepper were the dry perennial crops cultivated. Along with coffee and pepper, coconut and arecanut (referred as mixed crops) were also cultivated by farmers.

Coffee, pepper, coconut and arecanut were cultivated in the dry land mostly in mixed cultivation (92.4%). Mono-cultivation of coffee, pepper and arecanut constituted 3.5%, 3.6% and 0.5% respectively in the selected settlements.

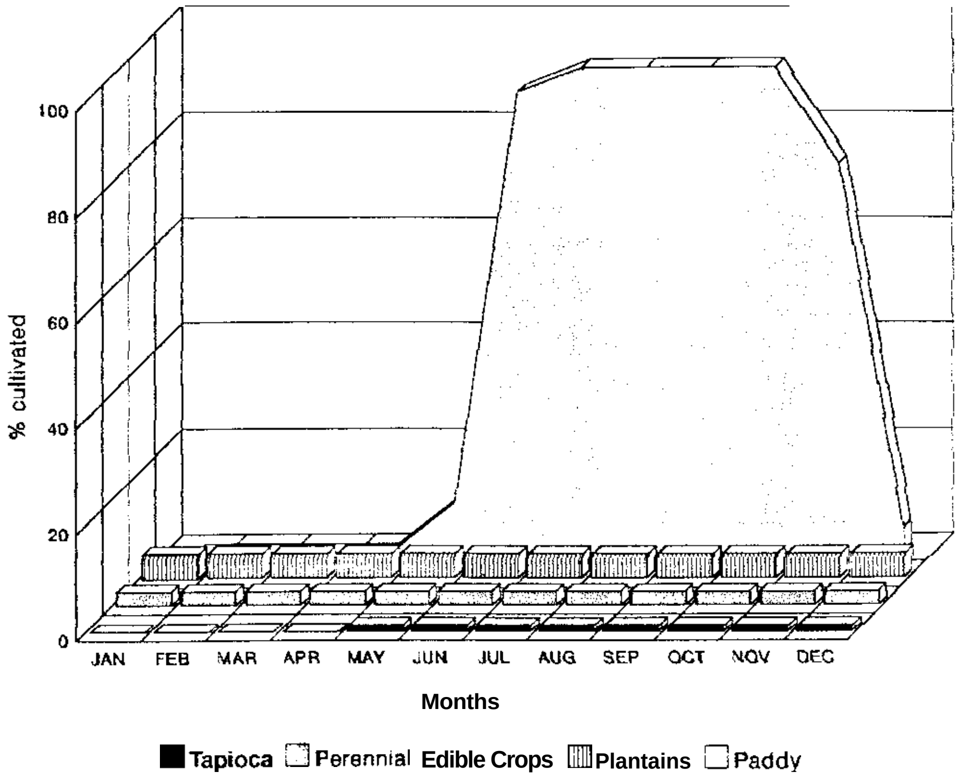
Monthly percentage of the total land under different edible crops in Southern Range is given in Figure 24. Tapioca was planted during May and harvested during December. Plantain and other perennial edible crops constituted 4.7% and 2.6% of the total respectively. These were available evenly in all the months round the year. Paddy constituted a larger proportion of the edible crops (>90%). Availability of paddy during May was only below 10% and increased to 87% in June. During the harvest season, the availability decreased and below 5% was available in December.

6.2.5 Crop damage

The selected settlements were visited twice in a month and visually checked for signs of damage. Information were collected on crops damaged, their pheno-phase and height. The total area damaged (in m^2, based on the length and breadth of the damaged area) were also recorded.

Percentage of damage due to feeding and trampling was recorded separately by laying a number of $1m^2$ plots for paddy and ginger, and by actual count for other crops. Plots of same size were laid in undamaged areas also for comparison and calculation of the quantum of damage. Trampling was considered as the area damaged by elephant while moving through the crop field without feeding or just walking across the field in the course of their movement

Fig. 24.Monthly percentage of the total land under different crops in Southern Ranges



between different feeding points or while being driven away by the people from the crop field before feeding. The area trampled by elephants while feeding was also considered as damage due to feeding if there was any sign of feeding.

Phenology of crop, especially of paddy were noted as vegetative (before flowering) and reproductive (in flower/fruits/grains).

Secondary data were also collected from the villagers during each visit for information on date of raiding, time, animal species and number of individuals. Information on the sex of the animal, identification (if possible) and number of individuals were also collected during the visit. If tracks of calves or juveniles were found in the field, the raiding was considered as that of a size. The fresh tracks were followed and the elephants observed for information on the sex, age group, number and identification marks.

The crop raiding and spacing pattern of habitual crop raiders (only males) were studied during 1995. The identified bulls were monitored regularly and collected information on the location, frequency of crop raiding in each settlement distance between the habitual crop raiders. The nearby settlements were also visited subsequently for collecting information on the damages caused by these.

The 'focal animal sampling' method suggested by Altmann (1974) was used to collect information on the activity pattern of male habitual crop raiders in the surrounding area of the study settlements.. Data were collected from the identified bulls, (One and half tusker (OHT) and Left finger torn makhna (LFM)). Observations were initiated on sighting the animals during the fieldwork. A total of 32 hours of observations were made. The data were pooled for the analyses of the activity time budget and diurnal activity pattern.

6.2.6 Economic loss

In the case of plantation crops such as coffee, pepper, plantain, tapioca, coconut and arecanut the actual number of plants damaged and their age were collected based on the method suggested by Sukumar (1985). The number of years of yield lost by the farmer is the same as the age at which the tree was damaged as he has to plant another sapling in its place and nurture it to the same stage. Hence, the age of the plant was multiplied with the expected total annual yield of the damaged plant to calculate the economic loss. This was added to the establishment cost such as planting and other maintenance charges.

The extent of damage to paddy and ginger were calculated using the total area damaged by males and herds. These were converted into per unit area (ha.). The crop lost per acre of damage was calculated in terms of potential expected yield.

The potential yield was arrived at from the yield obtained From the crops left undamaged in the same field or from the surrounding field.

6.3 Analysis

6.3.1 Quantity Damaged

The actual quantity of paddy damaged/day/elephant was calculated as suggested by Sukumar (1985) as shown below:

$$q_i = \frac{a_d \times Y}{e}$$

Where a_d = areas of the field damaged

Y = expected potential yield in terms of quintal

e = number of elephant raiding crops

For each settlement, the quantity of crops damaged was calculated using the following formula.

$$E \times F \times Q$$

Where E = mean raiding group size of elephants

F = frequency of raiding

Q = weighted mean quantity damaged / day / elephant in a village

6.3.2 Economic Loss

The market value of the crops collected from Government Agency or/and Wholesale Dealers for both the years did not differ significantly between years. Hence, an average was taken for the years and tabulated for the purpose of calculation (Table 86).

The cost for seeds, ploughing, fertilizers, pesticides, fencing, guarding at night, labour, irrigation etc. for paddy and ginger cultivation alone were computed and was about 20 % of the total yield. This was added to the total loss.

Table 86. Density, Yield and Cost of crops cultivated in the study area

Crop	Density/ha.	Average Yield/ha.	Cost (Rs.)
Paddy	523640	39.5 q.	500/q.
Ginger	79040	395.2 q.	1000/q.
Plantains	741	Rs.40/plant	29640/ha.
Tapioca	2470	123.5 q.	200/q.
Coconut	124	6200.0 Nos.	4/ No.
Coffee (Alone)	865	18.5 q.	4000/q.
Coffee (Mixed)	494	9.9 q.	4000/q.
Pepper (Alone)	988	24.7 q.	7000/q.
Pepper (Mixed)	618	14.8 q.	7000/q.
Arecanut	1235	Rs.30/plant	37050/ha.

63.3 Manslaughter by elephants in the study area

Information on manslaughter by elephants in the study area was collected with the details such as name, sex and age of the persons killed, the place of encounter, the activity of the victim and those accompanying, circumstances of the encounter, sex of the elephant and the nature of injury.

All the analyses were done using SPSS for Windows Release 6.0 (Anonymous, 1987).

6.4 Results

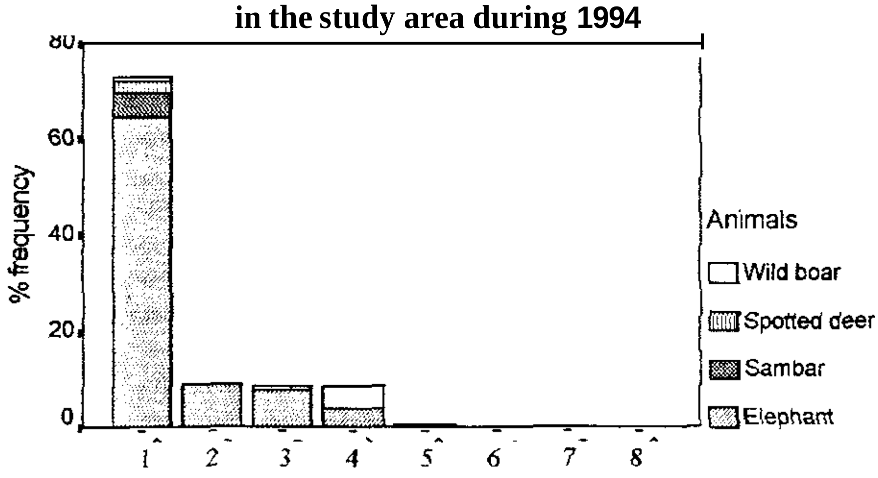
6.4.1 Frequency of crop raiding by different wild animals

Elephant, sambar, spotted deer and wild boar in the Southern Ranges mostly raided the cultivated crops. There was a highly significant differences in the frequency of raiding between the animals in both the years ($\chi 2$ =112.43; *df*= 3; P < 0.05). Elephants were responsible for most of the raids in both 1994 and 1995 with slight annual variation (Figs. 25 and 26). Among the crops, paddy was the most vulnerable to raiding (72.88%). Of these, elephants were responsible for 64.34% and were mostly by feeding and trampling. The raid by sambar and chital were 5.43%

and 2.33% respectively and the damages to paddy during the raid were due to feeding alone. Paddy was followed by ginger (9.3%) which was damaged entirely by elephants, coffee (8.52%) tapioca (8.53%) and plantains (0.78%) were the other crops. Wild boar raided paddy (0.78% of the total on paddy), coffee (0.78%) and tapioca (4.65%) and the damage were by feeding and trampling. There was no damage to arecanut, coconut and pepper in the selected settlements during 1994.

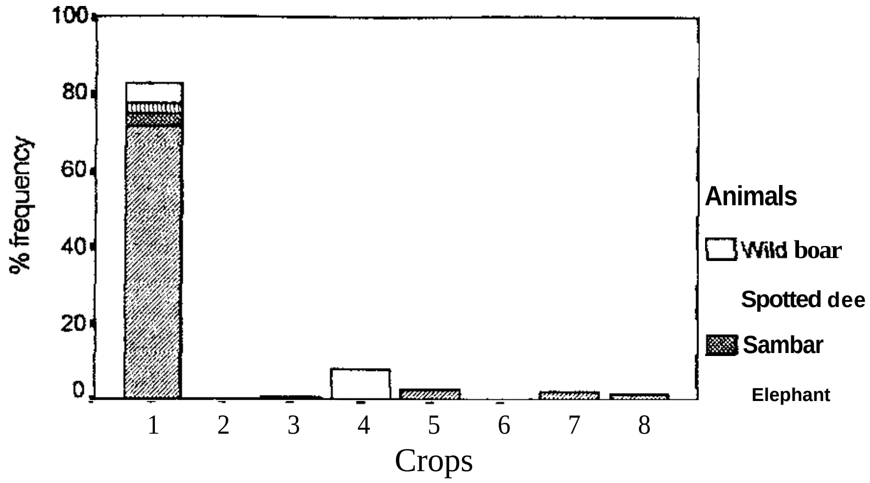
During the year 1995, the frequency of raiding on paddy was comparatively high (82.9%) and the damage due to elephants was higher (71.76%) (Fig. 26). The percentage of damage by elephants on plantains (2.78%), coconut (2.32%) and arecanut (0.46%) were also higher. The damages during these raids were due to both feeding and trampling. Ginger (0.46%) and coffee (0.93%) were also raided by elephants and mostly trampled. Sambar and spotted deer raided 3.91% and 2.79% respectively on paddy. Ginger, coffee,pepper, plantains, arecanut and coconut were raided and damaged only by elephants. Tapioca was raided and damaged entirely by wild boar.

Fig. 25. Percent age frequency of crop raid by different wild animals in the study area during 1994



Crops
1-Paddy, 2-Ginger, 3-Coffee, 4-Tapioca, 5-Plantain, 6-Arecanut 7-Coconut 8-Pepper

Fig. 26. Percent age frequency of crop raid by different wild animals in the study area during 1995



1-Paddy, 2-Ginger, 3-Coffee. 4-Tapioca, 5-Plantain, 6-Arecanut, 7-Coconut, 8-Pepper

6.4.2 Habitual crop raiders

Five habitual crop raiders were identified from direct observations in 1995. The total number of crop raiding by each habitual crop raider in the selected settlements is shown in Table 87.

Table 87. Total number of crop raiding by the habitual crop raiders in the selected settlements during 1995

Name of the Settlement	CTM	LFM	OHT	CK	TT
Alathur	1	0	0	1	4
Arakunji	0	0	10	0	9
Chetty Alathur	0	0	0	0	0
Kallumukku	0	0	6	0	0
Kumuzhi	0	0	0	9	29
Kurichiat	0	0	0	0	0
Nulpuzha	0	0	0	1	0
Ponkuzhi	11	25	0	4	0
Total	12	25	16	15	42

CTM = Cut Tail Makhna; CK = Chulli Komban; OHT = One and Half Tusker;
TT = Twisted Tusker, LFM = Left Ear Finger Torn Makhna

Among the identified animals, TT raided more times (42 nights) followed by LFM (25 nights) in the selected settlements. The OHT was observed raiding crops only for 16 nights in the selected settlements. But OHT was reported to raid several times (73 nights) in the other settlements. The CTM and CK were observed to raid crops for 12 and 15 nights respectively in the study area.

6.4.2.1 Spacing pattern in the crop raiding bulls

Table 88 shows the monthly frequency of crop raiding by the habitual crop raiders in different settlement in the study area. The pattern that was observed in the crop raiding by these identified males (Fig 27). The CTM visited the study area during last week of August and remained up to second week of September. It was confined to the areas between Alathur and Ponkuzhi. In Alathur, it raided only once when the power fence was not functioning properly. On repairing the fence, the animal moved towards Ponkuzhi and raided continuously for 11 days. When CTM was operating in the area, no other male was found to be raiding crops in the above two settlements. CK was observed to raid crop in July in Nulpuzha and went out of sanctuary for about one and half months. Then it came back at the end of September and operated in the areas surrounding Alathur and Ponkuzhi raiding crops. LFM spent continuously 25 days in Ponkuzhi areas in October and November and raided crops literally every night. The OHT was operating between Arakunji and Kallumukku area during the entire period of the crop season while TT was operating in Arakunji, Alathur and Kumuzhi areas. However, there was the avoidance between OHT and TT thus not raiding the same area together. The animals, which raided crops in Chetty Alathur, Kallumukku, Kurichiat and Nulpuzha could not be identified as the tracks were not clear or mingled with the tracks of other elephants.

6.4.2.2 Time budget and activity pattern of habitual crop raiders

The time spent on various activities by male habitual crop raiders is given in Figure 28.They spent more time for resting (66.8%) followed by feeding (17.6%) and moving (12.5). The time devoted for the other activities (comfort behaviour) were negligible.

Fig. 27. Schematic representation of spacing pattern of the identified habitual crop rading males in selected settlements

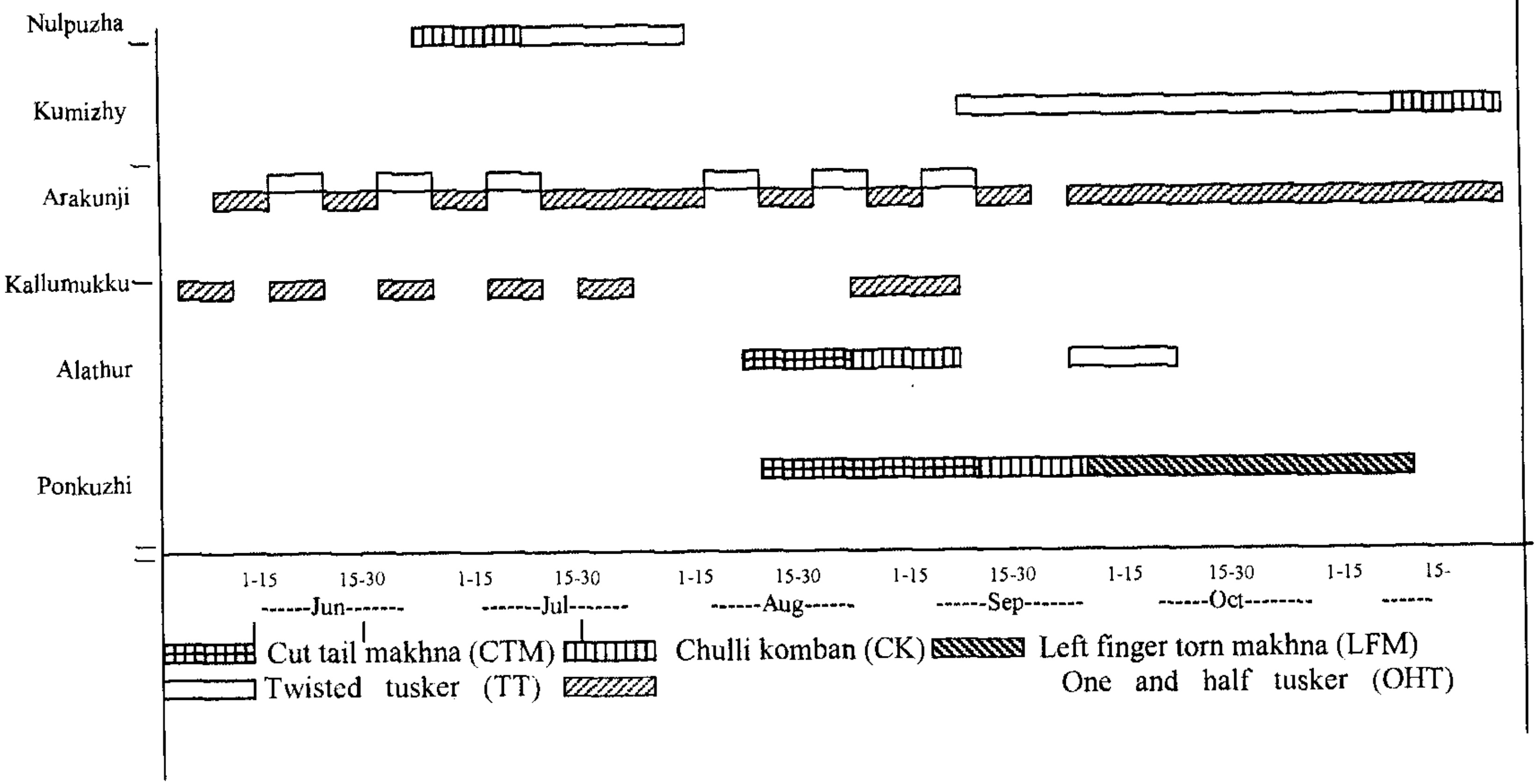
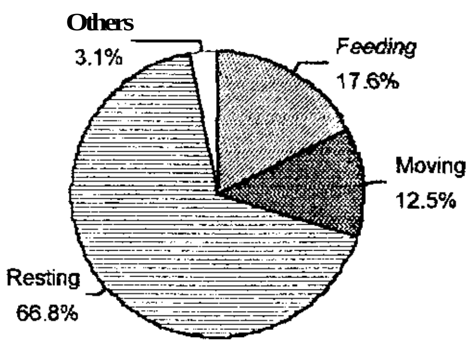


Table 88. Monthlyraiding pattern of habitual crop raiders in different settlementsin the study area during 1995

Months	Habitual crop raiders											
	CTM		CK				LFM	OHT		TT		
Settlements	AL	PN	AL	KU	NU	PN	PN	AR	KA	AL	AR	KU
June	-	-	-	-	-	-	-	1	2	-	2	-
July	-	-	-	-	1	-	-	1	2	-	3	-
August	1	4	-	-	-	-	-	1	-	-	2	-
September	-	7	1	-	-	4	-	2	2	-	2	8
October	-	-	-	-	-	-	6	3	-	4	-	7
November	-	-	-	9	-	-	19	2	-	-	-	14
Total	1	11	1	9	1	4	25	10	6	4	9	29

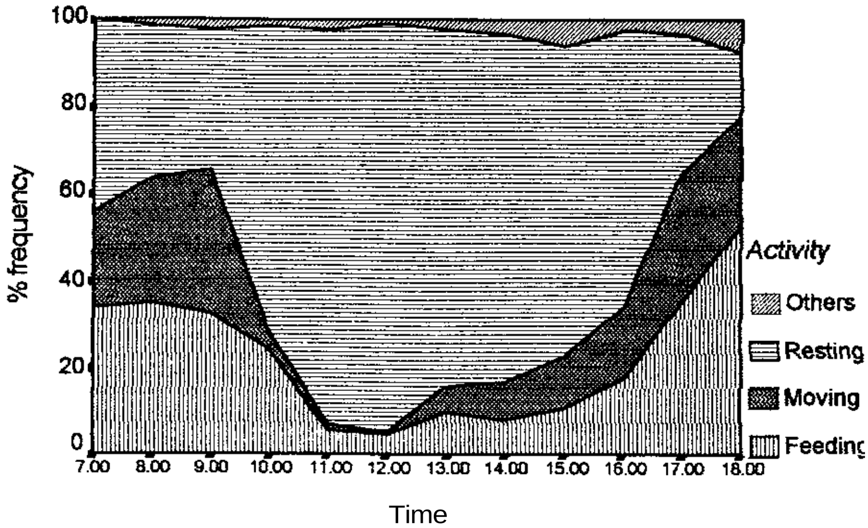
CTM = Cut Tail Makhna; CK = Chulli Komban; OHT = One and Half Tusker; TT = Twisted Tusker; LFM = LeftEar Finger Tom Makhna; AL = Alathur; AR = Arakunji; CA = Chetty Alathur; KA = Kallumukku; KU = Kumuzhi; KR = Kurichiat; NU = Nulpuzha; PN = Ponkuzhi

Fig. 28. Time budget of habitual crop raiding male elephants



Results of analysis of diurnal activity pattern of male habitual crop raiders are illustrated in Figure 29. It indicates a bimodal diurnal feeding pattern with peaks in the morning and evening hours. Feeding was interrupted mainly while moving and resting. Almost an equal time was spent on feeding, moving and resting during the period between 07.00 and 09.00 hours. A steep increase in time spent for resting and decrease in feeding and moving between 09.00 and 11.00 h. were observed. There was a sharp rise in feeding and moving from 15.00 h. onwards. Time spent for resting was considerably reduced in the evening hours.

Fig. 29. Diurnal activity pattern of habitual crop raiding male elephants

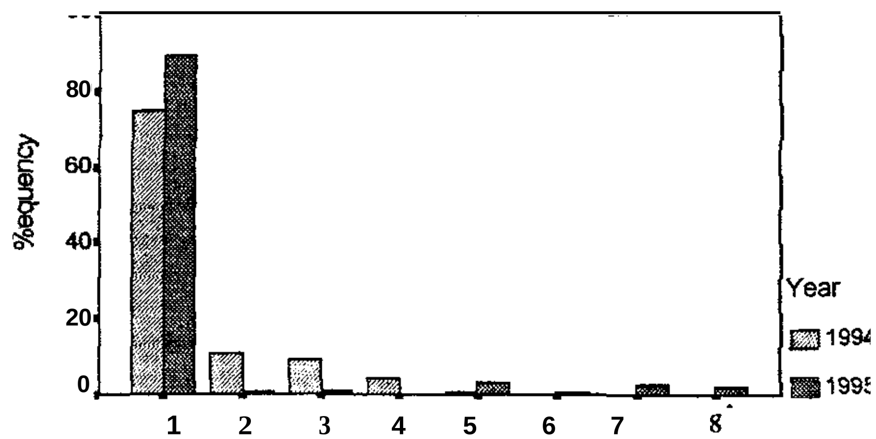


6.4.3 Frequency of crop raiding and feeding pattern by elephants

During 1994, paddy formed about 74.77% of the crops damaged by elephants and was significantly higher compared to other crops ($\chi 2$ = 68.41; *df*= 4; P < 0.001) (Fig. 30). Elephants showed a preference for certain parts of the plant. The entire plant was plucked and consumed during vegetative phase. During the reproductive stage of the crop, the terminal portion bearing inflorescence alone were chewed off and consumed, and the basal part was discarded. The frequency of raiding on ginger, coffee and tapioca constituted about 10.81%, 9.01% and 4.5% respectively. The damages in all these were due to trampling in the fields when they move between the sites of edible and favourable crops or while chased away by people. There was no raid on arecanut, coconut and pepper during 1994. Plantains constituted only less than 1% of the total raided by elephants.

Paddy sustained substantial damage from elephants during the year 1995 with 89.08% of the raids. The frequency of raid on other crops such as ginger, coffee and pepper were negligible and constituted about 0.57%, 1.15% and 2.3% respectively. Damage to these crops was entirely due to trampling. On an average, the frequency of raid on plantains was 3.45%. The raid on arecanut and coconut were 0.57 % and 2.87 % respectively. Plantains were broken and split to feed on the central pith. The central rachis of coconut and arecanut were pulled out and fed by elephants.

Fig. 30. Percentage frequency of crop raiding by elephants in different years in the study area



Crops

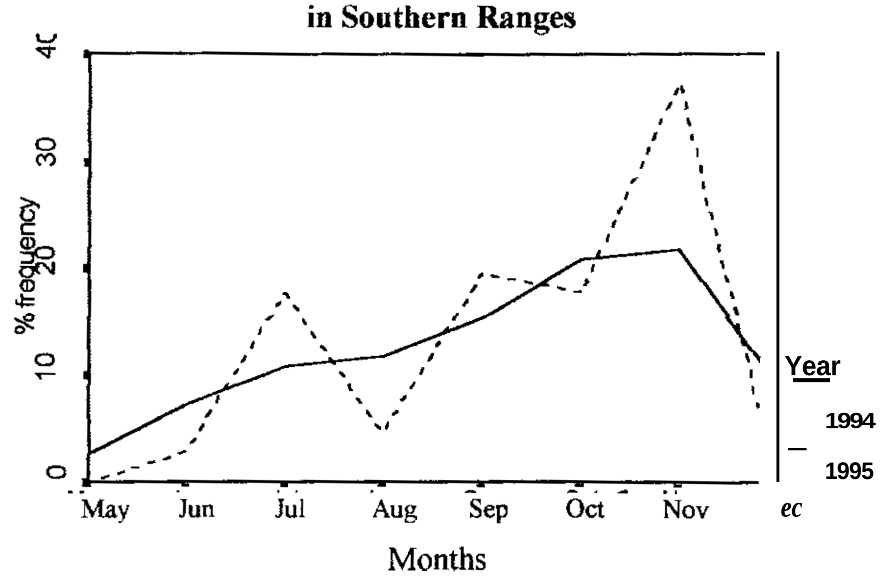
1-Paddy, 2-Ginger, 3-Coffee, 4-Tapioca, 5-Plantain, 6-Arecanut, 7-Coconut, 8-Pepper

6.4.4 Monthly frequency and area damaged by elephants

The monthly frequency of crop raiding by elephants during 1994 and 1995 showed a distinct pattern (Fig. 31) and differed significantly between the months in both the years ($\chi 2=36.45$; df=7; $P< 0.05$). Crop raiding frequency was almost nil between January and May and showed an increasing trend towards the end of the year. Crop raiding was observed from May in 1994 and from June in 1995. There was a gradual increase in the frequency of raids from May to November and a decline in December during 1994. During 1995, a steep increase in July, September and November was observed.

About 5.96% and 5.66% of the total area under paddy was damaged during 1994 and 1995 respectively. Of these, males damaged more (3.4%) than herds (2.6%) in 1994. During 1995, the percentage of damage was 3.2% and 2.04% by males and herds respectively. The males raided 78 times and damaged a total area of 9.04 ha. in 1994. These were 32 times and 6.8 ha by the herds. The percentage frequency of raiding by both the males and herds and percentage area damaged is given in Table 89.

Fig. 31. .Monthly percentage frequency of crop raiding by elephants in Southern Ranges



In 1995, males raided 135 times compared to 39 times by the herds. The area damaged was 9.62 ha. and 5.42 ha. by males and herds respectively. The details are given in Table 90.

However, the average damage on paddy during 1994 was calculated as 0.12 ha/raid by males and 0.21 ha/raid by herds. Taking the mean herd size of 12.56 during raiding into account, it was calculated as 0.02 ha. per individual.

Table 89. Percentage frequency of crop raiding and area of paddy damaged by males and herds during 1994

Months	Males		Herds	
	% Frequency	% area damaged	% Frequency	% area damaged
May	2.56	1.96	3.13	3.01
Jun.	5.13	4.1	12.50	8.23
Jul.	12.82	9.0	6.25	5.22
Aug.	12.82	11.2	9.38	12.64
Sep.	14.10	15.21	18.75	16.21
Oct	20.51	22.21	21.88	18.26
Nov	21.79	27.65	21.88	25.62
Dec	10.26	8.67	6.25	10.81

Table 90. Percentage frequency of crop raiding and area of paddy damaged by males and herds during 1995

Months	Males		Herds	
	% Frequency	% area damaged	% Frequency	% area damaged
Jun.	3.70	2.15	0.00	0.00
Jul.	10.37	9.56	43.59	35.22
Aug.	5.93	6.11	0.00	0.00
Sep.	23.70	24.03	5.13	3.32
Oct	16.30	12.95	3.08	30.21
Nov	40.00	45.20	28.21	31.25

The males raiding the crops were observed to be solitary during raiding throughout the study period except on two occasions when the Twisted Tusker (an identified sub adult bull) joined with the Chullikkomban, another identified bull, to raid crop in Kumuzhy.

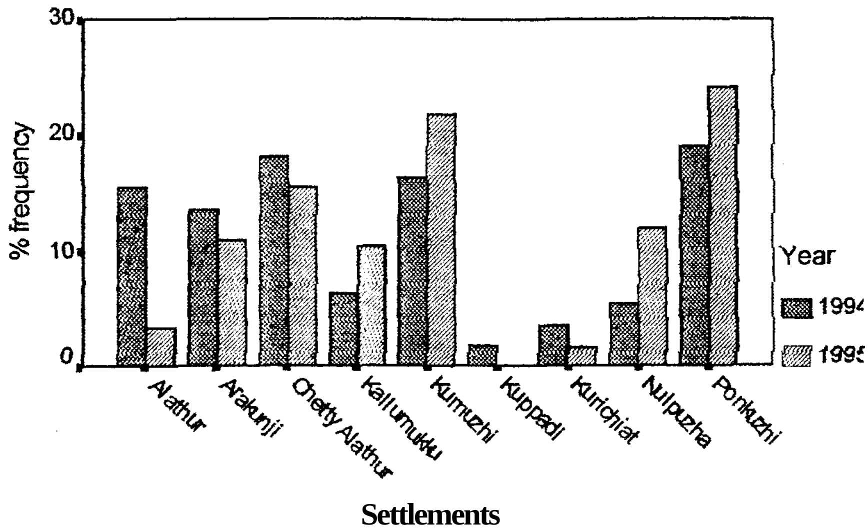
The mean herd size of elephants raiding crops was 7.25. A statistical test (G test) between the mean herd size of elephants involved in crop raiding and of those observed in forest did not show any significant difference ($\chi 2 = 0.91$; $df = 1$; $P < 0.05$).

6.4.5 Frequency of raiding in tbe selected settlements

Among the settlements selected for the study, the frequency of raids were significantly higher in Kallumukku, Kumuzhi, Nulpuzha and Ponkuzhi during 1995 than the previous year (Fig. 32) ($\chi 2 = 109.15$; $df = 8$; $P < 0.001$). In the other settlements, the frequency of raids decreased considerably during 1995.

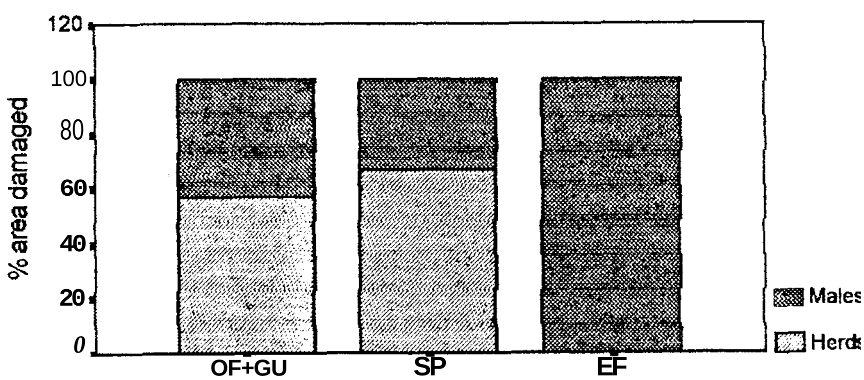
The percentage damage by males and herds in different type of protection methods in the study area is given in Figure 33. About 60% of the damages in the ordinary fenced and guarded fields were by herds. In the specially protected fields, the damage due to herds were higher (>65%). The damages in the electric fenced field were entirely due to males.

Fig. 32. Percentage frequency of crop raiding by elephants in selected settlements



Both males and herds damaged more or less equally during the vegetative phase of paddy under the ordinary fenced and guarded fields (Fig. 34). Only males were responsible for the damages in electric fenced fields during the vegetative phase.

Fig. 33. Percentage damage by males and herds in different types of protection methods



Type of protection methods

OF+GU=Ordinary fencing+Guarding

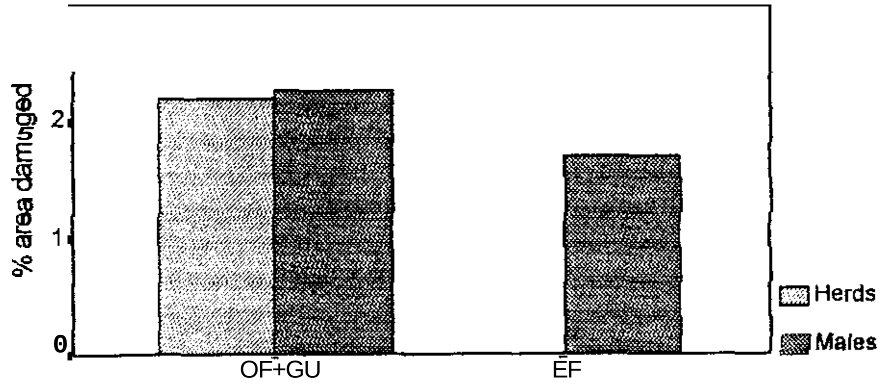
SP-Special protection, EF-Electric Fencing

The percentage area damaged by herds were considerably more than males in the ordinary fenced and guarded fields during the reproductive phase of paddy (Fig. 35). The areas damaged by males in ordinary fenced and guarded fields were almost equal to those in specially protected fields during reproductive phase. The damage in the electric fenced field was considerably low. The total area under each protection was calculated. The percentage damage (of the total) under each protection method was then worked out.

6.4.6 Raids and attempts by males and herds

Figure 36 shows the percentage success of males and herds in crop raiding in different types of protection methods in the study area. The difference between the males and herds in the success was highly significant during 1994 ($\chi 2 = 19.24$; $df = 5$; $P < 0.001$) and 1995 ($\chi 2 = 17.48$; $df = 5$; $P < 0.001$). The males and herds were successful in almost all their attempt in the ordinary fenced and guarded fields (96.1% and 92.9% respectively). In the specially protected fields, the number of success by males (81.8%) and herds (82.35%) were considerably less than the ordinary fenced and guarded fields. In the electric fenced field, the percentage success of males was 63.63% and the herds attempted but did not succeed.

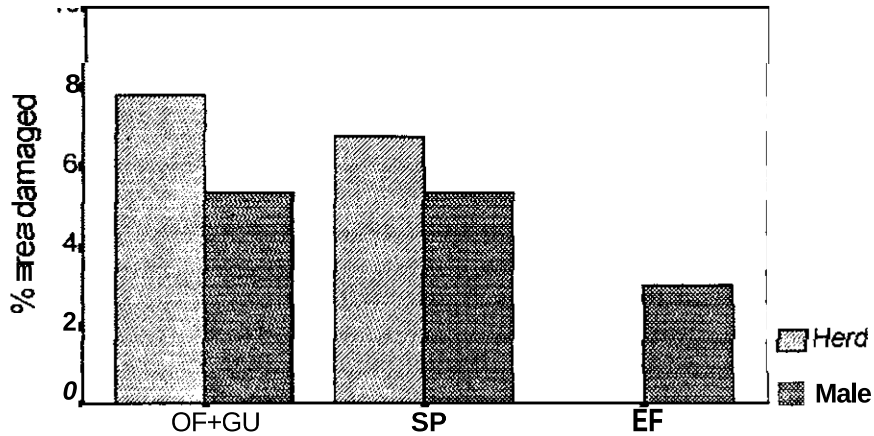
Fig. 34. Percentage area damaged by elephants in different kinds of protection methods during vegetative phase of paddy



Type of protection methods

OF+GU=Ordinary fencing+Guarding,EF-Electric Fencing

Fig. 35. Percentage area damaged by elephants in different kinds of protection methods during reproductive phase of paddy

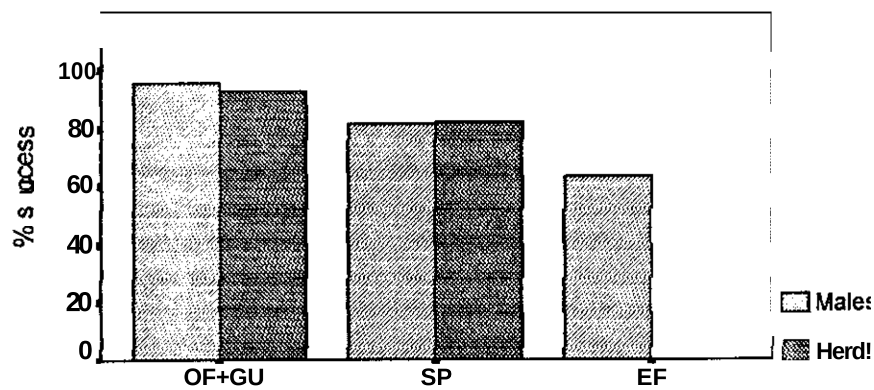


Type of protection methods

OF-GU=Ordinary fencing+Guarding

SP-Special protection, EF-Electric Fencing

Fig. 36. Percentage success in the crop raiding attempts by males and herds in different types of protection methods



Type of protection methods

OF+GU=Ordinary fencing and Guarding

SP=Special protection method; EF=Electric fencing

6.4.7 Kind of damage

The damage to paddy due to trampling was higher in the early period. The damage due to feeding increased with the growth of paddy (Fig. 37). Though only males damaged in May, there was not much difference between the sexes in the other months except in December.

6.4.8 Quantity of different crops damaged by elephants

The total area of paddy damaged by elephants during 1994 in the selected settlements was 9.04 ha and 6.8 ha. by males and herds respectively (Table 91). In the case of ginger, this was 0.64 ha by males and 0.89 ha. by herds. The total damage of 27 coffee plants was by males. Damage of plantains by males was higher (51 Nos.) than herds (8 Nos.). But in the case of tapioca, herds destroyed 41 plants compared to 29 by males.

There were no significant annual differences in the total area damaged in paddy and ginger by males and herds in the study area.

During 1995, the damage to paddy by both males (9.62 ha.) and herds (5.42 ha.) were almost equal to the previous year (Table 92) though there was a reduction in the area damaged by herd. There was a decrease in the total area damaged in ginger field by both males (0.27 ha.) and herds (0.65 ha.). In addition to Coffee and Plantains, Coconut, Arecanut and Pepper were also damaged during 1995. Damage on Tapioca was not observed

Fig. 37. Percentage damage on paddy due to feeding by males and herds

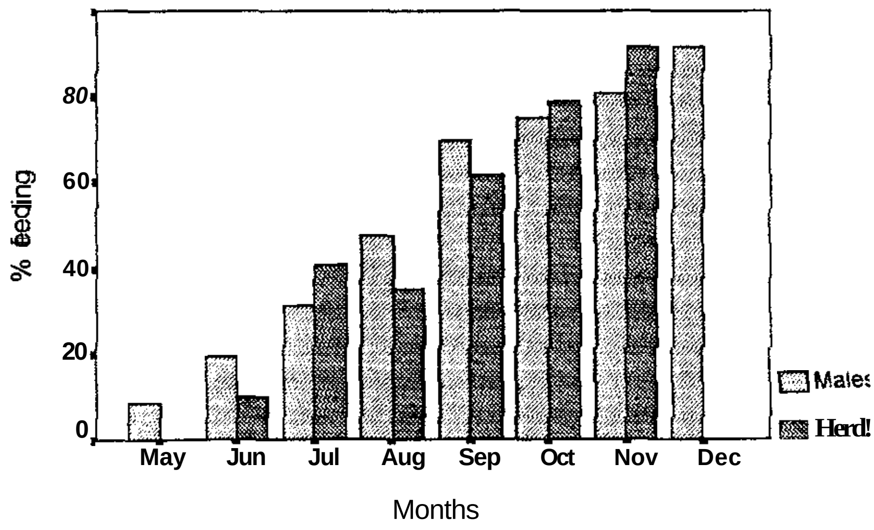


Table 91. Crop damage by males and herds in terms of total area and number of plants in the study area during 1994

Name of the settlement	Paddy (ha.)		Ginger (ha.)		Coffee (Nos.)		Plantains (Nos.)		Tapioca (Nos.)	
	Males	Herd	Males	Herd	Males	Herd	Males	Herd	Males	Herd
1.Alathur	0.10	-	0.01	-	-	-	-	-	-	-
2.Arakunji	1.16	0.70	0.01	-	14	-	-	-	-	-
3.Chetty Alathur	1.20	3.31	0.09	0.22	-	-	26	8	29	41
4.Kallumukku	1.58	-	-	-	8	-	18	-	-	-
5.Kumuzhi	1.86	-	0.10	-	-	-	-	-	-	-
6.Kuppadi	0.24	-	-	-	-	-	-	-	-	-
7.Kurichiat	0.10	-	-	-	-	-	-	-	-	-
8.Nulpuzha	0.20	2.79	-	0.67	-	-	-	-	-	-
9.Ponkuzhi	2.60	-	0.43	-	5	-	7	-	-	-
Total	9.04	6.80	0.64	0.89	27	0	51	8	29	41

Table 92. Crop damage by males and herds in terms of total area and number of plants in the study area during 1995

Name of the Settlement	Paddy (ha.) Males/Herd		Ginger (ha.) Males/Herd		Arecanut (Nos.) Males/Herd		Coconut (Nos.) Males/Herd		Coffee (Nos.) Males/Herd		Pepper (Nos.) Males/Herd		Plantains (Nos.) Males/Herd	
1.Alathur	0.50	-	-	-	-	-	-	-	2	-	3	-	-	-
2.Arakunji	1.17	0.21	0.01	-	-	-	2	-	9	-	2	-	-	-
3.Chetty Alathur	0.89	2.68	0.13	0.42	20	42	11	-	-	-	-	-	64	112
4.Kallu-mukku	1.21	-	-	-	-	-	-	-	3	-	2	-	-	-
5.Kumuzhi	2.09	-	-	-	-	-	-	-	-	-	-	-	-	-
6.Kuppadi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7.Kurichiat	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8.Nulpuzha	0.60	2.53	-	0.23	-	-	-	-	-	-	-	6	-	-
9.Ponkuzhi	2.80	-	0.02	-	-	-	8	-	7	-	6	-	-	-
Total	9.62	5.42	0.27	0.65	20	42	21	-	21	-	13	6	64	112

6.4.9 Economic Implications

The total area under paddy cultivation in the selected settlements was 265.56 ha. (88% of the total wet lands). In 1994, an area of 15.84 ha. (5.89% of the paddy area) have been by elephants. During 1995, a total area of 15.04 ha. (5.66% of the paddy area) were damaged. Of these, 63.96% of the damages were due to feeding by bulls and 36.04% by herds.

The total loss to farmers due to damage by elephants in each village during 1994 and 1995 are given in Tables 93 and 94. The total economic loss to farmers was Rs. 9.67 lakhs in 1994 Rs. 7.97 lakhs in 1995. Among the selected settlements, Nulpuzha had the highest loss in economic terms during 1994 (Rs.3.24 lakhs). The total area of the settlement is 140.44 ha. Thus the loss incurred was Rs. 2,306 per hectare of cultivation. However, Ponkuzhi had the highest loss per hectare (Rs. 14,462) and Arakunji and Chetty Alathur followed this. Alathur and Kurichiat had the lowest in per unit area (below Rs. 100). During 1995, the overall economic loss due to elephants was comparatively less. Ponkuzhi had the highest loss per hectare (Rs. 6,459) followed by Chetty Alathur (Rs. 5,541) and Arakunji (Rs. 3,619).

Table 93. Economic value of crops damaged by elephants during 1994

Name of the settlement	Value of crops damaged (in Rupees)						
	Paddy	Ginger	Coffee	Plantains	Tapioca	Total loss	Loss/ ha.
1. Alathur	1975	3952	0	0	0	5927	99
2. Arakunji	36735	3952	23954	0	0	64641	4315
3. Chetty Alathur	89073	122512	0	1360	700	213645	3502
4. Kallumukku	31205	0	13688	720	0	45613	909
5. Kumuzhi	36735	39520	0	0	0	76255	1391
6. Kuppadi	4740	0	0	0	0	4740	158
7. Kurichiat	1975	0	0	0	0	1975	73
8. Nulpuzha	59053	264784	0	0	0	323837	2306
9. Ponkuzhi	51350	169936	8555	280	0	230121	14462
Total	312840	604656	46197	2360	700	966753	2129

Table 94. Economic value of crops damaged by elephants during 1995

	Value of crops damaged (in Rupees)								
Name of the Settlements	Paddy	Ginger	Areca nut	Coco-nut	Coffee	Pepper	Plan-tains	Total loss	Loss/ ha.
1. Alathur	9875	3952	0	0	3422	4200	0	21449	358
2. Arakunji	27255	3952	0	4800	15399	2800	0	54206	3619
3. Chetty Alathur	70508	217360	16740	26400	0	0	7040	338048	5541
4. Kallumukku	23898	0	0	0	5133	2800	0	31831	634
5. Kumuzhi	41278	39520	0	0	0	0	0	80798	1474
6. Kuppadi	0	0	0	0	0	0	0	0	0
7. Kurichiat	7110	0	0	0	0	0	0	7110	264
8. Nulpuzha	61817	90896	0	0	0	8400	0	161114	1147
9. Ponkuzhi	55300	7904	0	19200	11977	8400	0	102781	6459
Total	297040	363584	16740	50400	35931	26600	7040	797335	1756

6.4.10 Man slaughter by elephants

Elephants in the study area lulled four people (all men) during the study period. Among them, three belonged to the tribal community and one 'Chetty' community. The identified habitual crop raiders, CTM, LFM and CK were responsible for three of these. One of them could not be followed for identification.

6.5 Discussion

A number of factors seem to influence the crop raidmg behaviour of elephants. Sukumar (1989), Balasubramanian *et al.,* (1995) and Kumar and Sathyanarayana (1995) have dealt with these factors while studying crop raiding elephants. Sukumar (1989) list the factors as those related to movement pattern, availability of water and food, reduction, fragmentation and degradation of habitat, and the difference in the palatability and nutritive value of crops compared to the natural food species.

Elephants' far ranging behaviour and larger requirement of the resources often lead them into contact with cultivation in the fragmented forests (Sukumar, 1988). Increased elephant population and local over abundance result in habitat degradation leading to crop raiding (Desai, 1997). Elephant in the study area shows a distinct pattern of movement with increased density in the peripheral region during dry season. The interior areas, where the settlements are located have an almost equal density during the first and second wet seasons. The density figures in Wayanad are higher compared to similar elephant ranges.

Straying of elephants has also been observed in Wayanad. On one occasion, four elephants strayed out from the forest in Padri Range into Panamaram area through coffee plantations. This was ultimately driven back by the forest officials. In another incidence an adult tusker followed the same route, surrounded by mob, killed a person and ultimately was shot dead by police. It is possible that these areas had been the usual elephant paths much before the conversion and settlements started. Further, the areas surrounding the settlements are degraded to a greater extent because of the dependence of the people on the surrounding forest for cattle grazing, fire wood collection and similar activities.

Food availability study also indicated low grass biomass in areas surrounding the settlements. The conversions of natural forests into plantations have also contributed to the degradation considerably. This is clearly evident in the eucalypts plantation, where the under growth is dominated or fully occupied by *Lantana* and *Eupatorium.* The increased rate of crop raiding in the settlements surrounded by plantation especially of eucalypts plantation indicate the degradation of habitat as a possible causative factor for crop raiding. Degradation of habitats has been reported to lead a futile search for non-existent food sources ending up in crop raiding (Desai, 1997).

The elephant habitat in the study area though not fragmented in the strict sense of the term was disturbed due to the scattered nature of the settlements. The movement of the people during day time, force the elephants to confine themselves to smaller undisturbed patches and put them under stress and strain.

Among the wet land crops, paddy was the dominant one extensively cultivated in all the settlements selected for the study. Paddy was also the crop which, was damaged most by the elephants and other animals. The damage to ginger and dry crops except coconut were mostly due to trampling, more often while going for paddy. The damage of paddy due to elephant during vegetative phase was almost exclusively due to trampling. The paddy in reproductive phase were fed and thus damaged. Sukumar (1985) has mentioned the high nutrient value and digestibility coupled with lesser toxins as the possible reasons for preference for paddy.

Palatability of paddy was also high compared to the matured grasses in second wet season. The crude protein content of paddy in inflorescence was higher than the short grass available in the moist deciduous forests surrounding the settlements. Sukumar (1989 & 1990) has also reported higher calcium and sodium content in the mature paddy. Further, the present observation of high intensity of raiding during the reproductive phase could also be due to the sudden increase of sucrose and amino acids in the developing grains of paddy. The very low percentage of time spent for feeding by habitual crop raiders observed also indicate the possibility of meeting the nutritional requirements within the short period of raiding on the highly nutritious crops.

In the study area, the frequency of crop raiding by males was higher than the herds. The success in the attempts were also more in the case of males. Sukumar (1989) and Kumar and Sathyanarayana (1995) have made similar observations. Males due to their solitary nature can very well stay over days together in the areas surrounding settlements compared to the herds with juveniles and calves.

There was no significant difference in the herd size of elephants in the natural and crop raiding herds. Sukumar (1985) observed herd formation even among the bulls while raiding crops. Datye and Bhagawat (1995c) observed an increased mean herd size among the elephant raiding crops. It may be probable that the herds in the study area do not go purposefully for crop raiding and more often raid once coming into contact with the cultivated area. The present observations in the study area do not show any positive correlation between the size of settlement and frequency of crop raiding. This is contradictory to the observations made by Sukumar (1989).

Considering all the factors discussed above the habit of the animal seems to play an important role in crop raiding behaviour in the study area. In one incidence, an adult bull in the company of another adult bull tried to break open a live wire fence but retreated on getting the shock. But the other adult bull broke the fence and both raided the field. The bull, which failed was later reported to be raiding crops all alone even in the electric fenced settlements. The habitual crop raiders stay around the settlements and continuously raid irrespective of the protection methods employed. These elephants wen follow a spacing pattern among them and once chased move to the next settlement to repeat the process. These observations indicate the possibility of acquiring the crop raiding habit through learning process and possibly act in combination with all the proximate factors discussed earlier.

Sukumar (1985) estimated a loss of Rs. 1.9 lakhs during 1981-82 in nine settlements and per hectare loss was Rs. 59. Per hectare loss incurred in Dharmapuri Forest Division of Tamil Nadu was between Rs. 134.11 and Rs. 145.54. The per hectare economic loss in Wayanad is comparatively more than other areas studied. A much higher loss has been reported from Malaysia by Blair *et al.* (1979) and Blair (1980) where the damage has been on perennial crops such as oil palm, coconut or rubber. The damage of cash crops in the study area could be one of the reasons for the higher rate of economic loss. But, estimation without cash crops also show a higher economic loss compared to other crop raiding areas. A preliminary comparison made with the compensation paid by the authorities point out that most of the raids go unreported and loss unclaimed due to several reasons.

Electric fencing was found to he the most efficient protection method, if properly maintained. But the habitual crop raiders break open electric fences and raid the crops. Properly maintained electric fencing coupled with guarding was found to be more effective against habitual crop raiders. Most of the settlements, where electric fencing were erected in the middle of the study showed a decrease in crop raiding incidences.

The human deaths due to elephants in the study area were less compared to Dalma in Bihar (Datye and Bhagawat, 1995c) or Northeast (Lahiri-Choudhury, 1980). The attitude of the people seems to contribute a lot while projecting the problem of crop raiding in Wayanad. Francis (1994) has mentioned crop raiding as a common phenomenon in the erstwhile Wayanad where swamps were under cultivation. He has described the innumerable number of 'machans' raised by the tribal communities as one of the characteristic features of Wayanad. Intrusions of the area by the settlers who are unused to wildlife and intolerant to the ways of wildlife have also influenced the attitude of the present day tribals. The changes in the vegetation of the area as a result of increased settlements, cultivation and relationships between communities have also contributed to the socio-economic changes which have not been proved to be too good for wildlife especially elephants.

Recommendations

1. A number of factors influence the density distribution of animals in the area. Year round food and water availability are crucial to ensure an even distribution. The importance of species browsed such as *Helicteres* has been evident. It is important to enrich the habitat with browse species such as *Helicteres* and bamboos. Protection of habitat for natural regeneration of bamboo in the flowered area will ensure availability of young bamboos in large quantities. Grass being the major food species of elephants in the area, maintenance of vayals should also be ensured.
2. Control of fire within and the adjacent areas in Tamil Nadu and Karnataka is equally important to reduce the pressure on the habitat during the lean period.
3. The scattered settlements within the forest are hindrances to the free movement of elephants. Measures may be taken for resettling the interior enclosures thereby consolidating areas to ensure free movement of wildlife.
4. Eco-development programmes may be implemented to reduce the impact of the inhabitants on the habitat.
5. Compensation for damages due to wildlife is not a permanent solution to the problem. However, timely action for compensating the loss would help in building up support to the conservation efforts.
6. Elephants are responsible for most of the crop depredation in Wayanad. Regular monitoring of habitual crop raiders would help in studying their behavioural ecology.

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