# HABITAT UTILIZATION BY LARGER HERBIVORES IN SOUTH INDIAN FORESTS

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
IN ZOOLOGY

by

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# CERTIFICATE

This is to certify that the thesis entitled "**Habitat utilization by larger herbivores in South Indian forests**" submitted to the University of Calicut by **Mr. Abdul Hameed Seere Valappil** in partial fulfilment for the award of the degree of Doctor of Philosophy in Zoology is a bonafide record of the research work carried out by him under my supervision and guidance and that neither this thesis nor any part of it has formed the basis for the award of any degree or diploma.

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# DECLARATION

I hereby declare that the thesis entitled "**Habitat utilization by larger herbivores in South Indian Forests**" submitted by me for the award of Doctor of Philosophy in Zoology of Calicut University is an original research work done by me in the Department of Zoology, St. Joseph's College, Devagiri, Calicut, and that it has not been submitted earlier in part or in full to any other University for award of any Degree of Diploma.

**Abdul Hameed Seere Valappil**

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# CHAPTER- 1

# INTRODUCTION

The forests of the Peninsular India once harboured a rich fauna of mammalian herbivores. This included the true Indian forms such as the spotted deer, the nilgai, the blackbuck and the four horned antelope and the Malayan forms such as the gaur, the sambar, the muntjac and the elephant. Except the nilgai, the blackbuck and the four horned antelope, which are open forest or country species, all others are inhabitants of dense forests. However the spotted deer prefers dry forests.

The Western Ghats in South India, in contrast to the adjoining Deccan, had dense forest cover in the past. At several places the ghats form extensive grassy downs and tablelands seemed with densely forested gorges or sholas. The sholas with the surrounding grasslands provide ideal habitats for animals such as elephant, gaur and sambar, which share several food plants particularly grasses and herbs.

Poaching and extensive removal of forests and grasslands for agriculture, plantations and various developmental activities have considerably reduced the number of the larger mammalian herbivores such as the elephant (*Elephas maximus*), the gaur (*Bos gaurus*) and the sambar (*Cervus unicolor*). They are driven to isolated pockets

on the hills, mostly in protected areas. Since these three animals have almost similar ecological requirements, the reduction in the habitat may lead to competition among them. A study on the habitat utilization pattern of these three herbivores has been taken up in Periyar Tiger Reserve with a view to identifying their habitat requirements in different seasons.

The objectives of the study was to gather adequate information on the distribution, behaviour, food habits and habitat utilization pattern of elephant, gaur and sambar in Periyar Plateau and their responses to environmental changes taking place in the area in different seasons. Use of different types of vegetations, variation in herd size in different seasons, resource availability and activity patterns in relation to time and other physical factors, population structure, seasonal movements and factors affecting movements such as fire, water level in the lake, cattle menace, tourism and pilgrimage will also be studied. It is proposed to fill the gap in the existing information on these larger mammals, which would be helpful for their management.

# CHAPTER II

# REVIEW OF LITERATURE

The Asiatic elephant (*Elephas maximus L.*) has a wide distribution throughout South and Southeast Asia extending to Sumatra and Borneo (Freeman 1980). Extensive studies on African Elephant (*Loxodonta africana*) have been done by Hanks (1969, 1972b, 1979), Field (1971), Douglas-Hamilton, (1973, 1987), Wyatt and Eltringham (1974), Douglas-Hamilton et. al., (1975), Leuthold (1976), Merz (1986), Dunham (1986), Moss (1988) and Viljeon (1989) mainly described the size of home range of elephants in relation to environmental factors, vegetation, shape and spatial distribution and various ecological aspects. Vegetation changes induced by elephants were studied by Buchner et. al., (1961) and damage in the vegetation composition by Laws (1970), Anderson et, al., (1974), Field and Ross (1976). Bell et. al., (1984) and Mc Shane (1987) studied the influence of fire on elephant movement. Bax Sheldrick (1963), and Barnes (1980, 1982), Williamson (1975), Guy (1976), Barnes et, al., (1983), have studied the food and feeding behavior of elephants.

Several accounts on Asiatic elephants (*Elephas maximus*) have been published in India. Of these, the contributions of Sanderson (1878), Williams (1950) and Stracey (1963) have provided with useful information on the ecology and behaviour of elephants in India. Based on detailed study in Sri Lanka, a comprehensive account on Asian

Elephants has been published by Eisenberg et. al., (1971, 1972). Publications on elephants came up in subsequent years, however didn't add significantly to the existing information on the species, though Sukumar (1985) has presented some details of man-elephant conflict especially the crop depredation by the species.

The ecological studies on the Asian elephant carried out in Sri Lanka by Eisenberg and Lockhart (1972), Muller-Dombias (1972), Mckay (1973), Kurt (1974), Vacuylenberg (1977), Olivier (1978a, 1978b), Ishwaran (1983a, 1983b, 1984, 1993), Santiapillai et. al. (1984, 1985), Santiapillai (1987) provided information on the species from Sri Lanka. Khan (1967, 1980, 1985), Olivier (1978) and Santiapillai and Superhman (1985) described some ecological aspects of elephants in Sumatra. In India, Krishnan (1972), Daniel (1980), Sukumar (1985, 1986a, 1986b, 1989, 1989a, 1989b), Sukumar et. al., (1987, 1988), Daniel et. al., (1987), Easa (1988, 1989), Desai (1991), Desai et. al., (1987), Sivaganesan (1991) and Balasubramannian (1998) studied different ecological aspects of this species. Some aspects on distribution and ecology of Asiatic elephants have been documented by several workers such as Krishnan (1972), Hoffman (1975, 1978), Whittaker (1979), Krishnamurthy (1980), Storer (1981), Balakrishnan et. al., (1986), Santiapillai and Suprahman (1985, 1987), Dobias (1985, 1987), Sukumar (1985), Nair et. al., (1985), Jayawardene (1986, 1989) in the subcontinent.

But very few long-term studies on this species have been carried out in the rainforest habitats of southern India.

Ecological studies on some of the common ungulate species found in the Indian subcontinent were conducted by Berwick (1974), Jarmen et. al., (1979), Eisenberg et. al., (1972, 1976) Sharachandra and Gadgil (1975, 1980), Martyn (1977), Dinerstein (1980), Miura (1981), Mishra (1982), Mishra and Wemmer (1987), Johnsingh (1983,1984), Mc Naughton et. al., (1986), Green (1990), Barrette (1991), Johnsingh et. al., (1991), Karanth et. al., (1992), Khan et. al., (1995) and Shankar Raman (1997).

The genus Bos, in addition to the domestic cattle (*Bos indicus*) and the yak (*Bos grunneus*) contains several other species of wild cattle, all confined to the Oriental Region (Schaller, 1967). There are three subspecies of gaur, of which *Bos gaurus gaurus* inhabits India and Nepal, *Bos gaurus readei* in Burma and Indochina and *Bos gaurus hubbacki* in Malaya. The Indian subspecies inhabits the forest of India throughout Southeast Asia and it occurs in the Western Ghats, the Central Indian highlands and the foothills of Himalayas including the hills of the Brahmaputhra river (Schaller, 1967). A fairly good population of gaur occurs along the Eastern Ghats of Orissa and Madya Predesh, while it is recorded in small numbers from the northern Andhra Pradesh, Maharashtra and Bihar. According to Krishnan (1972) the chain of undulating hills on the Western Gnats are suitable habitat for gaur in India, which is a fine

ground stamping place for this species in the world. In the Western Ghats it ranges from Karnataka southward to Tamil Nadu and Kerala mostly confined to the hilly forest areas and two isolated populations survive along the Tamil Nadu - Kerala boarder, on the Anaimalai hills and around Periyar Lake (Schaller 1967). Presently Periyar harbours a fairly good population of the gaur, though it has completely been exterminated in the late seventies due to rinderpest disease.

Shrinkage of habitat and the epidemic diseases like rinderpest and foot and mouth through infected cattle grazing in the forest have considerably affected the distribution of gaur. Habitat destruction and indiscriminate shooting of gaur for sports are the major reasons for the decline its population (Krishnan, 1972) and these factors have considerably affected the Central Indian Population (Stewart, 1928; Ali, 1927; Baker, 1980; Bansal and Joshi, 1980). The gaur survives now in isolated pockets in India and considered as a threatened species. Habitat selection, movements and home range of the Malyan Gaur, *Bos gaurus*, were studied by Conry (1981,1989). Several studies on the related American bison were carried out by Mc Haugh (1958), Nelson (1965), Meagher (1989a, 1989b), Reynold et. al., (1982), Campell et. al., (1983) Van Vuren (1983), Van Vuren et. al., (1987) and James et. al., (1990).

The limited literatures on gaur in India include those on its status and distribution (Cameron, 1929; Brander, 1935; Blackburn,

1935; Morris 1930, 1937, 1937b, 1938a, 1938b, 1947, 1948, 1948a, 1948b, 1952, 1954a, 1954b; Biddulph, 1936; Mustil, 1938; Russel, 1938, 1940; Rynjah, 1950; Hutton, 1951; Belsare et. al., 1984; Dwivedi and Shukla, 1988) and scanty observation on its behaviour and habitat use. Schaller (1967) and Krishnan (1972) described different aspects of the ecology of gaur. Vairaveli (1998) studied its habitat utilization in Parambikulam Wildlife Sanctuary. Studies on the status of gaur in India have also been carried out by Basappanavar (1985), Samant (1990), Debroy (1991), while those on the food habits by Srivasthava et. al., (1996).

The sambar, *Cervus unicolor*, is a common species inhabiting the forest of India through South-east Asia. It is a major prey species of larger mammalian predators like tiger, leopard and wild dogs in India. Though Sambar is a typical and widespread forest dweller of Southern Asia, little has been investigated of its biology. A brief account of this species has been given by Schaller (1967). According to Krishnan (1972) its sound is familiar in the forest, which has been described by Peacock (1933) and Bentley (1976). Short accounts on the antler shedding and rutting of sambar is available through the publication of Medway (1969) and Thom (1937). Ngampongsai (1977) has studied the habitat relation of the sambar in Khao-Yai National park, Thailand.

Periyar Tiger Reserve in south India harbours the largest populations of major herbivores such as the Asiatic elephant (*Elephas maximus*), the Gaur (*Bos gaurus*) and the sambar (*Cervus unicolor*) in South India. But little information is available on the ecological requirements of any of these species in the reserve and surrounding areas other than scanty notes or part of the preliminary studies on wild life of the reserve carried out by Kurup (1971), Vijayan et al. (1979). Nair et. al. (1985), Ramachandran et al., (1986), Srivastava et al., (1995, 1996). Recently, Harikumar et al., (1999) has given an account on the population dynamics of sambar in Periyar.

# CHAPTER - III

# STUDY AREA

## III .1. LOCATIONS AND HISTORY

Periyar tiger Reserve is the largest protected area in Kerala situated on Periyar plateau a portion of the Western Ghats, within latitude 9° 15' to 9° 40' and longitude of 76° 55' to 77° 25', in the Peermede taluk of the Idukki district, about 113 Km. east of Kottayam and 135 Km. west of Madurai (Fig.1).

The reserve has two river basins, Periyar and Mullayar, the river Periyar originating from Chokkampatty and Mullayar from Kallimalai side join together as the Mullaperiyar which was impounded by the construction of a masonry dam in 1895. This has resulted in the formation of a lake of about 25 Sq. Km.. The Periyar plateau includes, Periyar lake Reserve (600 Sq. Km.), Rattenden valley (12.95 Sq. Km.) and Mount plateau (163.17 Sq. Km.). Out of these, the actual forest area excluding Periyar lake residential colonies and Sabarimamalai Temple premises are estimated to be 741 Sq. Km. (Chandrashekaran 1973). The bordering high wavy mountain in the Tamil Nadu area has also been included in the study area.

In 1899, the forest around the lake was declared as a reserve forest known as Periyar Lake Reserve forest, No. 39 under section

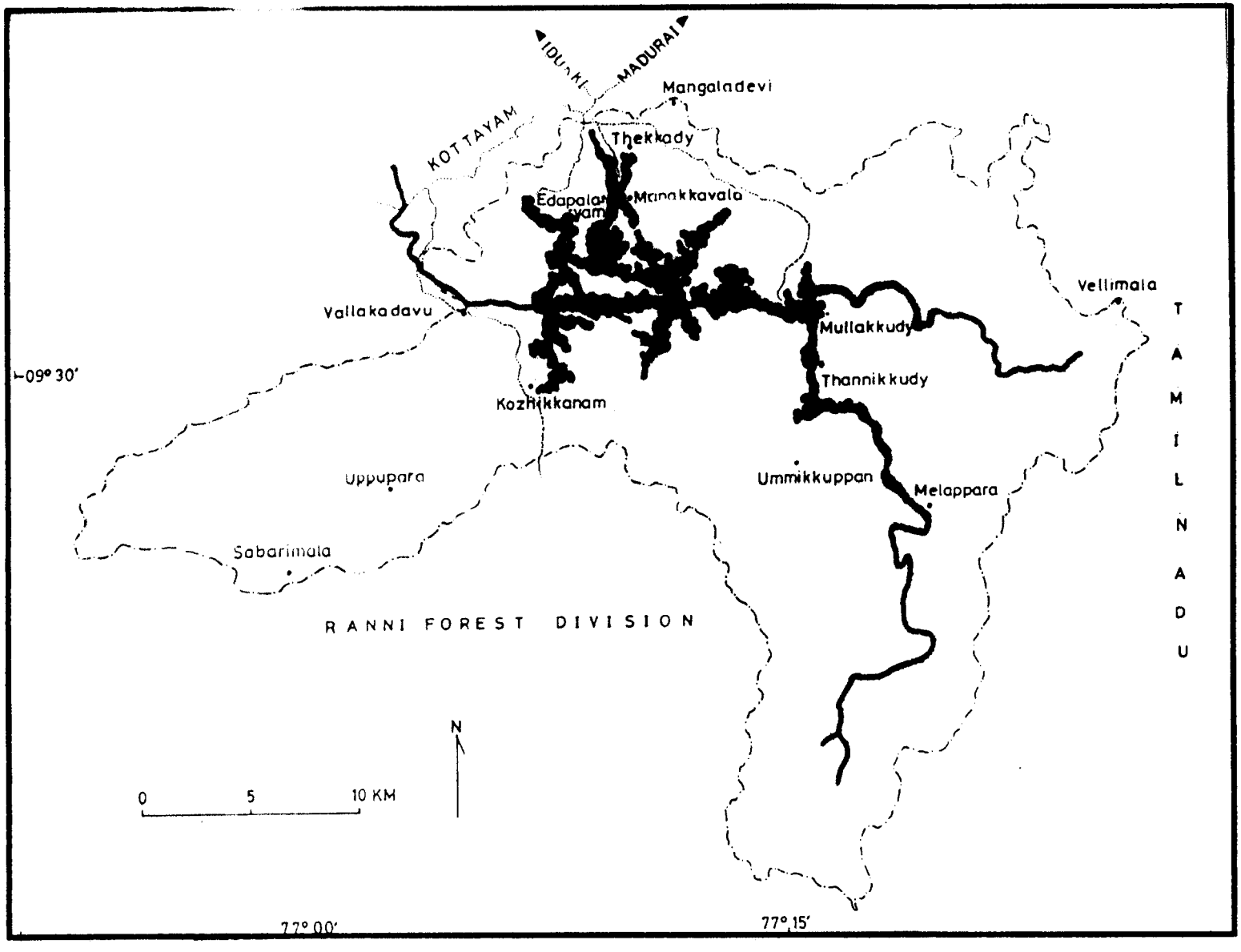


**Fig. 1 - Periyar Tiger Reserve - Study area**

18 of Travancore Regulation Act 1068. In 1934 a game sanctuary called Nellikampetty sanctuary with an area of 600 Sq.Km. (Nair et. al., 1978) was formed, and Mr. C.H. Robinson, the first game warden was appointed by the then Maharaja of Travancore. An independent Game Department was formed in 1940 for better management of game reserves. After the retirement of Mr. Robinson in 1945 a High Range Division was formed and Mr. M.P. Subbaiah, the then game warden, took charge of High range Division. Then the Game Department came under the Conservator of Forests. Later the High Range Division was abolished and the sanctuary was brought under the Divisional Forest Officer, Kottayam.

In 1950, more area was added to the Nellikampetty sanctuary to the present extent and the Periyar Wildlife Sanctuary was constituted. And separate game warden Mr. C. Chacko was appointed as Game warden by the government. The head quarters of game warden was shifted from Peermed to Kottayam in 1964-65 periods. In 1966, the Game Department was merged with the Forest Department and in 1978 the area was selected for Project Tiger launched by the Government of India. In 1982 the core area of 350 Sq.Km. of the reserve was notified as a National Park by the Government of Kerala (Nair et. al., 1978; Ramachandran et. al., 1987).

## III.2. BOUNDARIES

The boundary of the main study area on the north, northeast and east, approximately 90 Km. is the state boundary between Tamil Nadu and Kerala. On the north the boundary is formed by the Madurai district and on the east by Ramnadu and southeast by Tirunelveli district of Tamil Nadu. On the south the reserve is bordered by Ranni forest division and on the west by Kottayam division.

## III.3. GEOMORPHOLOGY

The terrain of the study area is rugged with a large number of hills and hillocks, often rolling and occasionally with precipitous slopes. The elevation ranges from 700 to 2019M. There are large number of peaks in the reserve area and its boundary with Tamil Nadu state. The prominent peaks are Karimalai (1844M.), Sundaramalai (1808m.), Chokkampettymalai (1801M.), Paachimalai (1800M.), Nagamalai (1733M.), Komalai (1641m.), Kallimali (1637M.), Udumalai (1589M.), Koyilmalai (1569M), Chovarakuzhimalai (1549M), Sivagirimalai (1740M), Pulamalai (1498M.), Thottimalai (1640M.), Changumalai (1522M.), Paachiyammalai (1750M.), Suruliparamalai (1626M.) and

Mangladevimalai (1626M.). The highest peak in the area is the Vellimalai (2014M.) Which is on the boarder with Tamil Nadu. The tract is hilly and rocks are crystalline and plutonic origin. There are numerous boulders on the ground particularly on the stream banks. Depth of soil varies according to the terrain and soil is always wet.

## III.4. HYDROLOGY

The reserve has two river basins, Mullayar and Periyar. The river Periyar originates from Chokkampetty side and Mullayar from Kallimalai side and joins Periyar at Mullakudy forming Mullaperiyar River, which form the main drainage of the area. The lake was formed as a result of the construction Mullaperiyar dam in 1895 and has an area of 26 Sq. Km. with depth ranging from 32m. to 46 M. Most of the tributaries of Mullaperiyar are not named, and the important ones being Inchiparathodu, Vazhukkumparathodu, Chorakkatia river and Mullathodu. The water level of the lake varies in different months as given in the table 1, and depend mainly on precipitation rates. The maximum water level in the lake was recorded during the month of June to December (Monsoon and Post monsoon) and the mean water level of the lake is given in the Fig.2.

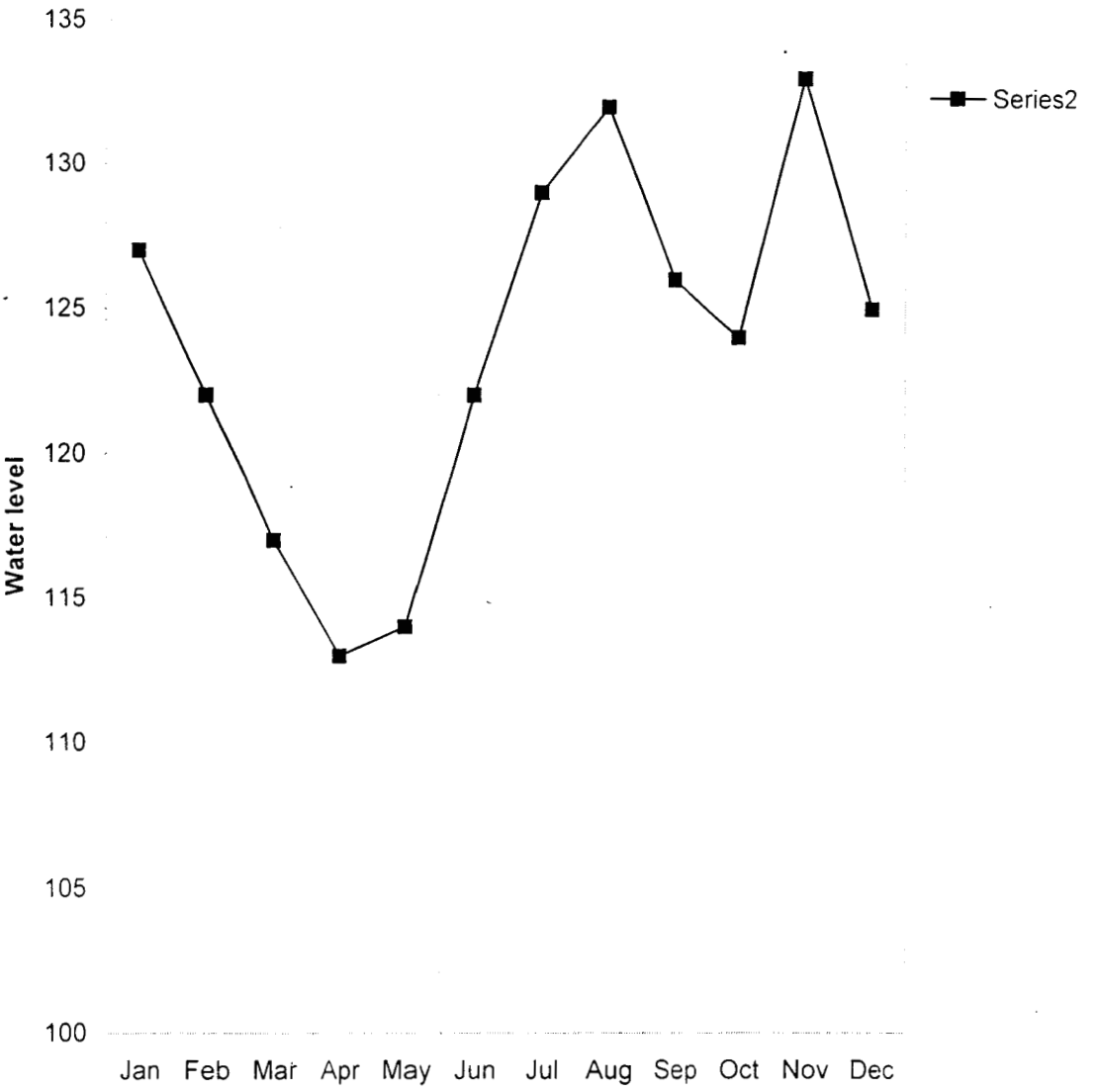


**Fig.2 Monthly mean water level of Mullaperiyar Lake**

## Table - 2

**Monthly mean rainfall of four stations in the study area**

| Month | Stations | | | |
|---|---|---|---|---|
| | Thekkady mm | Manakavala mm | Mullaperiyar Dam mm | Mullakudy mm |
| Jan. | 10 | - | 10 | - |
| Feb. | 23 | 16 | 29 | 28 |
| Mar. | 13 | 7 | 20 | 4 |
| Apr. | 114 | 107 | 59 | 68 |
| May | 131 | 94 | 168 | 74 |
| Jun. | 338 | 192 | 576 | 233 |
| Jul. | 378 | 264 | 640 | 276 |
| Aug. | 275 | 58 | 304 | 119 |
| Sept. | 197 | 73 | 163 | 101 |
| Oct. | 217 | 88 | 294 | 158 |
| Nov. | 316 | 112 | 293 | 193 |
| Dec. | 150 | 1 | 19 | 8 |

## III.5. CLIMATE

The study area has rather cool climate. Temperature varies from 14°c to 35°c throughout the year. March and April are comparatively warmer months and the rest of the year is wet. Average rainfall is 2500mm with maximum precipitation from June to September. Although the area receives both the monsoon, southwest monsoon is responsible for more than half of the annual precipitation, which normally starts by the first week of June preceded by a few pre monsoon showers. The highest rainfall is recorded during June to August months. Monthly mean rainfall of the four stations of the study area is given in the table 2 and fig.3. Based on the precipitation pattern the seasons were classified as winter, summer, monsoon and post monsoon.

## III.6. VEGETATION

Champion and Seth (1968) have described the terminology of forest types in the area. The vegetation types and their extent were reported by Chandrashekaran (1973). According to him the major vegetation types of the study area as given in the table 3 and Fig.4, comprise west coast tropical evergreen forest (305 sq. Km.), West coast tropical semi evergreen forest (275 sq. km.), Southern secondary moist mixed deciduous forest (98 sq. km.). South Indian subtropical hill savannah and southern montane wet grassland (12

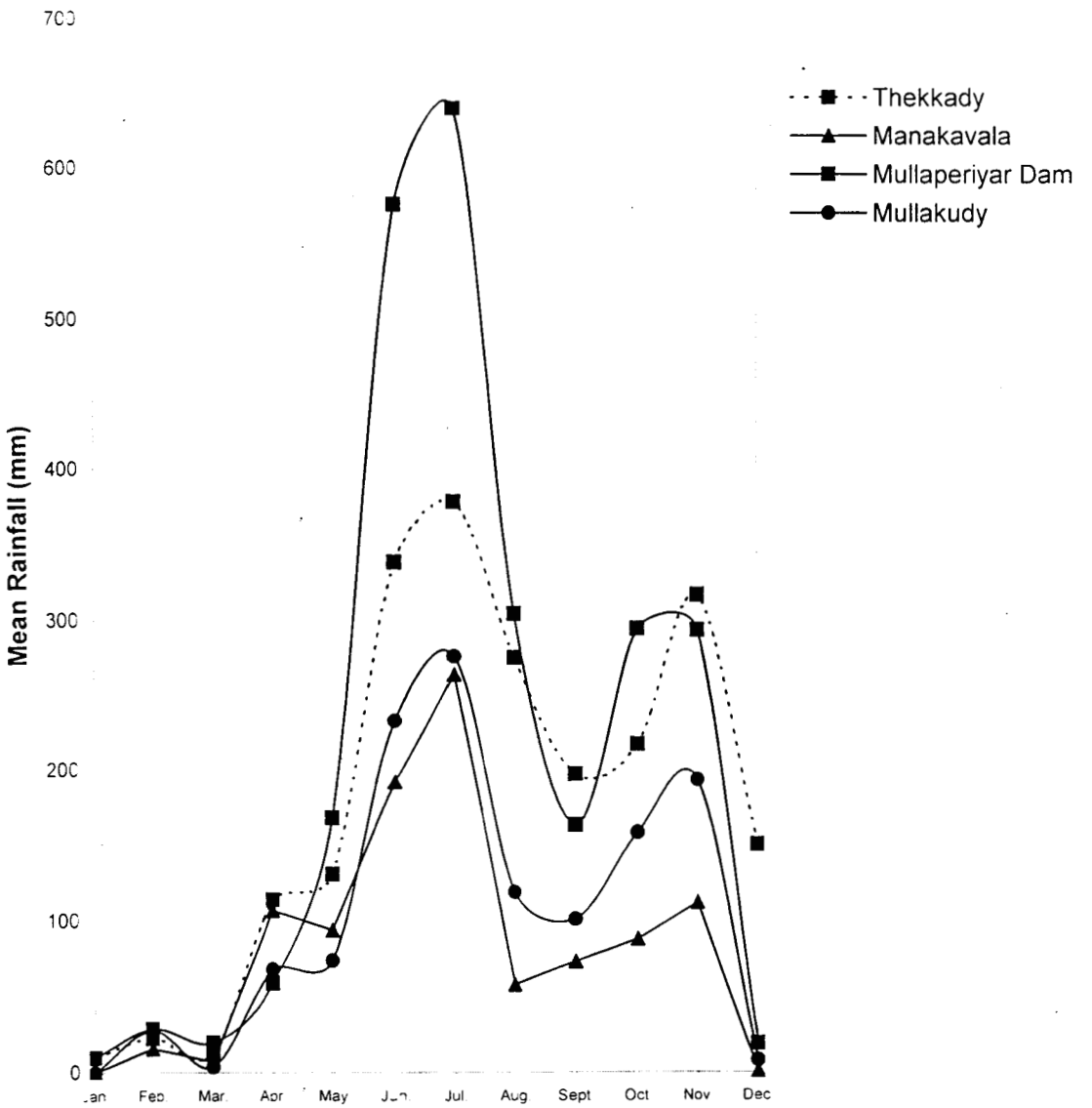


**Fig.3 Monthly mean rainfall of four stations in Periyar**

sq. km.), Eucalyptus plantation (55 sq. km.) and reed brakes (10 sq. km.). Grasslands in the core area are savannah type probably because of annual forest fire. Grasslands of Periyar being grazed by cattle coming in large numbers from the eastern side of the erstwhile Tamil Nadu and are subjected to forest fire made by the grazers. The submerged area of the lake was known to have marshy vegetation, sandy riverbed and patches of forest in between hillocks.

## III. 6.1. WEST COAST TROPICAL EVERGREEN FORESTS

This type of forest are mostly confined to the core area of the reserve namely Vekiletan, Koyilmalai, Kodammalai, Inchipara, Nedumpara, Valiyameenkayam, Tholakkumpara, Sivagiri, Vallimalai and the Sabari malai area. On the eastern boarder of the reserve, this type of forest forms a belt. This vegetation consists of lofty trees and undergrowth of herbs, canebrakes and ferns and trees are predominantly of soft-wooded species. Species common to this biotope are *Artocarpus hirsuta, Mesua ferrea, Mesua magassarium, Elaeaocarpus tuberculatus, Elaecarpus serratus, Canarium strictum, Evodia lunu-akenda, Nephelium longana, Cullenia exarillata Hopea parviflora* and *Vateria indica* etc. The undergrowth consists of *Strobilanthes spp., Psychotria spp., Laportea crenulata, Curcuma spp.* and *Clerodendron spp.* etc. Bamboo reeds (*Ochlandra spp.*) are seen in swampy areas of this

**Table - 3**

**Forest types of Periyar Tiger Reserve**

| Forest Types | Area in Sq. Km. | Percentage |
|---|---|---|
| West Coast tropical evergreen | 305 | 40.39 |
| West Coast tropical semi evergreen | 275 | 36.42 |
| Southern secondary moist mixed deciduous | 98 | 12.98 |
| South Indian subtropical hill savannah woodland & Southern montane wet grassland | 12 | 1.6 |
| Eucalyptus plantation | 55 | 7.28 |
| Reed brakes | 10 | 1.3 |

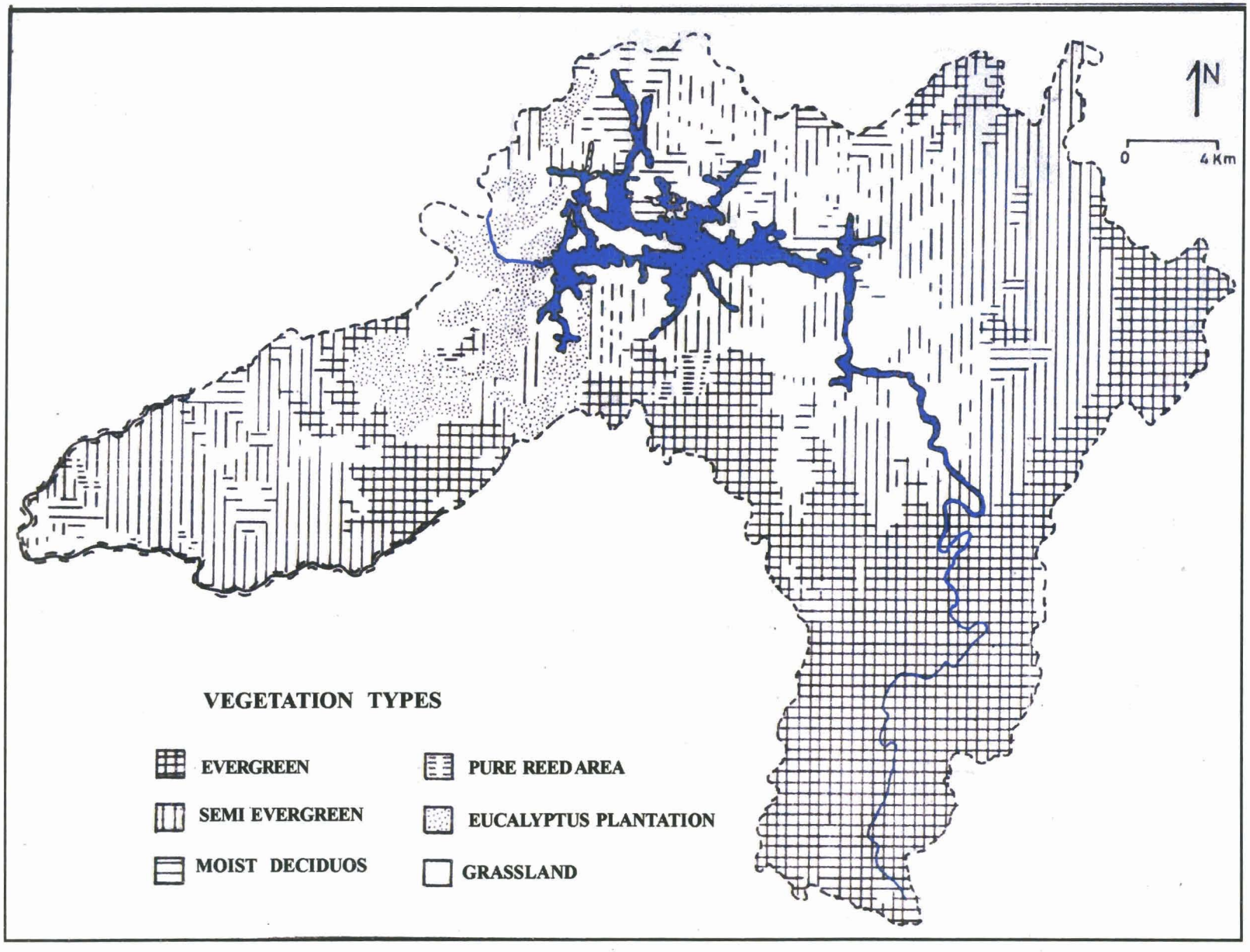


**Fig. 4 - Periyar Tiger Reserve - Vegetation Map**

biotope. Climbers such as canes (*Calanus spp.*) are also the characteristic of this type of vegetation. In the eastern side of the study area and in the Sabarimalai and Mangaladevi areas, particularly the southern hill top tropical evergreen forests (sholas) are common which support a good number of mosses. epiphytes orchids, impatiens etc.

## III. 6.2. WEST COAST TROPICAL SEMIEVERGREEN FOREST

This type of vegetation occurs as patches in Periyar, larger patches being confined to Sabarimalai area and between Pakadimettu and Mlappara. The latter is a narrow strip, contiguous with evergreen forest in the east and also seen in small patches in Cheriyakanam, Valiyakanam, several place along the lake margins between Ummikuppan and Ummikuppan mettu, Koyilmalai, Inchippara, Pothamperi, Mulankal, Kozhikanam and Pacchakanam etc. *Artocarpus hirsuta, Sallalia spp., Hopea parviflora, Tetrameles nudiflora* are dominant species in this type of vegetation. There are a number of openings where *Trema* and *Dillenia* come up. The undergrowth is thick and soil is same as in evergreen forest. In the tourist zone a mosaic of semi evergreen and moist deciduous forest mostly replaces the evergreen patches (Plate I).

**Plate I**

Semi evergreen forest near the lakebed

## III. 6.3. SOUTHERN SECONDARY MOIST MIXED DECIDOUS FOREST

This type of vegetation has a patchy distribution in the study area mainly Mullakudy, Ayyappankuruku and Cheriyakanam area. Majority of them shed their leaves in the dry season from March to May. Major species confined to this type of vegetation are *Tectona grandis*, *Dalbergia latifolia*, *Lagerstroemia lanceolata*, *Pterocarpus marsupium*, *Terminalia bellerica*, *Terminalia paniculata*, *Randia dumetorum*, *Grewia tiliaefolia*, *Bambusa spp.* and *Anogeissus latifolia*. *Lantana aculeata*, *Eupatorium odoratum* and *Zizyphus spp.* grow as dense under story at several places in the deciduous biotope. In deciduous forests, the number of grasses when compared to that of herbs is less. The important grass species are *Cyrtococcum oxyphyllum*, *Cyrtococcus nuricatam*, *Ottochloa nodosa*, *Oryza grannulata* and *Oplismenus compositus* etc. Shrubs like *Desmodium pulchellum*, *Helectres isora*, and *Grewia spp.* etc. grow as undergrowth. Orchids such as *Cymbidium aloifolium*, *Dendrobium macrostachyum* and *Pholidota imbricata* are also commonly met with.

## III. 6.4. GRASSLAND

There are two types of grasslands in the study area namely South Indian subtropical hill savannah and Southern montane wet grassland. Tall grasses interspersed with fire resistant trees like *Anogeissus latifolia*, *Bridelia retusa*, *Emblica officinalis*, *Careya*

*arborea*, *Kydia calycina* and *Grewia tiliaefolia* characterize the first. These were probably wooded regions earlier and might have been changed to grasslands due to frequent fire (Plate II). *Phoenix humilis* occurs among tall grasses especially on hill slopes in Swammikayam, Palkachimalai, Kumarikulam, Uppupara and Mangaladevi areas. Profuse regeneration of *Dalbergia latifolia* was noted in this type of grasslands on the top of certain hills like Kannimaramedu and Uppupara after fire season. Southern montane wet grassland is confined mainly to the top of hills and is characterized by a carpet of grasses without any tree species. Besides grasses, the grassland supports rich herbaceous undergrowth. There are insectivorous plants like *Drosera peltata*, *Drosera burmanni* and many species of *Utricularia*. Grass parasites such as *Strgalutea eupheasoides* and *Christisonia tubulosa* were commonly observed. Many terrestrial orchids thrive well in grassland viz. *Platanthera susannae*, *Satyrium nepalense* etc. the former being considered as an endangered species.

Grasses on the hilltop comprise mostly *Themeda cymbaria*, *Imperatta cylindrica*, *Chrysopogon orientalis*, *Apocopis wighttii* and *Arundinella mesophylla*, those on the slopes comprise *Themeda cymbaria*, *Themeda triandra* and *Crysopogon hackeli* and on the lakeshore and in the marshy areas consist mainly of *Cynodon dactylon* and *Panicum repens*. Grassland supports a large number of herbivores and needs protection and proper management. Fire plays an important role in maintaining the grasslands. Fire is supposed

## Plate II

Forest fire - Burning grassland

to enhance grass growth but it has some demerits also as it is known to cause erosion.

Grasses and herbs are most abundant on hilltops and savannahs and less so at the lakeside. *Chrysopogon spp.*, *Cymbopogon flexuosus*, *Eragrostis spp.*, *Themeda cymbaria*, *Themeda trindra*, *Imperata cylindrica* and *Arundinella spp.* are the most dominant grasses on the hilltop and savannahs where species diversity of grasses are more when compared to the lakeside and marshes.

## III. 6.5. EUCALYPTUS PLANTATION

As part of the policy of rapid industrialization in the 1950s, the grasslands on the Mount plateau reserve, parts of Ranni reserve and Goodrical reserve forest were subjected to large scale planting of *Eucalyptus grandis*. The first experimental plot was taken up at Vallakadavu in 1956, the details of plantations is given in the tables 4, 5 and 6. The satisfactory growth rate of this species led to the establishment of plantation of 28. 81 hectares and 45.73 hectares at Peermedu in 1959 and 1960. Consequently a functional forest division overlapping Periyar Wildlife Sanctuary, Ranni division and Kottayam forest division was formed in 1961, which was called Grassland Afforestation Division (GLAD). It took up Peermedu, Vallakadavu, Kozhikanam and Pachakanam areas of northern to southern portions of the Periyar sanctuary from 1961 to 1967. Eucalyptus trees were

## Table - 4

## Details of Plantations in Periyar

| Details of Plantations | Inside the Reserve | Outside the Reserve |
|---|---|---|
| Existing Plantations | 3973.664 | 184.606 |
| Failed Plantations | 758.950 | 795.124 |
| Converted Plantations | 79.337 | 140.010 |
| Captive Plantations | Nil | 853.145 |

## Table - 5

## Approximate rotation wise distribution of existing Plantations in the Reserve

| | Inside the Reserve (in ha.) | Outside the Reserve (in ha.) |
|---|---|---|
| First rotation completed | 2070.00 | Nil |
| Second rotation completed | 1200.00 | 184.00 |
| Third rotation completed | Nil | Nil |
| Un felled | 660.00 | 471.00 |

## Table - 6

## Approximate distribution of existing Plantation in the Reserve

| Location | Percentage | Area (in ha.) |
|---|---|---|
| Top of Hills | 10% | 397.000 |
| On slopes | 60% | 2383.00 |
| In Valleys | 30% | 1193.00 |

tall and the rate of growth was well comparable with that in their homeland. There were also areas where plantation failed with sparse on little growth, on hilltops and on the slopes. The undergrowth in plantations comprised mostly the original grassland vegetation. Saplings of tree species such as *Terminalia spp.*, *Actinodaphnea spp.*, *Pterocarpus spp.* etc. also came up under the shade of eucalyptus plantations while *Lantana aculeata* and *Eupatorium spp.*, grow well where there are openings. These plantations are being fire protected every year by clearing fire lines.

## III. 7. ESTATES AND OTHER PRIVATE HOLDINGS

There were private and developmental estates of cardamom inside the study area. Twenty seven privately owned cardamom estates are scattered along the northeastern boundary, in the core area of the sanctuary namely Mlappara, Lakshmipara, Naduthottam and Ummikuppan. In these estates the diversity of habitat is reduced to that of the single crop species as the growth of shrubs and other undergrowth is discouraged. Natural under story vegetation regenerated only after the area was brought under Project Tiger, but even now the estate areas have poor undergrowth and less species diversity.

## III. 8. CATTLE MENACE

Annually about two thousand five hundred cattle from the adjoining Kumily village enter the sanctuary area for grazing. The

cattle population could be classified into 1) transient population, which consists of the cattle passing from Tamil Nadu to Kerala through the Kumily village, and 2) The permanent population, which comprises cattle of the Kumily and the surroundings. Density of the latter is comparatively smaller and it is floating population, which spend the daytime inside the reserve for grazing and go back to the village during night. There is a small feral population of cattle, which is quiet aggressive, found grazing near Manakavala, which is a favorite feeding ground of herbivore like gaur and sambar. The transient population of cattle is dangerous as it is likely to bring epidemics like foot and mouth disease and rinderpest disease. A trench has been dug in order to prevent the entry of cattle into the sanctuary but the trench was damaged by the cattle themselves and also by the villagers to let the cattle inside. During the rainy seasons, extensive grazing area gets submerged and these cattle get into the interior of the sanctuary.

## III . 9. PILGRIMAGE

Sabarimalai Ayyappa Temple is one of the most famous pilgrim centers and is situated in the Perunad village of Ranni Taluk in Pathanamthitta district. It is surrounded by unique low altitude evergreen forest and is located in the southern portion of Periyar. The major impacts of the Sabarimalai pilgrims are firewood collection. Trees are being felled in good numbers and converted into firewood.

Pole collection from sholas around the temple along the routes for the construction of stalls and camp sheds prevent regeneration of several species. About sixty percent of the area around the temple didn't have any pole growth. Dumping of non-degradable plastic litter and other litters in the forest areas during the seasons by lakhs of pilgrims is a major environmental problem (Plate III). The presence of plastic bags in the faecal matters of wild animals especially elephant dungs have been observed at several places. The fly swarms after the pilgrimage season and the donkeys used for transporting materials to Sabarimalai during festival are potential carriers or causes of infectious diseases.

## III. 10. TRIBAL SETTLEMENT

There are three tribal settlements (Labbakandam, Vanchivayal and Moozhikkal) and one non-tribal settlement (Pambavalley Food Production Area) within the sanctuary in the buffer zone. The major tribal groups are Mannan, Paliyan, Uralis and Mala Aryans and Malampandarams.

## Plate III

Impact of pilgrimage - Sabarimalai area

# CHAPTER - IV

# METHODS

The study was carried out while I was working in a wildlife research project on elephants in Periyar, under the research officer, from October 1991(Zacharias, 1997). The data collection was started in October 1991 and continued till November 1994. In the study area, four localities were selected, with different type of vegetation, namely evergreen, semi evergreen, moist deciduous forests, savannah, grassland and eucalyptus plantations. In each of these four localities four transects described by Burham, et. al., (1980) each having about 8 to 10 Km. length were laid and larger herbivores were regularly observed once every month along these transects, which cover all the different habitats. Transects were directed perpendicularly to watersheds in order to sample varied habitats. Road strip counts developed by Hirst, (1969) and Berwick (1974) were also used every month for estimating animal populations.

In addition to the above, six study plots of 100 x 100 m. within which 10 x 10 m were also marked in different habitats, namely evergreen forests, semi evergreen forests, moist deciduous forests, savannah, grassland and Eucalyptus plantation in the study area. Vegetation characteristics in the study area are recorded. Since the relation between vegetation and animal populations are of great importance, the population estimates were also made on the transects.

The habitat preference was assessed by direct observations of animals and indirect evidences of their occurrence namely tracks, and faecal groups from the transects and plots. Elephant dung, gaur droppings and sambar pellets seen within two meters of either side of the transect baseline were recorded.

The pellet group count first described by Bennet et. al., (1944) and modified by Neff (1968) was used. All droppings were cleared from the plot areas during the start of the study. Each plot was visited once every month and the faecal groups were counted species wise and cleared. The chances of pellets being washed away during monsoon months were considered. Sightings of elephants, gaur and sambar in the transects and plots and indirect evidences of their occurrence in different types of habitats were recorded every month.

To determine the sex ratio of the animals, ground based composition counts of the herds were conducted and classification were made. The elephants were classified as per their age and sex as adult male, adult female, sub adult male, sub adult female, juvenile male, juvenile female and calves on the criteria adopted by Eisenberg and Lockhart (1972). The gaur was classified as adults, subadults and young ones, and sambar were classified into adults and young ones. The size difference, presence of pelage and coat colours were

taken as criteria to identify the sex and age of each individual in gaur as done by Schaller (1967). Similarly for calculating the accurate age and sex, the length and shape of the horns, method developed by Mc Hugh (1958) and Fuller (1959) was considered.

To gather information on the aggregation of elephants, the elephant herds were classified on the basis of the number of individuals in the herds. The elephant herds sighted were grouped into the following classes, class 1) 1 to 5 individuals, class 2) 6 to 10 individuals, class 3) 11 to 15, class 4) 16 to 20 and class 5) above 20 individuals and the gaur were grouped as 1) 1 -5, 2) 6-10, 3) 11-15 and 4) above 15. The sambar was grouped as solitary, up to two, 3 to 5, 6 to 10 and above 10. The occurrence of herds was recorded every month in different types of vegetations.

In each observations, careful note was made of the behaviour of the animals, the composition and structure of herds, the number of animals per herd, the location of the sightings, time of activity and factors affecting their behaviour in different seasons namely winter, pre-monsoon, monsoon and post- monsoon, and in different habitats.

Two factors are considered in herbivore food habit studies, the percentage of the animal's diet which a plant species constitute and the percentage of each forage which is cropped by the feeding animal, Papageorgiou (1972).

Food habit studies were carried out both directly and indirectly. Direct observations include the inspection of feeding site after the retreat of the animals. The remains of the plants were collected and identified. The twig count method used by Shafer (1963) was adopted to determine the amount of browsed and unbrowsed leafy twigs in the closed vegetations.

Indirectly, food habits were studied by the micro-histological analysis of faecal contents, developed by Stewart (1967), Todd and Hansen (1973), Wallamo et. al., (1973), Hansen and Reid (1975) and Dearden et. al., (1975). Epidermal characteristics of all possible food plants in the study area were studied by taking sections of upper and lower epidermis of leaves. Sections were mounted on micro slides and camera lucida drawings were made. A key was then prepared for all possible food plants of the study area. As next step, the pellets of sambar and droppings of gaur were collected from the field, brought to the laboratory, washed well and preserved in 5 % formaline. The leaf fragments in these samples were compared with the key prepared for identification. The results obtained by the micro-histological method were compared with the food plants of the herbivores observed and collected from the field.

$\chi^2$ - test for independence of attributes and regression analyses were used for the statistical analyses of the data. The $\chi^2$ test, used for testing independence of two attributes when a contingency table

is provided. If the first attribute, (eg. herdsize of elephants) consists of m level, and the second attribute, season consists of n level, we have m x n contingency table. The $\chi^2$ values computed after computing the expected frequency of each cell of the contingency table under the assumptions of independence. The $\chi^2$ statistics computed using the formula,

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

Where, O = Observed frequency from contingency table and E, expected frequency computed using the assumption of independence. The degrees of freedom for $\chi^2$ is (m - 1) x (n - 1) provided all the expected cell frequencies are > 5 (otherwise, Yate's proceedure should be conducted). If the calculated $\chi^2$ is greater than the table value, the hypothesis that "the attributes are independent" will be rejected, in that case the attributes are associated. $\chi^2$ test is used for the analysis of the herdsize variation by vegetation and season, seasonal habitat preference, seasonal difference in the herd composition and seasonal diet difference of these three herbivores.

To study the effect of an independent variable over a dependent variable, regression analysis is used. The significance of the contribution of the dependent variable is tested using F - test (ANOVA). As a measure of the dependence between the variables,

the correlation coefficient can be used and which was calculated using the formula,

$$\text{Correlation coefft.} = \frac{\text{Cov (XY)}}{\text{SD (X) SD (Y)}}$$

$$\text{Cov (XY)} = \Sigma \frac{(X-\bar{X})\,(Y-\bar{Y})}{N}$$

X = Independent variable

Y = Dependent variable

F - test was used for the analyses of the seasonal mean herdsize variation and birth season of elephants.

The area around Periyar, especially those in the Tamil Nadu, which are visited frequently by the larger animals especially by elephants were visited once in two months and the occurrence of the animals also recorded. Both direct sighting and indirect evidences of their occurrence were recorded. In addition, information has been gathered on the animal movements from the forest staff camping in the boarder areas, estate workers and tribal people. Data thus gathered was helpful to get an idea about the utilization of the rain shadow region of the ghats by elephants and other large herbivores.

# CHAPTER V

# POPULATION STRUCTURE AND HABITAT USE OF ELEPHANT (*Elephas maximus*)

## V. 1. POPULATION STRUCTURE

The Asiatic Elephant, *Elephas maximus*, lives in herds. Most of the sightings in the study area consisted of herds though there were a number of solitary individuals, both adult males and females. Herds often comprised adult, sub adults and young ones as observed by Eisenberg and Lockhart (1972) in Sri Lanka. Herds assemble for drinking and grazing at selected places, usually coming together in afternoon or in the early part of the evening. They may remain together perhaps for several hours before once again dividing into subgroups.

During the study period, a total of 2266 individual elephants forming 368 herds were observed in Periyar. Monthly frequency of different age groups of elephants is showed in the table 7. The elephants were classified into different age groups on the criteria adopted by Eisenberg & Lockhart (1972) as adult, sub adult, juveniles and calves.

**Table - 7**

**Population structure of elephants in Periyar**

| Month | AM | AF | SAM | SAF | JM | JF | C |
|---|---|---|---|---|---|---|---|
| Jan | 1 | 117 | 7 | 53 | 3 | 26 | 3 |
| Feb | - | 120 | 5 | 49 | 2 | 15 | 12 |
| Mar | 1 | 108 | 10 | 34 | 2 | 20 | 7 |
| Apr | - | 68 | 4 | 30 | 2 | 13 | 3 |
| May | 1 | 89 | 7 | 31 | 6 | 18 | 8 |
| Jun | - | 108 | 8 | 35 | 3 | 20 | 12 |
| July | 2 | 103 | 7 | 40 | 3 | 18 | 4 |
| Aug | - | 151 | 6 | 50 | 5 | 30 | 12 |
| Sep | 1 | 141 | 5 | 46 | 6 | 22 | 10 |
| Oct | 2 | 116 | 15 | 87 | 4 | 16 | 22 |
| Nov | 1 | 81 | 2 | 27 | 4 | 20 | 12 |
| Dec | - | 71 | 1 | 38 | 3 | 17 | 4 |

AM: Adult male. AF: Adult female

SAM: Sub adult male. SAF: Sub adult female

JM: Juvenile male. JF: Juvenile female

C: Calves

## V. 2. SEX RATIO

The distribution of males in the reserve is very sparse than the females. Of the total 2266 elephants observed, 9 were adult males, 1273 adult females, 77 sub adult males, 520 sub adult females, 43 juvenile males, 235 juvenile females and 109 calves. Besides these, 2 tuskless males (makhnas) were also observed during the study period.

The sex ratio among the different classes of elephants varied considerably, with a high proportion of adult females. The total percentage of males was only 5.69% while that of females was 89.42% and calves 4.81% in total (Table. 8 and Fig.5). The percentage of occurrence of adult males was only 0.39% while that of the adult female were 56.18%. This imbalanced sex ratio seems to be due to the high mortality in adult males since there is a high pressure of poaching on adult male in the reserve and around. The proportion of sub adult male was 3.4% while that of sub adult female was 22.94%, juvenile male with 1.89%; juvenile female was 10.37% and calves 4.81% (Fig. 6). According to previous studies in Periyar, among the males, adults comprised 51.5%, 1.2 % calves 19 % of juveniles and sub adults while in females, the calves consisted 1.2 %, juveniles 19 % and adult 8 % (Kurup, 1969). During the 1981-82 period among the females, proportion of the calves comprised 7.2 %, juvenile 6.6 %, sub adult 8.1 % and adult 56.7 % while among the males the calves comprised 7.2 %, juveniles 6.6 %, sub adult 6.7 % and adults

0.8% (Nair. et. al. 1985). During the 1987-89 period the proportion of different age groups in elephants changed slightly. Among the females the calves and juveniles formed 8.8 %, sub adult 18.5 % and adult 60.2% while among the males, calf and juveniles constituted 8.8 %, sub adult 3.3 % and adults 0.5 %. The proportion of different age groups of elephants noticed during the present study as shown in the table 9, exhibited much difference from that of previous studies.

In the overall pattern of different sexes in different age groups there is considerable variations in the ratios of different sexes as mentioned in the table, Table 9. The proportion of the adult male to adult female is very significant as there are 14.1 females to one adult male while the proportion between the sub adult male to sub adult female is 1: 6. The proportion of juveniles was 1 male to 5 females and total proportion of males and females including adults, sub adults and juveniles it is 1:15. The ratio between males and females were 1: 6 (Kurup, 1971), 1: 71 during 1981- 82 (Nair et. al., 1985). In all the age groups of elephants in the reserve the number of males was very low and the ratio between males and females was skewed. The variation between males and females was insignificant and there was no association between different sex or age groups and season ($\chi^2$ = 8.7246, df = 6, P > 0.01), however maximum frequencies of different sexes observed during post monsoon months. The actual and expected frequencies were given in the table 10 and 10A .

**Table - 8**

**Frequency of observation of different age groups and their percentage**

| Sex | Number | Percentage |
|---|---|---|
| Male | 129 | 5.69 |
| Female | 2028 | 89.42 |
| Calves | 109 | 4.81 |

**Table - 9**

**Sex ratio of different age groups of elephant**

| Age groups | Ratio |
|---|---|
| Adult Male to Female | 1:14 |
| Subadult Male to Female | 1:6 |
| Juvenile Male to Female | 1:5 |
| Calves to Adult Female | 1:8 |

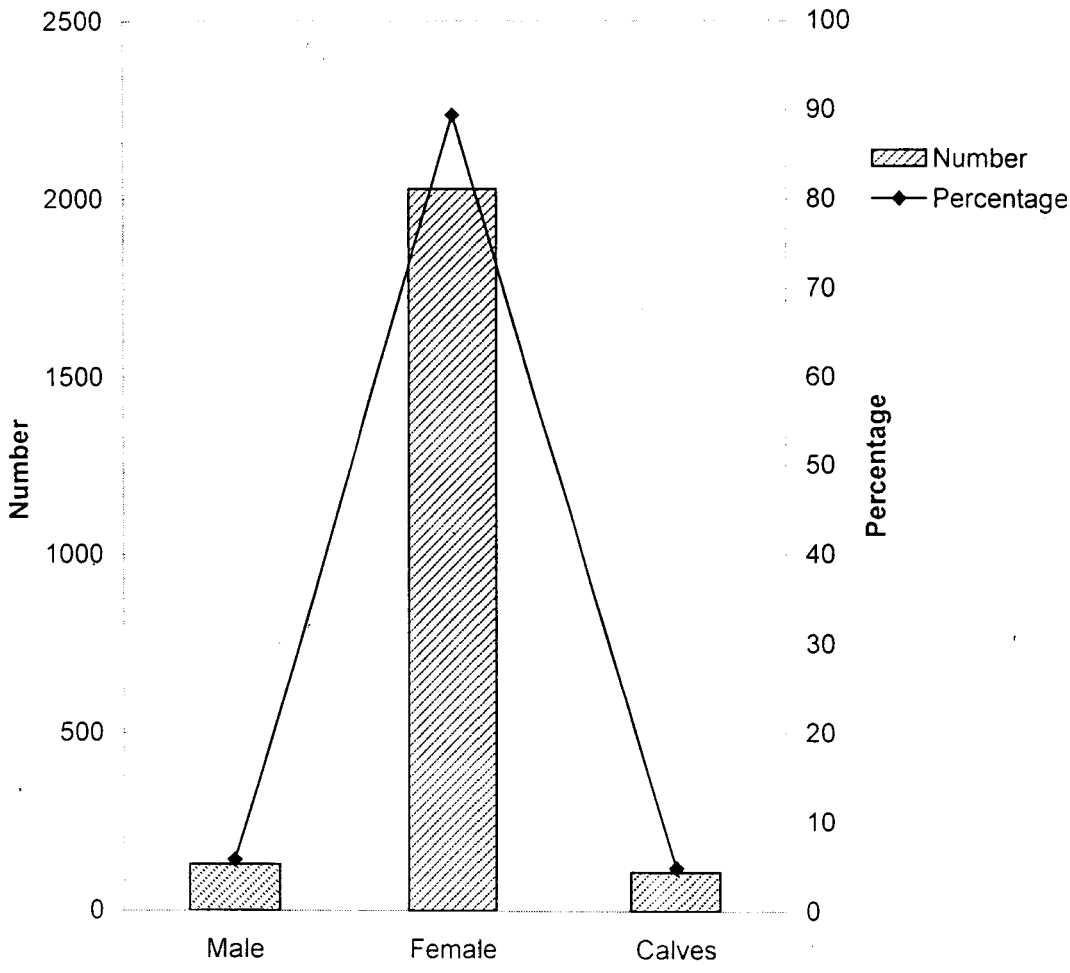


**Fig.5 Number and Percentage of different sex groups of elephant**

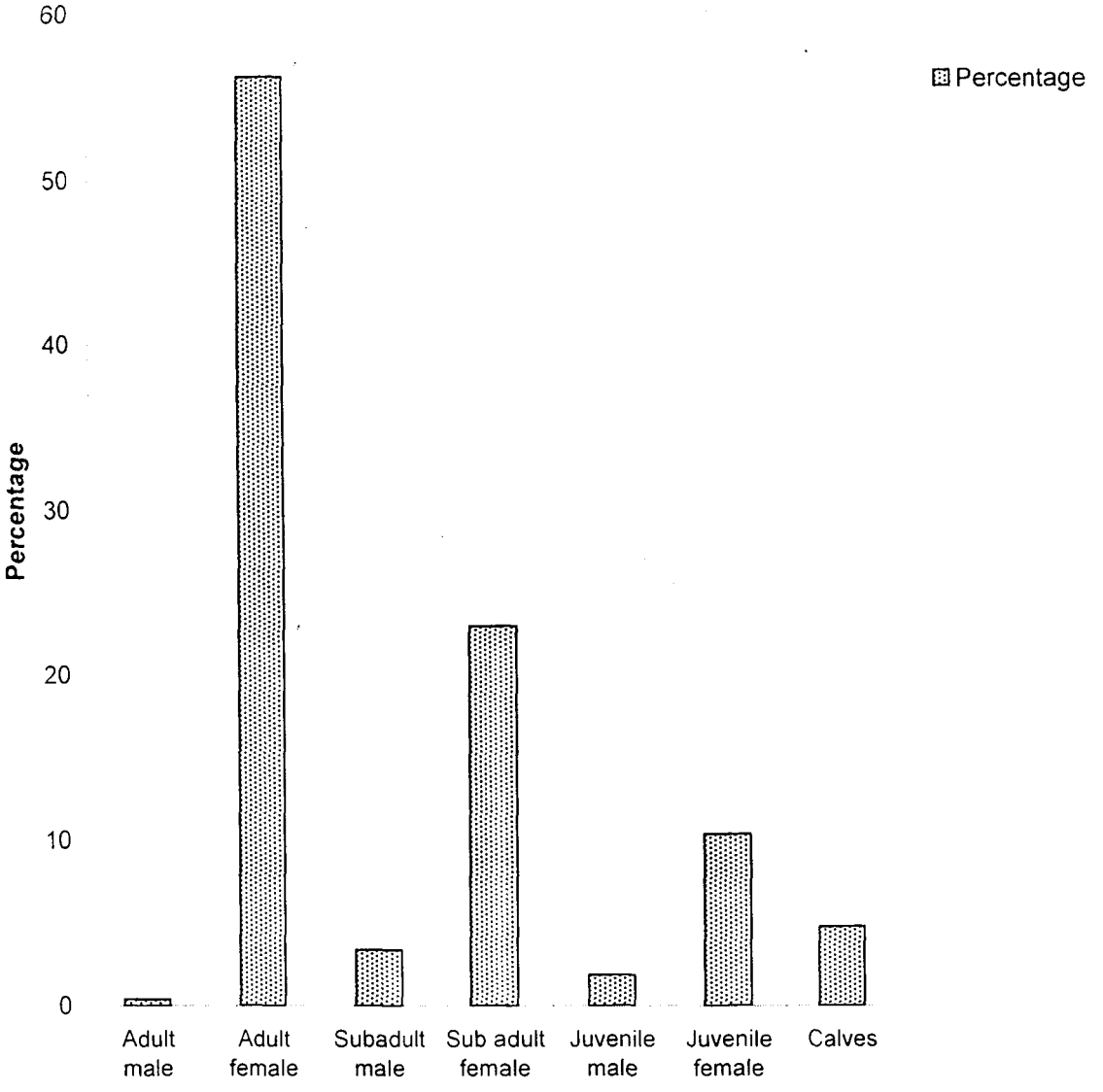


**Fig.6 Percentage of different age groups of elephant**

**Table - 10**

**Frequencies of observations of different sex class of elephants by season**

| Season | Male | Female | Calves |
|---|---|---|---|
| Winter | 18 | 380 | 15 |
| Summer | 33 | 411 | 18 |
| Monsoon | 34 | 555 | 28 |
| Post monsoon | 44 | 682 | 48 |

**Table - 10A**

**Expected frequencies of different sex class of elephants in different seasons**

| Season | Male | Female | Calves |
|---|---|---|---|
| Winter | 23.5115 | 369.6222 | 19.8663 |
| Summer | 26.3010 | 413.4757 | 22.2233 |
| Monsoon | 35.1249 | 552.1959 | 29.6792 |
| Post monsoon | 44.0627 | 692.7061 | 37.2312 |

## V. 3. NATALITY

According to Sukumar (1985) and Daniel et. al., (1987) in Asian elephants, the females are mature at 15 years and calf is born when the female is usually between 15-20 years of age. Young ones were observed several times during the study period and total of 109 calves to 1273 adult females were observed. The proportion between the adult females to calves was only 8:1. Newborn calves were observed throughout the year. Eisenberg and Lockhart (1972) reported that there is no evidence of seasonality in the births of elephants. Based on the samples collected during the study period, the fertility was estimated as 0.08 adults/female per year or mean birth interval of 11.6 years. The maximum number of calves were observed with the herds during wet seasons (Fig. 7) namely monsoon and post monsoon seasons with 25.68 % and 44% of occurrence respectively. However there was no prominent seasonality in the birth of elephant ($P > 0.01$. $R^2 = 0.8190$, SE = 6.0291, Co-efficient = 0.9439). The least frequencies were during late winter months (Fig.7).

## V.4 MORTALITY

The principal reason for the death of elephants in the reserve was poaching especially of the adult males. A total of 16 elephant deaths were observed during the study period, which consisted of 4 adult males, 6 adult females, 2 sub adult males, 2 sub adult females,

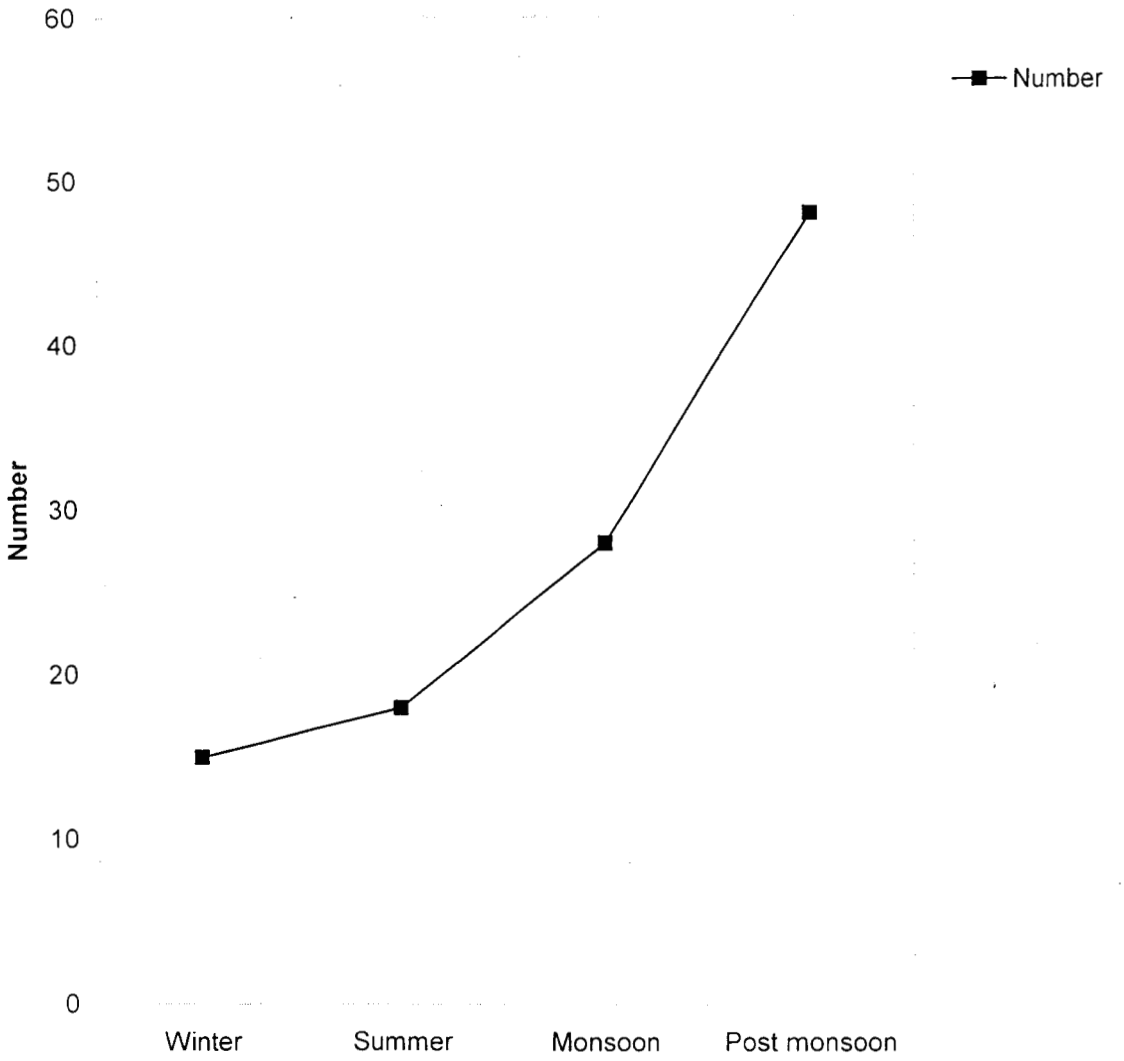


**Fig.7 Seasonal variations in proportion of elephant calves**

1 juvenile male and 1 calf, while the mortality in different age groups are considered the proportion of the mortality was very high in adult males. Only 1 calf died during 1991-94 period. In Periyar there was pronounced sex specific mortality. The causes of death are varied, but mainly due to poaching, besides injuries from gunshot, wounds and electric shocks (Table.11; Plate IV & V).

## V. 5. HERD SIZE AND AGGREGATION

Herd size and aggregation of grazing animals are known to influence by availability and abundance of food and other ecological factors such as rainfall, fire etc. As already mentioned, based on the number of individuals in the group, the elephant herds were grouped into 5 classes A (1-5), B (6-10), C (11-15), D (16-20) and E (above 20). Among the total number of herds observed, maximum frequencies were of smaller classes, class A and B with frequencies 178 and 122 respectively. The proportion of these two classes together was 81.52%. The class A comprised 48.37% and B, C, D with 33.15%, 13.04%, 3.53% respectively. Minimum number of herds was observed in a class E (1.9%) as showed in the fig. 8. Elephants have a propensity to become smaller in their herd size in the study area. The herd composition seems to be significant as members of all age groups were represented in most of the herds. However, only five herds were found with an adult male during the study period may be due to the low numbers of adult males in Periyar.

**Table 11**

**Frequency of died elephants and cause of death in the study area**

| Age group | Gunshot injuries | Electric shock | Unknown |
|---|---|---|---|
| Adult Male | 4 | - | - |
| Adult Female | 1 | 3 | 2 |
| Sub adult Male | 2 | - | - |
| Sub adult Female | - | 2 | - |
| Juvenile Male | 1 | - | - |
| Juvenile Female | - | - | - |
| Calves | - | 1 | - |

## Plate IV

Elephants – Electrocuted

## Plate V

Elephant - Poached and ivory removed

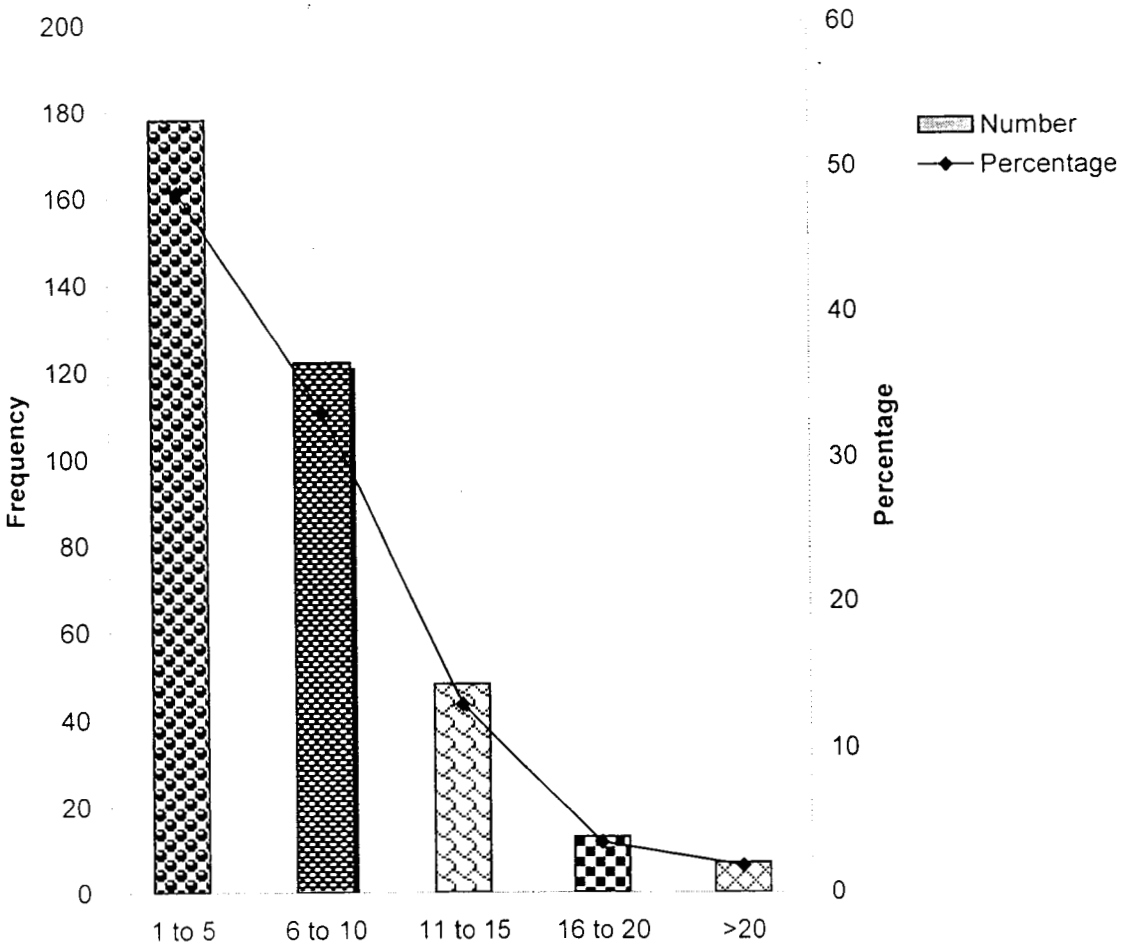


**Fig.8 Herdsize frequencies and percentage of elephant**

Solitary tuskers and adult females were sighted 4 times and 14 times, which constituted 1.08 and 3.8% respectively.

## V. 6. HERDSIZE VARIATION BY SEASONS

The availability of food and water seems to play an important role in the herdsize pattern and formation of elephants in the study area. Altogether 368 herds were observed during the study period. There was not much association between different herdsize classes of elephant with season was recorded in the study area ($\chi^2$= 9.3208, df = 12, P > 0.01). Of these 368 herds, 61 herds (16.57 %) were during winter, 82 herds (22.28 %) in summer, 102 herds (27.71 %) in monsoon and 123 (33.42) herds were during post monsoon season. The actual and expected frequencies (Table, 12 & 12 A) indicated that the maximum herds were sighted during post monsoon followed by monsoon seasons. The mean herdsize of elephants was comparatively larger during winter and post monsoon months constituted 6.7 and 6.3 respectively and in summer it was only 5.6 as shown in the fig. 9. However, the season and the mean herdsize have no significant association (P > 0.01, $R^2$ = 0.3146, SE = 0.7235, Co-efficient = 0.5609).

## V. 6.1. HERDSIZE IN WINTER

During the winter months altogether 61 herds were observed in all herdsize classes, of these the maximum number of herds

## Table - 12

**Seasonal variation of different herdsize group of elephant**

| Class | Winter | Summer | Monsoon | Post monsoon |
|---|---|---|---|---|
| 01 to 06 (A) | 35 | 39 | 48 | 56 |
| 06 to 10 (B) | 18 | 32 | 30 | 42 |
| 11 to15 (C) | 6 | 7 | 17 | 18 |
| 16 to20 (D) | 1 | 4 | 4 | 4 |
| Above 20 (E) | 1 | 0 | 3 | 3 |
| % | 16.57 | 22.28 | 27.71 | 33.42 |

## Table - 12A

**Seasonal variation of different herdsize group of elephant Expected frequencies**

| Class | Winter | Summer | Monsoon | Post monsoon |
|---|---|---|---|---|
| 01 to 06 | 29.5054 | 39.6630 | 49.3370 | 59.4946 |
| 06 to 10 | 20.2228 | 27.1848 | 33.8152 | 40.7772 |
| 11 to15 | 7.9565 | 10.6957 | 13.3043 | 16.0435 |
| 16 to20 | 2.1549 | 2.8967 | 3.6033 | 4.3451 |
| Above 20 | 1.1603 | 1.5598 | 1.9402 | 2.3397 |

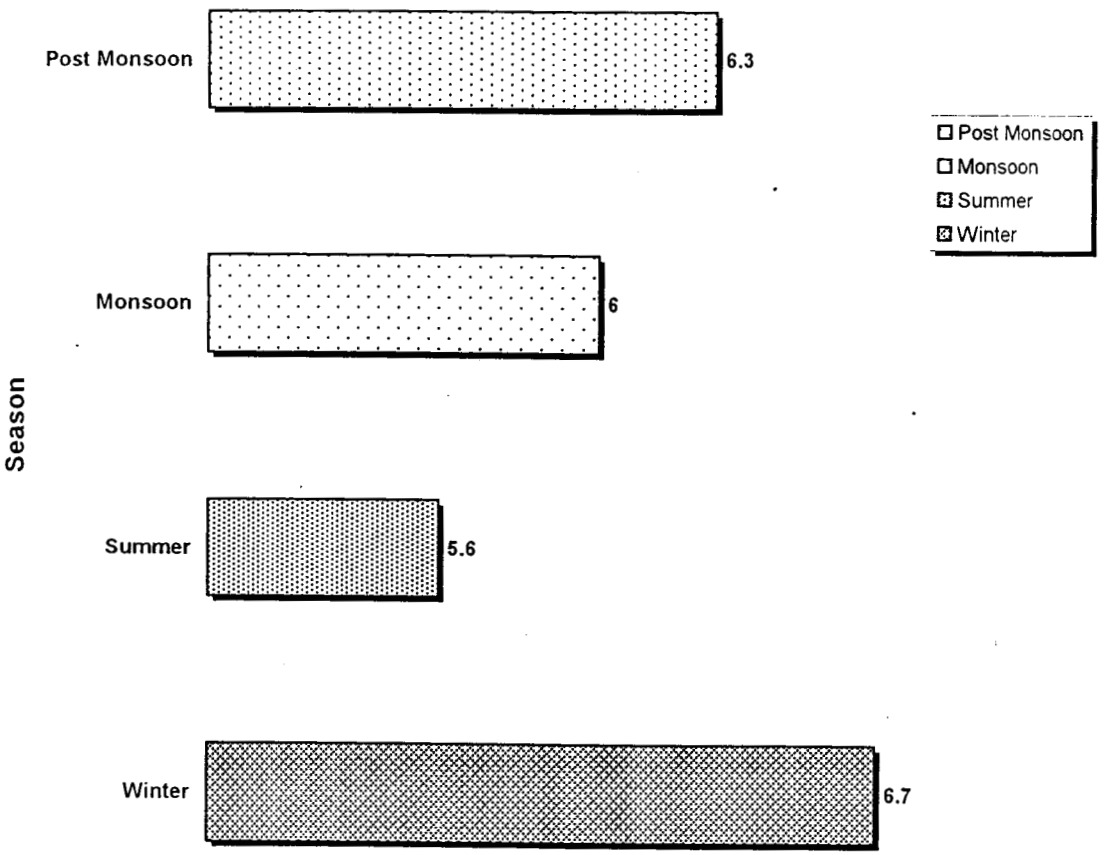


Fig.9 Seasonal variation in mean group size of elephant

belonged to the class A (57.37 %) followed by class B (29.50 %) and least frequencies were observed larger classes. D and class E (1.63 %) each and the class D comprised 9.83% as showed in the fig. 10. Thus the herdsize was maximum in smaller classes during this season.

## V. 6.2. HERDSIZE IN SUMMER

As shown in the figure- 10, 82 herds observed in summer months of which 47. 56 % herds belonged to class A comprising 39.02 % to class B 8.54 % to class C and 4.88% to class D. Larger herds representing the last class (Class E) was not observed during the study period.

## 4.6.3 HERDSIZE IN MONSOON

The smaller classes have more frequencies during rainy months in Periyar. Percentage of occurrence of different herdsize class during this season is shown in figure 10. The maximum number of herds belonged to class A and B with 47.65 % and 29.41 %, while the occurrence of classes C, D, and E constituted 16.6%, 3.92%, and 2.94% respectively.

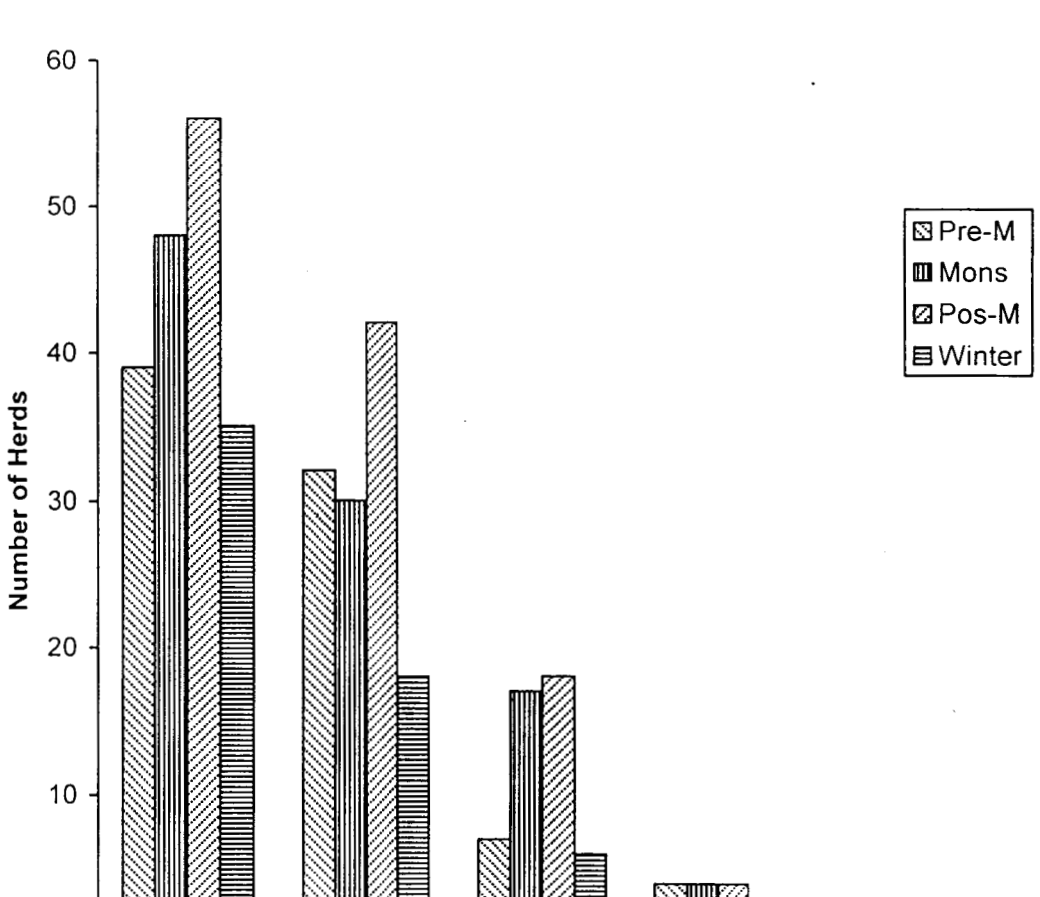


**Fig.10 Variations in the Herdize pattern of elephants by seasons**

## V. 6.4. HERDSIZE IN POST MONSOON

Out of the total 368 herds sighted, 123 herds were observed during this period, the percentage of occurrence being optimum for class A and B (45.52% and 34.14%). The sightings of larger herdsize classes (D and E) were 3.25% and 2.43% and class C consists of 14.63% (Fig. 10).

## V. 7. VEGETATION AND HERDSIZE VARIATION

The total numbers of herds observed were also grouped on the basis of the different vegetation types. There was not a significant influence of vegetation types on herdsize formation of elephants in Periyar ($\chi^2$ = 22.8140 df = 20 P > 0.01). Out of the 368 herds met with, 118 were sighted in grasslands, 100 in savannahs, 72 in moist deciduous forests, 42 in semi evergreen forests, 20 in evergreen forests and 16 in eucalyptus plantations (Table. 13). The actual frequencies and expected frequencies of different herdsize groups in different vegetations were given in the tables 13 and 13A . Among the 118 herds observed in grassland habitat, 53, 46 belonged to class A and B and 14 to class C. The frequency of observation of larger class, E, was only 2. The classes ranging from A to C were observed more in grassland vegetations. The herds above 20 were sighted in moist deciduous and evergreen forest with 3 and 2 herds respectively.

## Table - 13

## Frequency of observation of elephant herds in different vegetation types

| Herd size | Grassland | Savannah | Moist deciduous | Semi evergreen | Evergreen | Plantation |
|---|---|---|---|---|---|---|
| 01 to 06 (A) | 53 | 51 | 33 | 24 | 10 | 7 |
| 05 to 10 (B) | 46 | 32 | 19 | 13 | 6 | 6 |
| 10 to 15 (C) | 14 | 11 | 14 | 4 | 2 | 3 |
| 15 to 20 (D) | 3 | 6 | 3 | 1 | 0 | 0 |
| Above 20 (E) | 2 | 0 | 3 | 0 | 2 | 0 |

## Table - 13A

## Frequency of observation of elephant herds in different vegetation types Expected frequencies

| Class | Grassland | Savannah | Moist deciduous | Semi evergreen | Evergreen | Plantation |
|---|---|---|---|---|---|---|
| 01 to 06 | 57.0761 | 48.3696 | 34.8261 | 20.3152 | 9.6739 | 7.7391 |
| 05 to 10 | 39.1196 | 33.1522 | 23.8696 | 13.9239 | 6.6304 | 5.3043 |
| 10 to 15 | 15.3913 | 13.0435 | 9.3913 | 5.4783 | 2.6087 | 2.0870 |
| 15 to 20 | 4.1685 | 3.5326 | 2.5435 | 1.4837 | 0.7065 | 0.5652 |
| Above 20 | 2.2446 | 1.9022 | 1.3696 | 0.7989 | 0.3804 | 0.3043 |

## V. 8. HABITAT PREFERENCE OF ELEPHANTS

Darling (1960) has described the African elephant as the head of the larger group of browsing and grazing ungulates forming a spectrum covering the range of vegetations. This seems to be the same with the elephants in Periyar as the six types of vegetations in the Reserve, namely grassland, savannah, moist deciduous forest, semi evergreen forest, evergreen forest and eucalyptus plantation are visited and utilized by elephants. These habitats though not clearly distinguishable in many places, exhibit much diversity in their composition and are influenced by climatic factors such as temperature, wind, rainfall and fire.

The elephant herds observed in different habitats in different months during the study period in the reserve is given in the table 14. Grasslands, savannahs and moist deciduous forests were preferred to dense evergreen forest. In grasslands, a total 118 herds of elephants were sighted (Plate VI). Out of the total 368 herds sighted, 32.06 % were in grasslands, 27.17% in savannah and 19.56% in moist deciduous forests. The percentage of preference of elephants to semi evergreen and evergreen constituting 5.4% and 11.41% respectively. The least preferred habitat, plantation, consists only 4.3% (Fig.11).

The percentage of elephant herds observed was more in open habitats the percentage of sightings in grassland and savannah was

## Table 14

## Monthly habitat preference of elephants

| Habitat | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grassland | 6 | 8 | 10 | 5 | 7 | 8 | 9 | 21 | 17 | 11 | 10 | 6 | 32.06 |
| Savannah | 4 | 3 | 13 | 7 | 6 | 4 | 7 | 12 | 15 | 13 | 9 | 7 | 27.17 |
| Moist deciduous | 12 | 8 | 5 | 3 | 5 | 10 | 4 | 6 | 3 | 2 | 9 | 5 | 19.56 |
| Evergreen | 4 | 5 | 1 | 2 | 2 | - | 2 | - | 3 | 1 | - | - | 5.43 |
| Semi evergreen | 7 | 4 | 5 | 2 | 5 | 6 | 3 | 2 | 2 | 4 | - | 2 | 11.41 |
| Plantation | - | - | - | - | 4 | 2 | 3 | 3 | 2 | 1 | - | 1 | 4.33 |

## Plate VI

An Elephant herd on grassland near the lakeshore

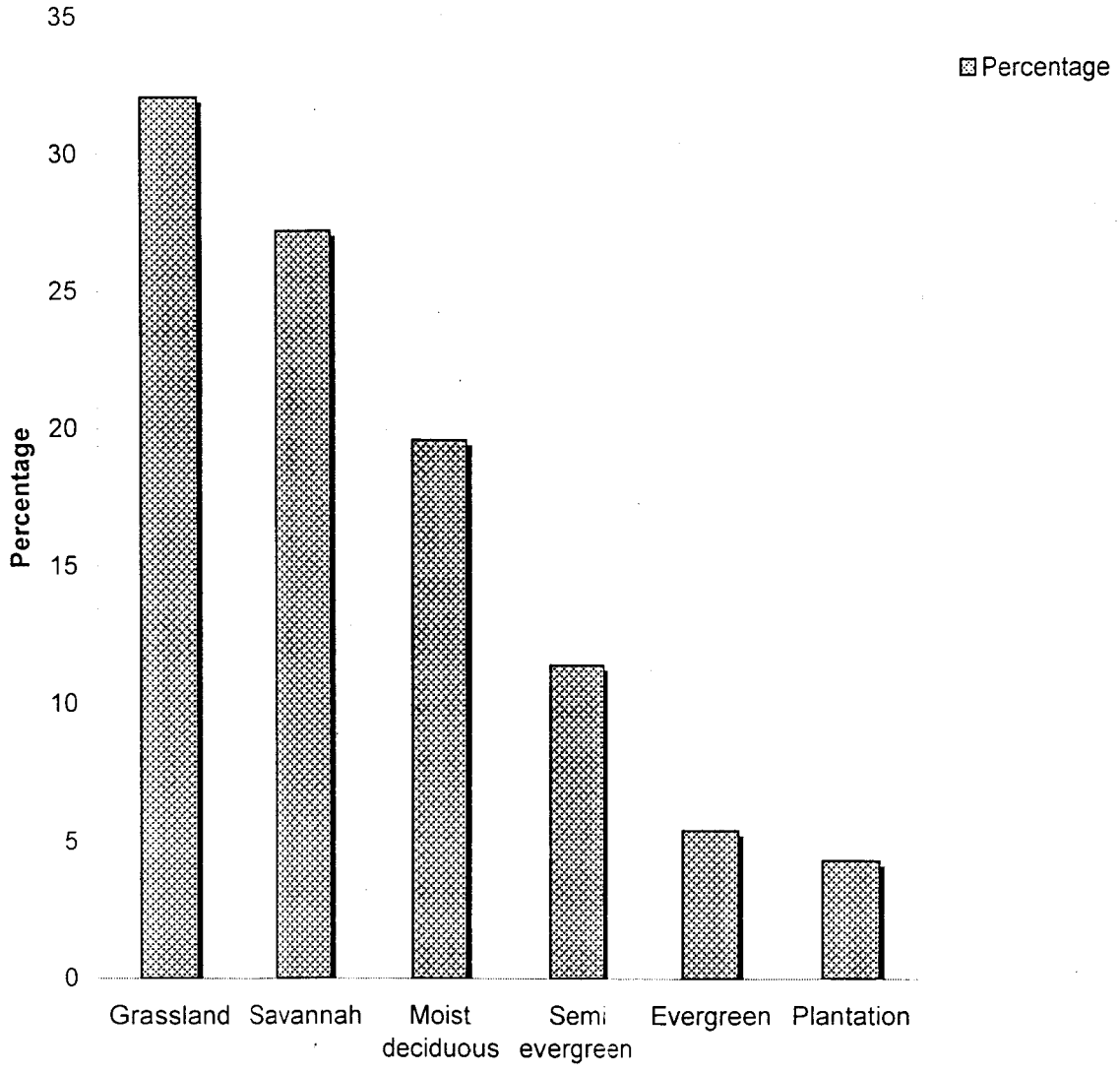


**Fig.11 Percentage of preference of elephants to various habitats**

together 59.2% though the proportion of this habitat comprised only 1.6% of the total area. The less preferred habitats like evergreen forests and semi evergreen forests however covered extensive areas in the reserve. The evergreen vegetation formed 40.39% of the total area while the preference of elephants to this habitat was only 5.43% as given in the table 15 and fig. 12.

Elephants in Periyar showed little preference to the semi evergreen and evergreen habitats. Only 42 and 20 herds were observed in these two habitats during the study period. As described by Darling (1960), elephant is the great " path maker " in evergreen forests. Elephant utilization of eucalyptus plantation in Periyar was 4.35%, which was its least preferred habitat.

## V. 9. SEASONAL VARIATIONS IN HABITAT USE

Out of the 368 of elephant herds, a total of 82 herds (22.28%) were observed in pre-monsoon, 102 (27.72%) in monsoon, 123 (33.42%) in post-monsoon and 61 (16.58%) in winter seasons in the study area. (Table.16). Maximum numbers of herds observed in grasslands and open forests during monsoon and post-monsoon seasons was 78.8%. Their occurrence in semi evergreen and evergreen in total was only 16.84% and in plantation 4.34%

Significant variation in habitat use by elephants during periods of low, medium and high precipitation was observed. The correlation

## Table 15

### Area and percentage of each habitats in Periyar and the percentage of occurrence of herbivores

| Habitat | Area (Sq. Km.) | Percentage | Elephant | Gaur | Sambar |
|---|---|---|---|---|---|
| Grassland & Savannah | 12 | 1.6 | 59.2 | 41.55 | 61.03 |
| Moist Deciduous | 98 | 12.98 | 19.6 | 28.57 | 30.68 |
| Semi evergreen | 275 | 36.42 | 11.4 | 18.18 | 6.20 |
| Evergreen | 305 | 40.39 | 5.43 | 7.79 | - |
| Plantation | 55 | 7.28 | 4.35 | 3.87 | 2.06 |
| Reed brakes | 10 | 1.32 | - | - | - |

## Table 16

### Seasonal difference of habitat use of elephants in Periyar

| Habitat | Winter | Summer | Monsoon | Post monsoon | % |
|---|---|---|---|---|---|
| Grassland | 14 | 22 | 38 | 44 | 32.06 |
| Savannah | 7 | 26 | 23 | 44 | 27.17 |
| Moist deciduous | 20 | 13 | 20 | 19 | 19.56 |
| Semi evergreen | 11 | 12 | 11 | 8 | 11.41 |
| Evergreen | 9 | 5 | 2 | 4 | 5.43 |
| Plantation | - | 4 | 8 | 4 | 4.34 |

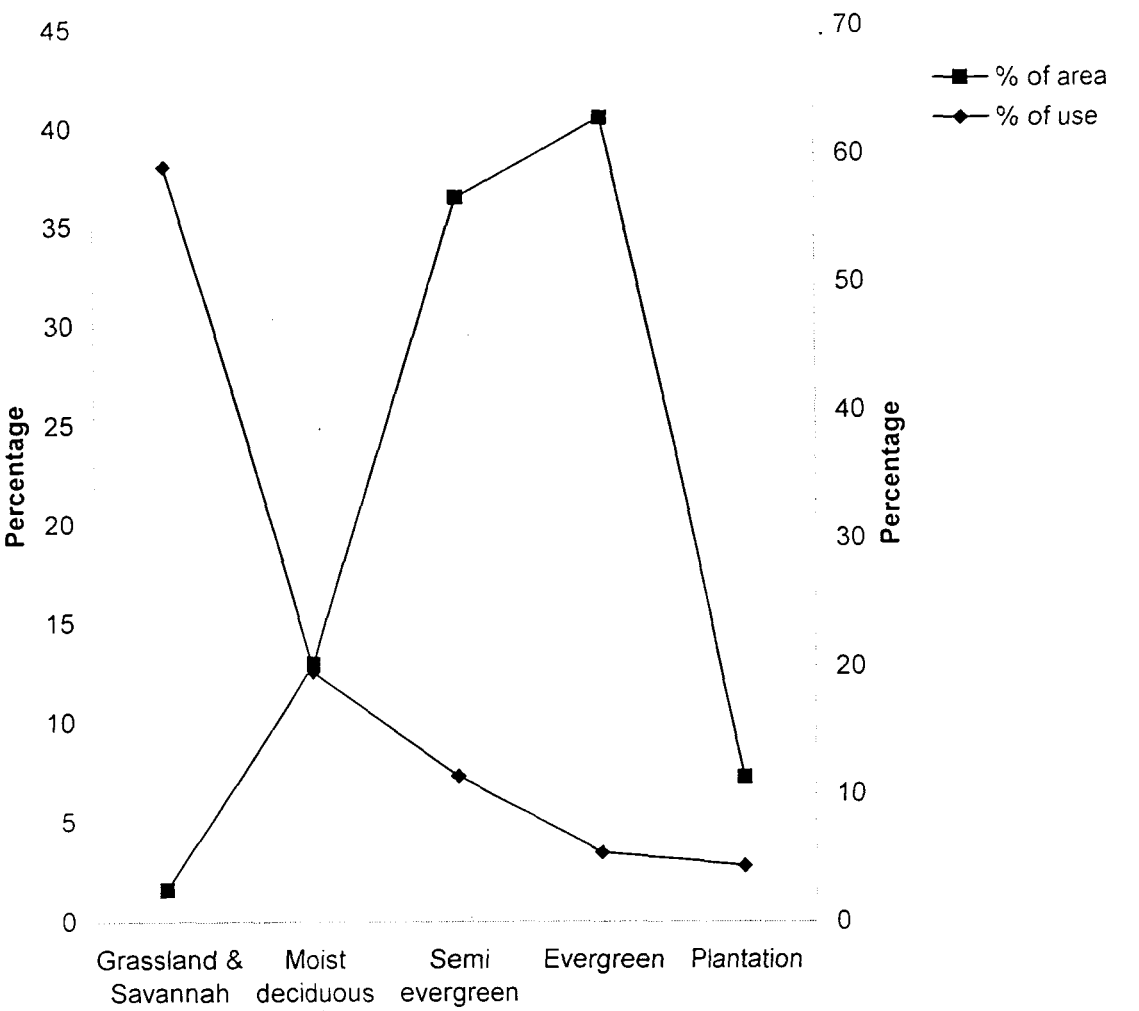


**Fig.12 Proportion of the areas of different habitats and percentage of elephants utilisation to each habitat**

between habitat utilization of elephants and season was very significant in the study area ($\chi^2 = 34.7892$, df = 15, $P < 0.01$). In grasslands up to a maximum of 44 and 38 herds were observed in post-monsoon (37.29%) and monsoon seasons (32.20%) respectively. Lesser number of herds utilized this type of vegetation during winter and pre-monsoon. Maximum utilization of savannah and moist deciduous habitats by elephants was in winter and post-monsoon while the use of dense forest was more during summer months.

## V. 10. FOOD AND FEEDING HABITS

Altogether 91 species of food plants of elephants were identified during the study period. Of these, 36 species were grasses, 21 herbs, 12 shrubs, and 22 tree species as shown in the table 17. The table shows that some tree species forms an important part of the elephants' diet especially during dry seasons and there were seasonal difference in the use of each tree species in the study area. For instance, some woody species like *Grewia tiliaefolia, Grewia aspera, Telia gamblia* were utilized throughout the year though these species preference was more during late winter and summer months. As far as the dietary diversity is concerned elephants used more grasses and they depend little on browse species during wet seasons and mostly utilized woody species during dry months. However they took much grass also during summer months in the study area.

## Table 17
## Food plants of Elephants collected from the study area

| Name of the plant | Family | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Achyranthes aspera* | Amarantaceae | * | * | | * | | | * | * | * | * | * | * |
| *Actinodaphne hirsuta* | Lauraceae | | * | * | | | | | | | * | | |
| *Ageratum conyzoids* | Asteraceae | * | * | * | * | | | * | * | * | * | * | * |
| *Alloteropsis cimicina* | Graminae | * | * | * | * | | * | * | * | * | * | * | * |
| *Apluda aristata* | Graminae | * | * | | * | | * | * | * | * | | * | * |
| *Apocopis wightii* | Graminae | * | * | | | | * | * | * | * | | * | |
| *Appolonias arnottii* | Lauraceae | | | | * | | | * | * | | | | |
| *Artocarpus hetrophyllus* | Moraceae | * | * | * | | | | | | | | | * |
| *Bambusa arudinacea* | Graminae | * | * | * | * | | * | * | * | * | * | * | * |
| *Bidens humilis* | Asteraceae | * | * | * | | | | | * | * | * | * | * |
| *Blanivillea rhomboidea* | Asteraceae | | * | | | | | | | * | | | * |
| *Canthium augustifolium* | Rubiceae | | | | * | * | | | | * | | | |
| *Careya arborea* | Lecythidaceae | | | * | | | | | * | * | * | | |
| *Caryota urens* | Palmae | | | | | | | | * | * | * | | |
| *Cassia mimosoides* | Caesalpiaceae | | * | | | | | | * | * | | | * |
| *Chloris spp.* | Graminae | * | * | * | * | | * | * | * | * | | * | * |
| *Cinnamomum malabaratum* | Lauraceae | | | | | | | | | * | | | |
| *Cipadessa baccifera* | Meliaceae | * | | | | | * | * | * | | | * | * |
| *Cordia myxa* | Boraginaceae | | | * | * | | | | * | * | | | |
| *Curculigo orchioides* | Zingiberaceae | * | | | | | | | | | * | * | * |
| *Curcuma angustifolia* | Zingiberaceae | * | | | | | | | | | * | | |
| *Cymbopogon flexuosus* | Graminae | * | * | * | * | * | * | * | * | | * | * | * |
| *Cynodon dactylon* | Graminae | * | * | | * | * | * | * | * | * | * | * | * |
| *Cyrtococcum oxyphyllum* | Graminae | * | * | * | * | | * | * | * | * | * | * | * |
| *Cyrtococcum patens* | Graminae | * | | | | * | * | | * | | | * | * |
| *Desmodium pulchellum* | Pappilionaceae | | | | | | * | * | * | * | | | |
| *Desmodium trifolium* | Fabaceae | * | * | | | | | | | * | * | * | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Digitaria spp.* | Graminae | * | * | * | | | * | * | * | * | * | * | * |
| *Dimeria spp.* | Graminae | * | | * | | * | * | * | * | * | * | * | * |
| *Dinebra retroflexa* | Graminae | * | * | * | * | * | * | * | * | * | * | * | * |
| *Eleusine indica* | Graminae | * | * | | * | | * | * | * | | * | * | * |
| *Emblica officinalis* | Euphorbiaceae | | * | * | | | | | | | | | |
| *Emilia sonchifolia* | Asteraceae | * | * | * | * | | * | * | * | | * | * | * |
| *Entada scandens* | Leguminosae | | | | | | * | * | * | | | | |
| *Eragrostis bifaria* | Graminae | * | * | | | | * | * | * | | * | * | * |
| *Eragrostis tenuifolia* | Graminae | | | | | | * | * | * | | | | |
| *Eragrostis unioloides* | Graminae | * | * | * | | | | * | * | * | | * | * |
| *Ficus hispida* | Moraceae | | * | | * | | | | | | * | * | * |
| *Ficus spp.* | Moraceae | | * | * | * | | | | | | * | * | * |
| *Garnotia arundinacea* | Graminae | * | * | * | | * | | * | * | | * | * | * |
| *Globba bulbifera* | Zingiberaceae | * | | | | | | | | | | | * |
| *Grewia aspera* | Teliaceae | * | | | * | * | * | * | * | | * | * | * |
| *Grewia teliaefolia* | Teliaceae | * | * | * | | | * | * | * | * | * | * | * |
| *Hackeria subpeltata* | Piperaceae | * | | | | | | | * | * | | * | * |
| *Helicteres isora* | Sterculiaceae | * | * | * | * | * | | * | * | * | * | * | * |
| *Hemidesmus indicus* | Asclepiaceae | | | | | | | | | * | | | |
| *Heteropogon contortus* | Graminae | * | * | * | * | * | * | * | * | * | * | * | * |
| *Imperata cylindrica* | Graminae | | | | * | | * | * | * | * | * | | |
| *Justicia spp.* | Acanthaceae | * | * | * | * | * | * | * | * | * | * | * | * |
| *Knoxia mollis* | Rubiaceae | * | | | | | | | | | * | | |
| *Kyllinga spp.* | Graminae | * | * | | * | | * | * | | * | * | * | * |
| *Lantana aculeata* | Verbenaceae | * | | | | | | | | | | * | * |
| *Maesa indica* | Myrsinae | | | | * | * | | * | | | * | | |
| *Mangifera indica* | Anacardiaceae | | | * | * | * | | | | | | | |
| *Manisuris granularis* | Graminae | * | * | | | * | | * | * | | * | * | * |
| *Mimosa pudica* | Mimosae | * | * | * | | | | * | * | * | * | * | * |
| *Ochlandra scriptoria* | Graminae | * | * | | * | * | * | * | * | * | * | * | |
| *Ochlandra travancorica* | Graminae | | * | * | | * | * | * | * | * | * | * | * |
| *Olea dioica* | Oleaceae | | * | * | | * | * | | | * | | | |
| *Oplismenus compositus* | Graminae | * | | * | * | * | * | * | * | * | | * | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Oryza granulata* | Graminae | | * | * | | | * | | * | | * | * | |
| *Panicum brevifolium* | Garminae | * | * | * | * | * | * | * | * | * | * | * | * |
| *Panicum javanicum* | Graminae | * | * | | | | * | | | | | * | * |
| *Panicum montanum* | Graminae | * | * | | * | * | * | * | * | * | * | * | * |
| *Panicum repens* | Graminae | * | * | * | * | | * | * | * | * | * | | * |
| *Paspalum compactum* | Graminae | * | | | | | | | * | * | | | |
| *Paspalum conjugatum* | Graminae | * | * | * | * | * | * | * | * | * | * | * | |
| *Pavonia zeylanica* | Malvaceae | | | | | | | | | | | * | * |
| *Phoenix humilis* | Palmaceae | * | * | | | | | * | * | * | * | * | * |
| *Psidium guajava* | Myrtaceae | | * | * | | | | | | | | | * |
| *Randia dumetorum* | Rubiaceae | * | * | * | * | | | | | | * | * | * |
| *Rottboellia exaltata* | Graminae | * | * | | * | * | * | * | * | * | * | * | * |
| *Saccharum spontaneum* | Graminae | * | | | | | | | * | | * | * | |
| *Schumannianthus virgatus* | Saxifragaceae | | | | | | * | * | | | * | * | * |
| *Setaria palmifolia* | Graminae | * | * | * | * | * | * | * | * | * | * | * | * |
| *Sida cordifolia* | Malvaceae | | * | | | | | | | * | * | * | * |
| *Sida rhombifolia* | Malvaceae | | | * | * | * | | | | | * | * | |
| *Solanum sisymbrifolium* | Solanaceae | | | | * | * | | | * | * | | * | |
| *Solanum torvum* | Solanaceae | * | | | | | | | | * | * | * | * |
| *Stachytarpeta indica* | Verbenaceae | | | | | | | | | | * | * | * |
| *Sterculia alata* | Sterculaceae | * | | | * | | | | | | * | * | * |
| *Syzigium cumini* | Myrtaceae | | | | | | | | | | * | | |
| *Telia gamblia* | Teliaceae | * | * | * | * | | * | * | * | * | * | * | * |
| *Tephrosia purpurea* | Fabaceae | * | | | | | | | | * | * | * | * |
| *Terminalia crenulata* | Combretaceae | | | | | | | | | * | * | * | |
| *Themeda cymbaria* | Graminae | * | | * | | * | * | * | * | * | | | * |
| *Themeda triandra* | Graminae | * | | * | * | * | | * | * | * | * | * | * |
| *Urena lobata* | Malvaceae | | | | | | | | | | | * | * |
| *Urena sinuata* | Malvaceae | * | * | | * | * | * | * | * | * | * | * | * |
| *Vateria indica* | Dipterocaraceae | | | | | * | | | | * | | | |
| *Vernonia cinerea* | Asteraceae | * | * | | | | | | * | * | | * | * |

As already known, grasses constitute the major portion of elephants diet in the study area, though a clear grass/herb separation was often not possible especially in ecotone areas. A close examination reveals that the elephants consumed at least small amounts of most of the plants found in the area. Grass species constitute major portion of its diet with slight variations by seasons. Besides leaves, the elephants consumed fruits and barks of a number of trees. Fruit of *Artocarpus hetrophyllus, Emblica officinalis, Ficus hispida, Ficus spp., Mangifera indica, Psidium guajava, Helicteres isora* were eaten along with twigs and leaves in the fruiting seasons. Bark of trees like *Telia gamblia, Cordia myxa, Ficus hispida, Ficus spp., Grewia teliafolia* and *Helecteres isora* are mostly eaten during summer and post-monsoon seasons. There seems to be seasonal variation in the use of these food items. However leaves, twigs and bark of plants are preferred in drier months when the availability of tender grasses is less. The variation in the use of different type of food plants by seasons was noticed; more browse species were taken during dry periods to that of wet months (Table18).

The elephants in the study area have knocked down or pulled down some of the trees and consumed. Branches that have been twisted off and partly debarked are characteristic of elephant feeding activity. If not debarked, the branches are often defoliated. Though their utilization of evergreen forest is less, they often make path through forest for moving from one place to another as observed in African elephant.

**Table 18**

**Seasonal variations in use of different species of food types of elephant**

| Type | Winter | Summer | Monsoon | Post monsoon |
|---|---|---|---|---|
| Grass | 35 | 30 | 36 | 36 |
| Herb | 17 | 10 | 8 | 21 |
| Shrub | 7 | 10 | 6 | 11 |
| Trees | 13 | 13 | 6 | 20 |

## V. 10.1. WINTER DIET

During the winter months, elephant feed mainly on grasses. However, herbs, shrubs and tree species are also included in their diet during winter. Of the total 91 species of food plants identified 72 (78.02 %) species were used by the elephants in this period. Grasses form the major portion of winter food with (48.61%) followed by herbs (23.94%), and shrubs (9.72%) and trees (18.05%)-Fig. 13.

The grass species favoured by the elephants during this period were *Alloteropsis cimicina, Apluda aristata, Bambusa arundinacea, Chloris spp., Cympopogan flexuosa, Cynodon dactylon, Cyrtococcus oxyphyllum, Digitaria spp., Dinebra retroflexa, Eleusine indica, Eragrostis bifaria, Eragrostis unioloids, Garnotia arundinacea, Heteropogon contortus, Kyllinga spp., Manisuris granularis, Ochlandra scriptoria, Panicum brevifolium, Panicum montanum, Panicum repens, Paspalm conjugatum, Rottboellia exaltata* and *Setaria palmifolia*. Of these, *Panicum repens* is the important food plant of elephant when they feed on the lakeshore and *Cymbopogon spp.* when they forage on hilltops and slopes. The favoured herb species in winter months include *Achyranthes aspera, Ageratum conyzoids, Bidens humilis, Desmodium trifolium, Justicia spp., Mimosa paudica, Urena sinuata and Vernonia cinerea and shrub species inculde Helicteres isora, Phoenix humilis. Grewia aspera, Grewia teliaefolia, Randia dumetorum* and *Telia gamblia* were most preferring tree forage of elephants in winter months in the study area.

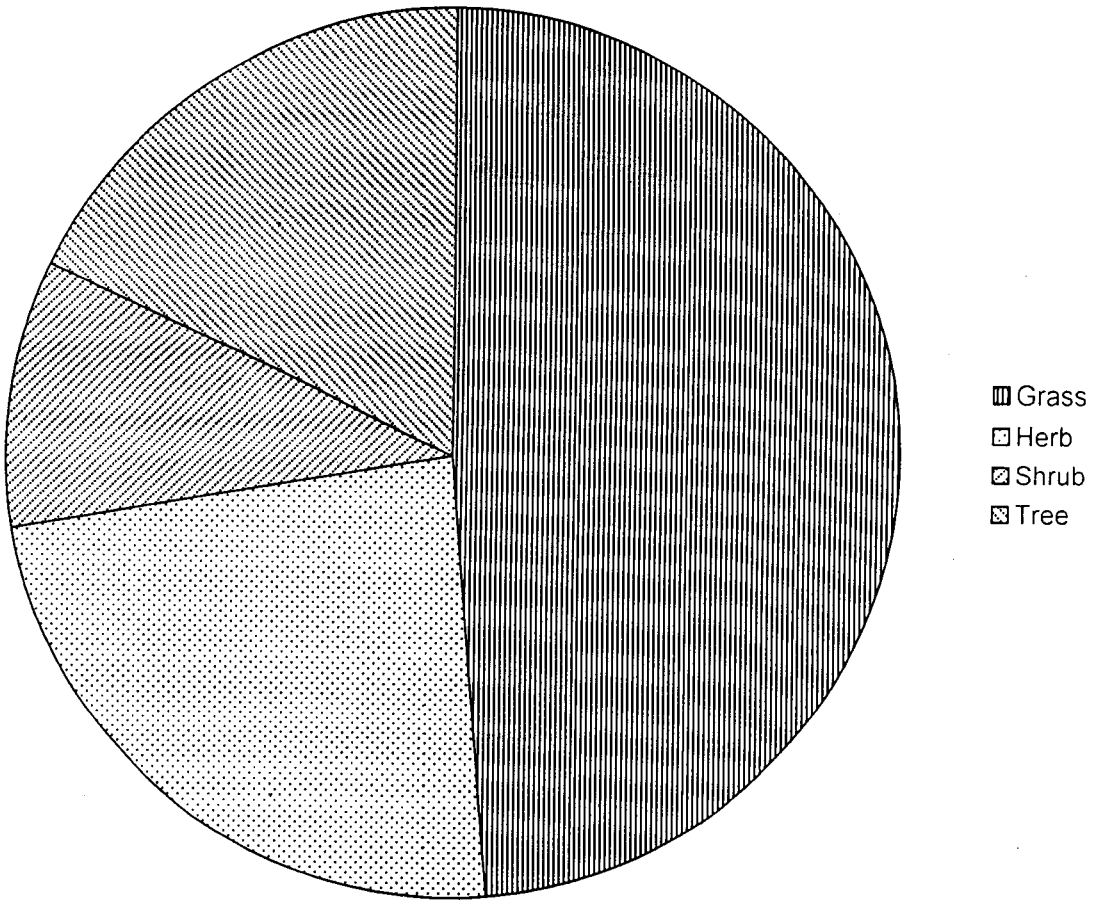


Fig. 13 Variations in forage types during winter

## V. 10.2. SUMMER DIET

The elephant use less grasses in summer months in respect to other seasons. A total of 63 food plants used by the elephants in this period, out of which 25 (39.68%) were grasses, 10 herbs (15.87%), 10 (15.87%) species of shrubs and 18 trees species that constitute 28.57% (Fig. 14).

The favoured grasses were *Cymbopogon flexuosus*, *Dinebra retroflexa*, *Heteropogon contortus*, *Panicum brevifolium*, *Panicum repens*, *Paspalum conjugatum*, *Setaria palmifolia and Themeda triandra* where as frequently using herbs were *Ageratum conyzoids*, *Emilia sonchifolia*, *Justicia spp.*, and *Urena sinuata*. The use of trees were observed more during these dry months and they mainly feed on trees like *Telia gamblia*, *Randia dumetorum*, *Maesa indica*, *Grewia teliaefolia*, *Grewia aspera*, *Ficus spp.* and *Emblica officinalis*.

## V. 10.3. MONSOON DIET

The utilization of herbs, shrubs and trees were found to be minimum in rainy months, while the consumption of grass attained its peak that constituted 64.28% while the consumption of herbs comprised 14.28%. The shrubs and trees were only 10.71% each (Fig. 15). The grass species mostly eaten by the elephants during this period were *Alloteropsis cimicina*, *Apluda aristata*, *Apocopis wighttii*, *Bambusa arundinacea*, *Chloris spp.*, *Cymbopogan*

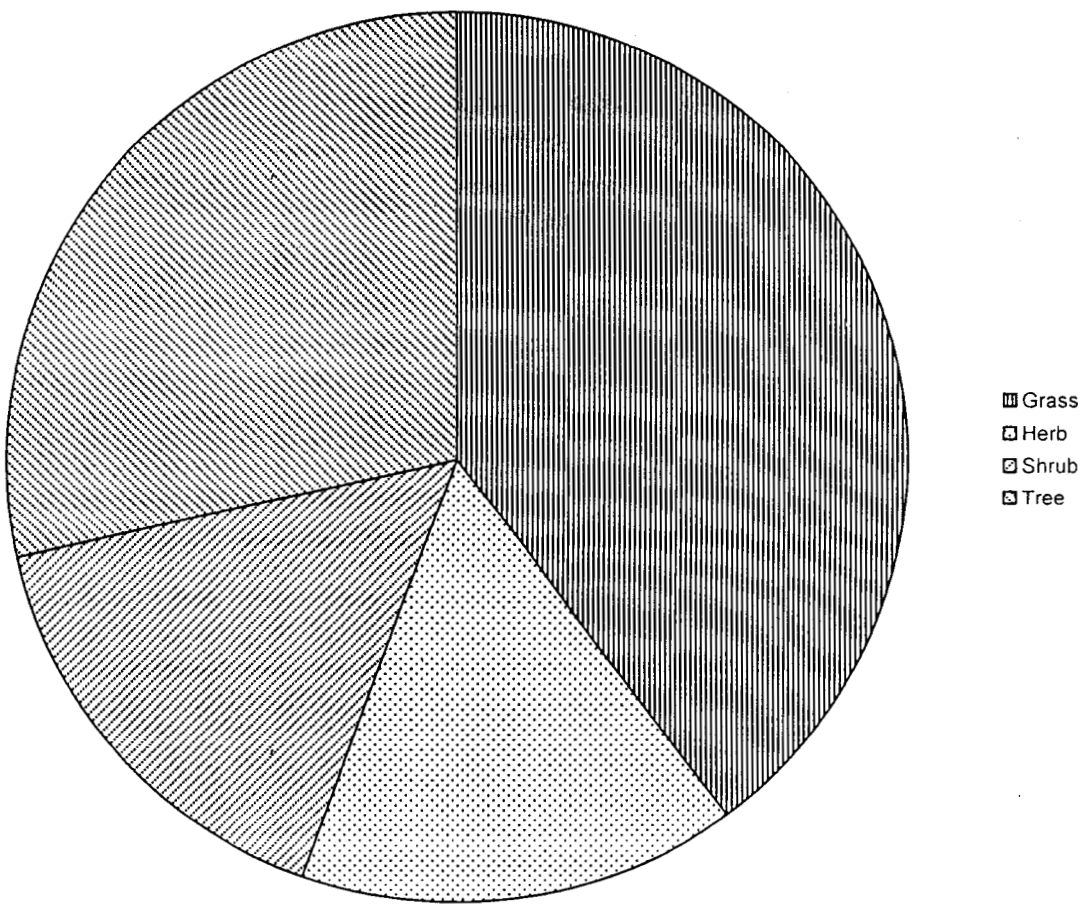


**Fig.14 Variations in forage types of elephants during summer**

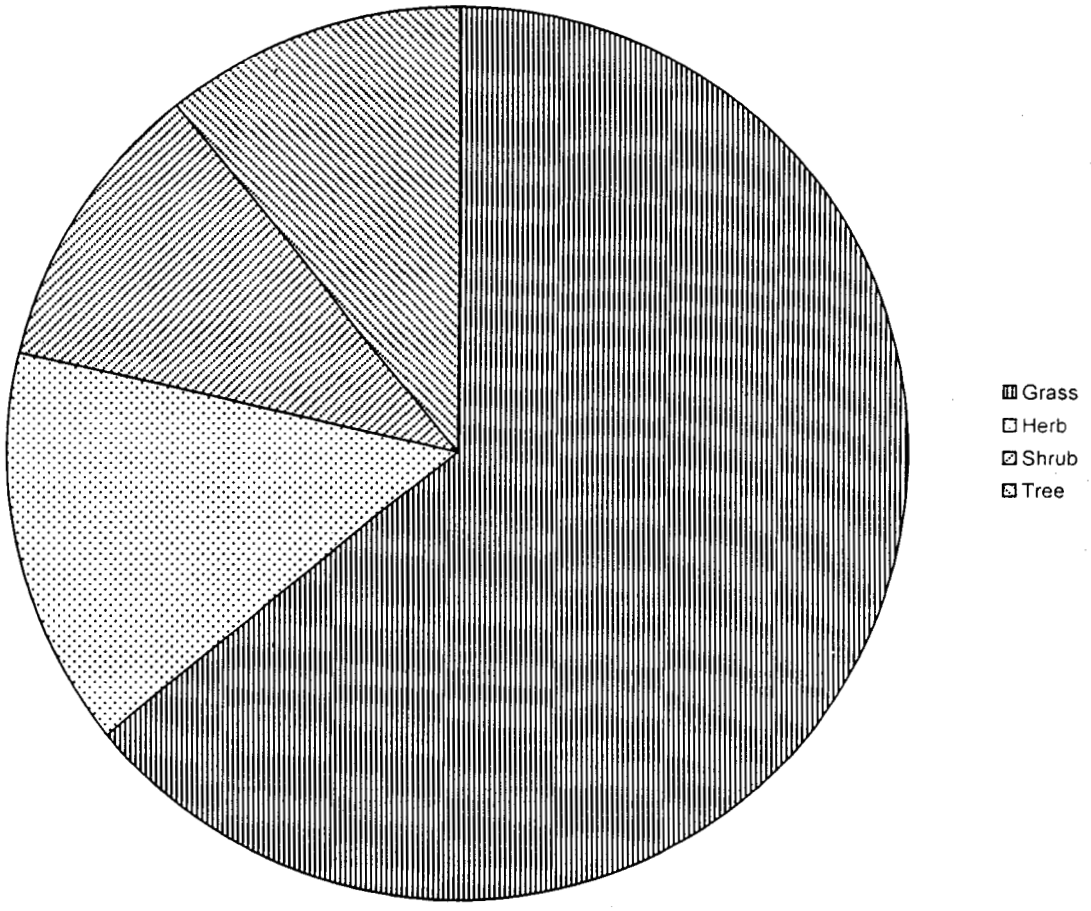


**Fig.15 Variations in forage types of elephants during monsoon**

*flexuosus, Cynodon dactylon, Cyrtococcum oxyphyllum, Digitaria spp., Dimeria spp., Dinebra retroflexa, Eleusine indica, Eragrostis bifaria, Eragrostis unioloids, Garnotia arundinacea, Heteropogon contortus, Imperata cylindrica, Manisuris granularis, Ochlandra spp., Panicum brevifolium, Panicum montanum, Panicum repens, Paspalum conjugatum, Rottboellia exaltata, Setaria palmifolia, Themeda cymbaria* and *Themeda traindra*. and the preferred herbs include *Achyranthes aspera, Ageratum conyzoids, Emilia sonchifolia, Justicia spp.* and *Urena sinuata*. The monsoon diet of elephants comprises shrubs like *Phoenix humilis, Helicteres isora, Entada scandens* and *Cipadessa baccifera*. Only three tree species semmed to have utilized viz. *Appolonias arnottii, Grewia aspera* and *Grewia tileliaefolia*. During this period the food of elephant comprised barks of trees like *Helicteres isora, Grewia aspera, Grewia tiliaefolia* and *Telia gamblia*.

## V. 10.4. POST MONSOON DIET

Utilization of all types of food plants was maximum during post monsoon season. (Fig. 16). Elephants used on 36 (40.90%) species of grasses, 21(23.86%) species of herbs, 11(12.51 %) species of shrubs and 20 (22.72 %) species of trees out of the total food plants identified during this period. Grasses like *Alloteropsis cimicina, Apluda aristata, Apocopis wighttii, Bambusa arundinacea, Chloris spp., Cymbopogon flexuosus, Cynodon dactylon, Cyrtococcum oxyphyllum, Digitaria spp., Dimeria spp., Dinebra retroflexa,*

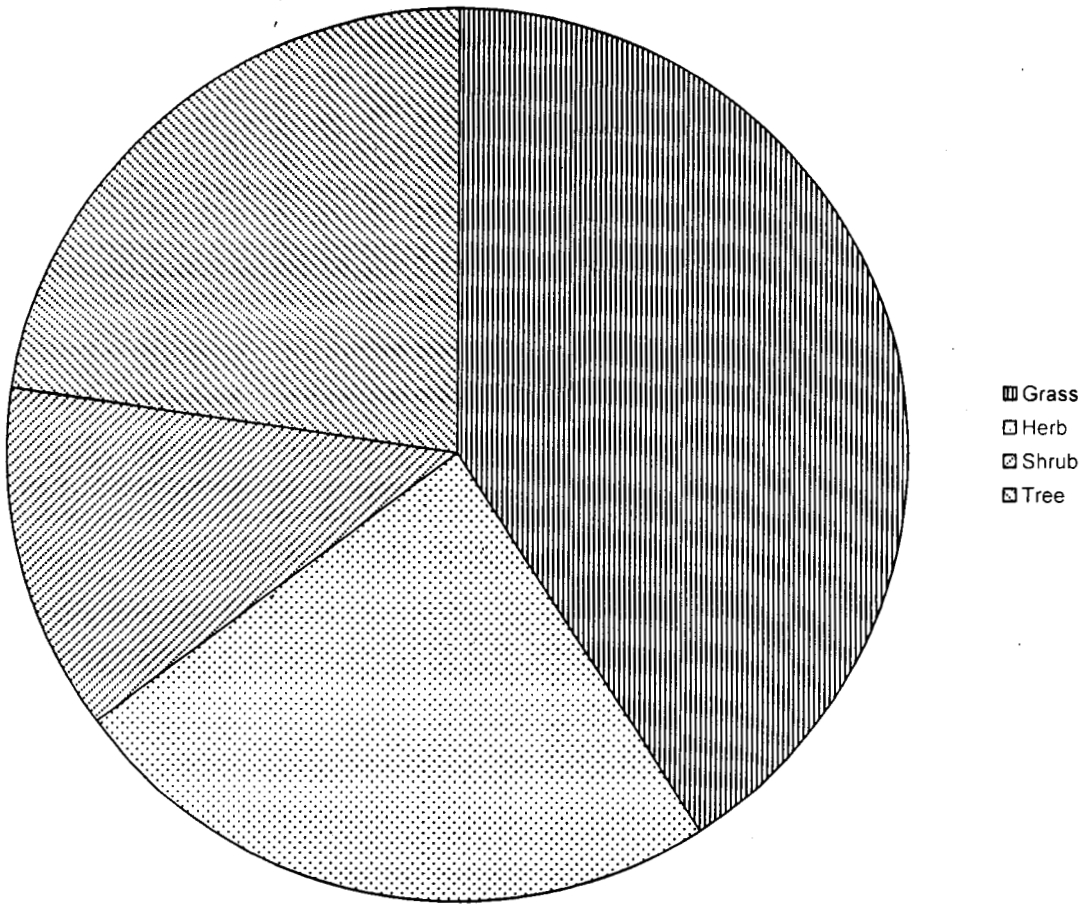


Fig.16 Variations in forage types of elephants during post monsoon

*Eleusine indica*, *Eragrostis bifaria*, *Eragrostis unioloides*, *Garnotia arundinacea*, *Heteropogon contortus*, *Imperata cylindrica*, *Manisuris granularis*, *Ochlandra spp.*, *Panicum brevifolium*, *Panicum montanum*, *Panicum repens*, *Paspalum conjugatum*, *Rotthoellia exaltata*, *Setaria palmifolia*, *Themeda cymbaria* and *Themeda traindra* were mostly eaten. Herbs like *Achyranthes aspera*, *Ageratum conyzoids*, *Bidens humilis*, *Curculigo orchioides*, *Desmodium trifolium*, *Emilia sonchifolia*, *Justicia spp.*, *Mimosa paudica*, *Sida cordifolia*, *Stachytarpeta indica*, *Tephrosia pupurea* and *Urena sinuata* were preferred during this period. Shrubs such as *Curcuma angustifolia*, *Helictere isora*, *Hackeria subpeltata*, *Phoenix humilis and Solanum torvum* and trees like *Terminalia crenulata*, *Randia dumetorum*, *Grewia teliaefolia*, *Ficus hispida*, *Ficus spp.*, and *Careya arborea* were consumed mostly during post monsoon months in Periyar.

Out of the total food plants identified during the study period, as given in the table 19, maximum dietary overlap with other two herbivores, namely gaur and sambar, was in grasses (61.76%) followed by shrubs (17.64%) where as it was minimum in herbs (11.76%) and trees (8.82%). Among the 36 grasses, elephant shared 11.11% with gaur. Dietary overlap of 23.80% with gaur and 9.52% with sambar in herb type food plants in Periyar. Elephant showed 16.66% and 4.16% of overlap in trees with gaur and sambar respectively.

**Table - 19**

**Food types of elephant observed to be shared by Gaur and Sambar in the study area**

| Species | Grass | Herb | Shrub | Tree |
|---|---|---|---|---|
| Elephant | 11 | 10 | 6 | 14 |
| Elephant & Gaur | 4 | 5 | - | 1 |
| Elephant & Sambar | - | 2 | - | 4 |
| Elephant, Gaur & Sambar | 21 | 4 | 6 | 3 |

# DISCUSSION

The elephant population is under severe threat in India particularly in the southern parts. The unequal sex ratio will likely to alter and disrupt the population size and population structure of elephants. The demographic studies of elephants in Periyar have indicated that an unequal ratio between sexes of all age groups, particularly the adults. The proportion of adult tuskers formed only 0.39 % of the total elephant population in Periyar, which is disproportionate to that of adult cow ratio of 56.16 %. The ratio of different sexes in other age groups of elephants is also unbalanced due to the stress of poaching. In south India, poaching for tusks is the greatest threat for survival of a viable population of elephants (Sukumar, 1985).

The elephant population became more female biased in Periyar today. The ratio between adult bulls to cow was 1: 6 during 1969 (Kurup, 1971) and now it is 1: 11 The sex ratio in the adult males to adult female elephant is already unequal, from 1: 10 to 1: 100 in the south (Sukumar, 1985). The decline of the natural ratio is significant, since firstly, the skewed ratio obtained in adult age class and gradually the other age class namely sub adult's and juvenile's ratios slanted, which indicate that there may be high pressure of poaching exerted on this population also as the offenders started to

hunt on sub adults and juveniles due to the lack of enough bulls in the populations and it might be the reason for the skewed sex ratio in these age groups also in Periyar. In periyar, population is stressed with sex specific mortality than age specific mortality and the selective poaching leads to genetic erosion and could have serious effects on population. As long as the female mortality is low, the population could still have capacity to increase or remain stable in spite of decreased fertility (Sukumar, 1989). Twenty percent of the female and 65 % of the male mortality in south India is due to human beings (Sukumar, 1989) and according to Daniel et. al., (1987) about 80 % of the mortality was due to human interference. This is true with the Periyar population since the major reasons for mortality are poaching and electric shock.

The high rate of poaching and slanted adult ratio would affect the birth rate of populations and the fecundity of more productive population was between 0.20 and 0.25 in Southern India (Sukumar, 1985) and the present study showing that the fertility was only 0.08/ adult female / year. In Periyar, there was no specific season for the birth of young ones even though maximum calves were observed during post monsoon months, supports the view of Eisenberg and Lockhart (1972) that there is no evidence of seasonality in the birth of elephants. The reduced number of breeding females could be the negative trend in elephant population in Periyar.

Makhnas are important in the population with low numbers of adult bulls, only two makhnas were observed in Periyar population, during the study period, and the lack of makhnas makes this population more desperate.

The availability of food and other factors such as rainfall, fire, and vegetation characteristics influence the herdsize and aggregation of elephants. The polymodal distribution of herdsize of elephants was described by Nair et. al., (1980), Sukumar (1985), and Olivier (1978). In Periyar, elephant herds have a tendency to become smaller in size and smaller herds were frequently observed. Laws et. al., (1975) described that the herdsize is a measure of the ecological health and large herd size reflects stressful conditions. There were no significant seasonal variations in the herdsize and smaller herds were observed throughout the year. However the aggregation was more during monsoon and post monsoon months. The difference in the seasonal mean herdsize of elephants seems to be due to the environmental factors such as rainfall. The vegetation become favourable in monsoon months, and hence resulted in to the aggregations of smaller units, as reported by Douglas-Hamilton (1972). During wet months the habitat become more congenial for the elephants since there is increased availability of forage during this period. There was no relation between herdsize classes and vegetations since all herdsize classes were observed in all seasons in

different types of vegetations. The tendency to form larger herds was observed in certain instance by reunion of smaller herds and according to Eltringham (1980) the possibility of larger herdsize due to poaching pressure. The present studies indicated that poaching pressure is high in Periyar but the elephant doesn't have a tendency to form larger herds.

The herd composition of elephants is significant since the major component of herds were females and which have matriarchal social set up as described by Buss (1961), Laws and Parker (1968) Douglas - Hamilton (1975) and Oliver (1978a). However, the herds have disproportionate number of males and females in Periyar.

The elephant herds were mostly without males especially the adult bulls and herds of females sighted comprised of 71.73% and herds with males 28 % in which all age groups were represented. Among these, five herds were observed with adult tuskers during the study period. McKay (1973) reported 60 % of herds without bulls and Sukumar (1985) found that 23 % herds without bulls. McKay (1973) described that the association of males with the herds was only for few days.

During rainy seasons and post monsoon months, elephants feed mostly as small herds which may be due to the abundance of quality forage during these periods and these herds were found to

unite to form as a single large herd on certain occasions, strictly in open habitats. Ishwaran (1984) and Sukumar (1985) have reported that this could be the aggregation of different family units from extended family and has no long-term cohesion.

In Periyar, elephants utilize a variety of habitats, of which, the grassland, savannah and moist deciduous habitats were frequently used in all seasons probably because of the availability of grasses in these habitats than that of dense forest habitats in the study area. Vacuylenberg (1977) described that the grassland was the most preferred habitat of elephant and grass constitute about 80 % of the diet. The elephant was observed to spend a greater part of their activity in open-air habitat in Periyar. Eisenberg and Lockhart (1972), McKay (1973), Olivier (1978), Ishwaran (1983) reported the same sort of activity in open habitats. Utilization of grassland was maximum during wet months which may be due to the abundance of preferred food species in grassland vegetations is more in wet seasons than the drier months. Utilization of habitat principally depends on water availability and food abundance but in Periyar water is not a limiting factor and grassland patches were distributed around the lake. Elephants of Periyar utilize grassland in all seasons, often in the ecotonal region of grasslands and forest. This gives them a variety of food plants. In summer months elephant herds retreat to moist deciduous forest habitat since the grass is withered and prone to fire.

The polyphagous nature of elephant has been described by Crawley (1983) and the herbivore is not adversely affected by the fluctuation in the abundance of plant species. The intake of food by herbivore is influenced by the vegetation height, bulk density (Chacon and Stobbs, 1976) and the biomass (Short, 1983). Less use of dense forest area in Periyar seems to be due to the shortage of food species and poaching pressure is more in dense forest particularly in boarder areas of the reserve. However they often make path through forest for moving from one place to another an activity they share with the African elephant. In few occassions by the indirect evidences that the movement of elephant herds to the border areas during pilgrim season and also recorded the crop raiding near Vellimalai region of the reserve. Elephant avoided the plantations in the study area due to the shortage of diet diversity and constant disturbance.

In moist deciduous forest elephant spent more time for feeding and feeding bouts was longer than that of grassland and savannahs. They spent more time for feeding on a single species since species like *Grewia tiliaefolia* and *Helicteres isora*, which are, preferred food species in those habitats. According to Barnes (1982) elephants have longer feeding bouts on each tree than on each shrub and bulls spend more time than cows feeding on each tree or shrub, Present study did not adequately cover time budget aspect of elephants.

The Asiatic elephant studied by Eisenberg and Lockhart (1972) in Sri Lanka, described that they spent more time in grassland and forest / grassland ecotone. As per the study the elephants tend to spend a relatively large amount of time at the interfaces between forest and grassland. It seems to be due to the facts that they are able to feed on grass without venturing too far from the relatively safe forest area and by feeding in an ecotone since they get a variety of potential food plants during any given period. The study area presents extensive ecotone area. The preference of ecotone by elephants was also described by McKay (1973), Olivier (1978) and Ishwaran (1983, 1984). In Periyar, the forest- grassland 'interface' provides the elephants with their favourite food items, grass within reach and protection in the nearby forest. In Periyar the ecotone of grassland with moist deciduous forest nearer to the Periyar Lake also seems to be advantageous to the feeding elephant herds.

According to Owen-Smith (1982) the dietary habit of herbivore is influenced by several factors including anatomical and physiological characteristics of the animals, plant community structure and chemical constituents. Baile (1975) and Bines (1976) reported that the food intake is also influenced by body weight and digestibility of the animal and according to Olivier (1978) factors such as food dispersal patterns, nutritive value and toxicity are important in influencing the selection of food plants by elephants. The dietary preference of the two living genera of elephants probably

also affected by their evolutionary histories (Ishwaran, 1979). In Periyar elephants live in herds and they feeding as a group and feeding on a variety of plants including grass, herbs, shrubs and trees thus elephant depends on both graze and browse in the study area. The advantage of polyphagy has been described by crawly (1983). The major food of elephant comprises grasses, almost throughout the year irrespective of seasons, though it was more preferred during wet months, namely monsoon and post monsoon period. Hence elephant in Periyar prefers grazing to browsing as its digestive efficiency is low (Benedict, 1936). The relatively low energy costs associated with preparation and feeding on grasses might also favour grazing (Mckay, 1973; Ishwaran, 1983). Grass, sedges, legumes hence form the major part of its food and its daily requirements is about 150 Kg. Per day (Vacuylenberg, 1977; Ishwaran, 1983) in the diet and its seasonal utilization. Importance of wood species was also mentioned by Vacuylenberg (1977).

Certain grass species were more frequently used in the study area. For instance, species like *Cymbopogan flexuous*, *Cynodon dactylon*, *Cyrtococcum oxyphyllum*, *Dinebra retroflexa*, *Heteropogon contortus*, *Panicum repens* and *Themeda triandra* were eaten throughout the year in good quantity. Of which, *Panicum repens* was eaten when they are feeding along the lakebed. The movement of elephant towards forested areas from grasslands in summer clearly indicates the scarcity and low quality of grass during

these period as attributed by McKay (1973), Santiapillai et. al., (1984) and Sukumar (1985). The quality index however was not documented during the present study.

Selective feeding on bamboo species was often noticed, usually elephant feed on leaves, twigs, rhizomes and shoots of Bamboo species, but during drier months they were uproot the young plants and searched for rhizomes and rarely they consumed the inner portion of bamboo rhizome after peeling of its outer part, as observed by Easa (1989) in Parambikulam sanctuary. The detailed chemical analysis of grass species was not attempted. The mineral contents, total ash and tannin content was high during wet months Easa (1989) and decreased protein content of grass in dry season (Bax and Sheldrick, 1963; Sukumar, 1985). During the present study, the elephants did not take the grass *Themeda cymbaria* in summer months, which may be due to the low protein content on its leaves. Elephants mostly feed on browse species during summer months in Periyar, since the availability of grass species are comparatively less and also due to the low protein and fatty acids in graze species as attributed by Drysdale and Glover (1964), Field (1971) and Sukumar (1985). Seasonal and opportunistic species preference has been described by Crawley (1983) and number of authors reported the seasonal difference in grazing and browsing among the elephants

(Buss, 1961; Bax and Sheldrick, 1963; Hanks, 1969; Field 1971; McKay, 1973; Wyatt and Eltringham, 1974; Laws et. al., 1975; Guy, 1975, 1976; Santiapillai and Suprahm, 1985; Sukumar, 1985; Easa, 1989). The congregation of elephants in open areas near the lakebed and their dependency on graze than the browse in Periyar support the findings of McKay (1973) and Kurt (1974) that the ungulate grazing tend to be concentrated around water-holes during dry seasons. Grass height was an important predictable variable influencing elephant-use of grassland during the dry seasons (Ishwaran, 1979). Olivier (1978) discussed the elephant's body size and dental structure have specialized for feeding on grasses, but because of shortage of grasses during certain seasons they must be able to switch to alternative foods such as dry season browse. According to Olivier (1978) since elephants do not have a rumen, they do not benefit from the synthesis of amino acids and vitamins by the rumen bacteria, they must feed upon a variety of supplementary species to provide the necessary range of nutrients. He has also argued that the anatomy of the elephant's digestive system makes them more sensitive than the ruminants to secondary compounds of toxic plant. This would then force the elephants to diversify their supplementary foods. Thus in the wet seasons the bulk of elephant's diet would be provided by grasses supplemented by small amounts from a range of other species.

Besides leaves, elephant diets include fruits and barks in the study area. They feed on fruits of trees like *Emblica officianalis, Mangifera indica, Psidium guajawa, Artocarpus heterophyllus* and *Helecteres isora*, which were taken along with twigs, and leaves in winter and early summer months. They feed on barks of *Grewia teliafolia, Grewia aspera, Telia gamblia, Randia dumetorum, Carya arborea* and *Ficus spp.* particularly during summer months. The elephants have knocked down or pull down some of the trees like *Grewia tiliafolia* and taken its bark. Branches that have been twisted off and partly debarked are characteristics of elephant feeding activity. According to Vacuylenberg (1974) elephants pulling of trees enable it to feed on any desired part, but considering the amount of plant matter destroyed and not used, it is a wasteful mode of feeding. This kind of wasteful feeding pattern was observed several occasions in the study area. The bark stripping by elephants has been reported by Bax and Sheldrick (1963), Croze (1974), Williamson (1975), Guy (1975, 1976) and Olivier (1978). Elephants were known to strip bark most frequently at the start of the rains and in the wet seasons (Laws, 1966; Croze, 1974; Laws et. al., 1975; Vacuylenberg, 1977) and during drier months (Guy, 19676; Olivier, 1978). In Periyar the bark stripping was frequently observed during late summer months. Bark feeding constitute 20-25 % (Vacuylenberg, 1974) and McKay (1973) has reported that while 80 % of the leaves removed from tree and

shrubs were likely to be eaten, only 50 % of leaves and 20-25 % of bark removed from trees and shrubs seems to be eaten. Higher quantity of lenolic acids (McCullagh, 1973), minerals such as manganese, iron. copper, boron (Doughall et. al., 1964) and calcium (Bax Sheldrick, 1963; Easa 1989) in barks are the reason probably for bark feeding of elephants.

# CHAPTER VI

# POPULATION STRUCTURE AND HABITAT UTILIZATION OF GAUR (*Bos gaurus*)

## VI. 1. SEX RATIO

A total of 77 herds of gaur were sighted in Periyar during the study period comprising 529 individuals, of which 97 were males, 361 females, 49 calves and 22 individuals were unidentified. The gaur come to forage on the open grasslands in the late evening hours though they are mostly confined to moist deciduous forest areas in the study area.

Out of the total sightings the proportion of males were 18.33% while that of female was 68.24% and the calves 9.26%. The percentage of unknown individuals were 4.15%(Table. 20 and Fig.17). Thus the ratio of male to females was 1: 3.5. It seems that there were 28 adult bulls for 100 cows in Periyar. In subadults the male to female ratio was 24:100 (Table 21). The adult bull constituting 12.83% to that of 45.74% cows. The sub adult male 5.48% while the sub adult female was 22.49% and 0.20% of calves to adult females. The composition of different sexes seems to be almost stable during the study period but adult's calves' ratio varies with seasons.

**Table - 20**

**Proportion of different sex group of Gaur in Periyar**

| Sex group | Number | Percentage |
|---|---|---|
| Male | 97 | 18.83 |
| Female | 361 | 68.24 |
| Calves | 49 | 9.26 |
| Unknown | 22 | 4.15 |

**Table - 21**

**Proportion of different age class of gaur in Periyar**

| Class | Male | Female | % | Sex Ratio M: F | Proportion of M to F |
|---|---|---|---|---|---|
| Adult | 68 | 242 | 58.60 | 28: 100 | 1: 3.5 |
| Sub adult | 29 | 119 | 27.97 | 24: 100 | 1: 4.1 |
| Calves | - | - | 9.26 | - | 1: 0.20 * |
| Unknown | - | - | 4.15 | - | - |

* Proportion of calves to female

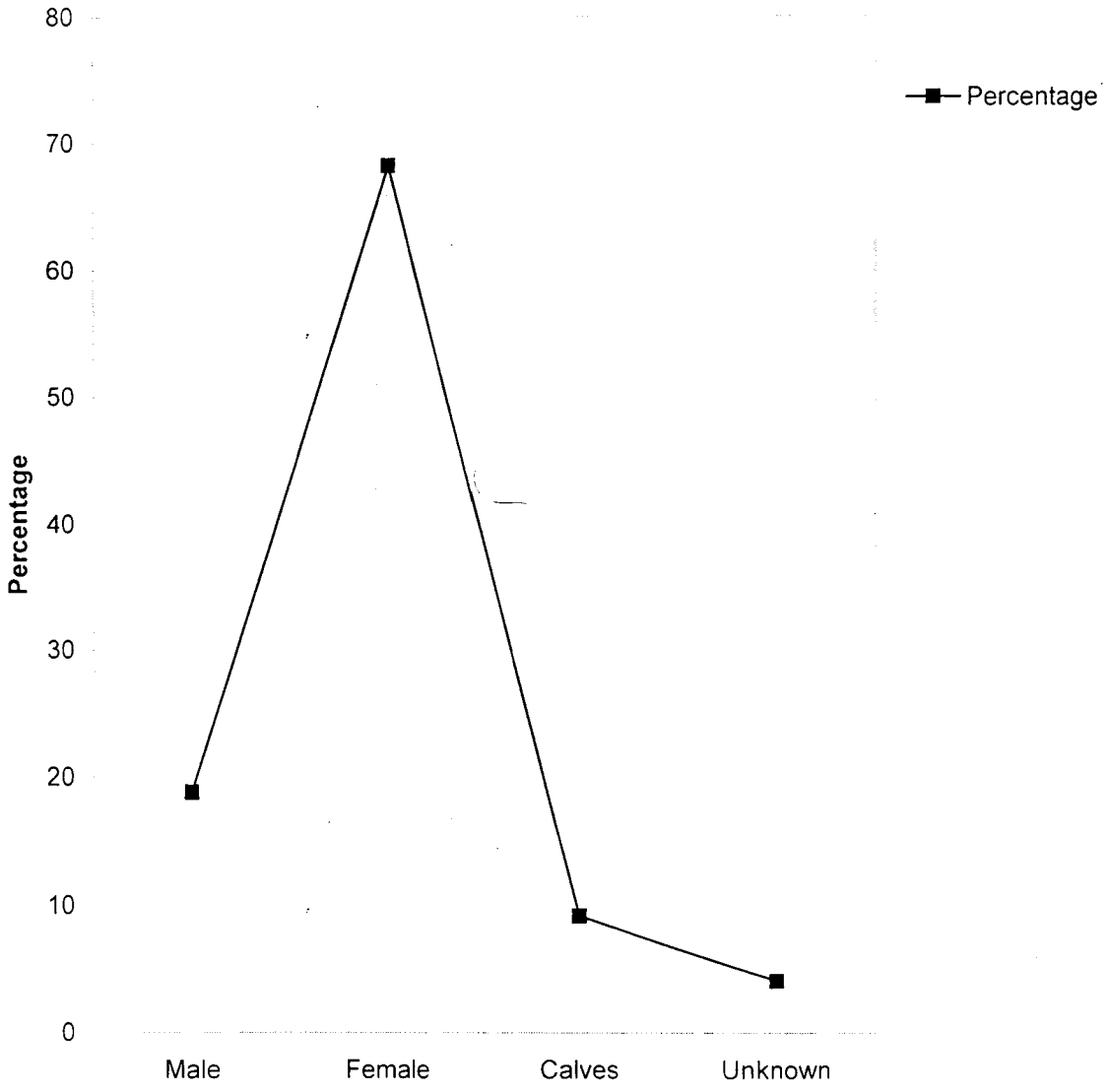


**Fig.17 Percentage of different age groups of gaur**

## VI .2. BIRTH OF YOUNG ONES

Brander (1923), Stebbing (1911) and Sanderson (1912) have reported that most mating occurs in December to January and calves are born in April, May and June. According to Morris (1937a) the peak rutting period in southern India is from November to March. In Periyar during the study period the calves were observed in all months with peak in September to December months as shown in the table 22.

## VI. 3. MORTALITY

Rinderpest, foot and mouth and anthrax are widespread causes of death of gaur in India. Rinderpest has been reported from south India by Anderson (1954) and from central India by Baker (1890) and Stewart (1928). Foot and mouth disease reported by Ali (1953) and anthrax by Peacock (1933). In Periyar the rinderpest killed hundreds of gaur in 1970s. However, during the present study, there was only one incidence of gaur being killed of rinderpest disease.

In the study area, gaur is one of the prey species of tiger evidenced by tiger kill and from the analysis of tiger scats. Poaching is another threat for the survival of gaur as per information gathered from local people and tribes. Due to the lack of sufficient data on mortality the age wise and sex wise mortality is not encountered.

**Table - 22**

**Seasonal difference in different sex group of gaur**

| Season | Bull | Cow | Calve | Unknown |
|---|---|---|---|---|
| Winter | 17 | 56 | 6 | 2 |
| Summer | 13 | 41 | 15 | 1 |
| Monsoon | 20 | 72 | 9 | 7 |
| Post-monsoon | 47 | 192 | 19 | 12 |

## VI. 4. HERD SIZE COMPOSITION

Of the total 77 herds of gaur sighted during the study period, gaur herdsize varied from 1 to 38. The largest herd sighted had 38 individuals. The gaur herds are classified into four herdsize classes, class1) 1 -5, 2) 6 -10, 3) 11-15 and 4) group with above 15 individuals. The class 1 formed 36.36 % of the total sightings followed the class 2 with 33. 76 % while the class 3 and 4 had 24.67 % and 5.19 % respectively (Fig.18). The average herdsize recorded for Periyar was 7. Inverarity (1889) reported that an average herd of gaur contains 12 to 20 animals. Brander (1923) observed 8 to 12 individuals in a herd while Russel (1900) found 10 to 20 and it was about 12 according to Sanderson (1912). Schaller (1967) reported the average herd size of gaur in Kanha being 8 to eleven.

Of the total observation, lone animals were observed 16 times which was 20.77 % of the total sightings. The herdsize seems to be smaller in Periyar since the maximum herds observed belonged to smaller classes. The larger herds of gaur were mostly in open habitats like grassland, savannah and moist deciduous habitats (Fig.19). The observed frequencies and expected frequencies of different herdsize in different vegetation types is given in the table 23 and table 23A which indicated that there were no much variations in the size of herds in different types of vegetations ($\chi^2$ =11.3477, df = 15, P > 0.01) though the largest herd was sighted in the moist deciduous

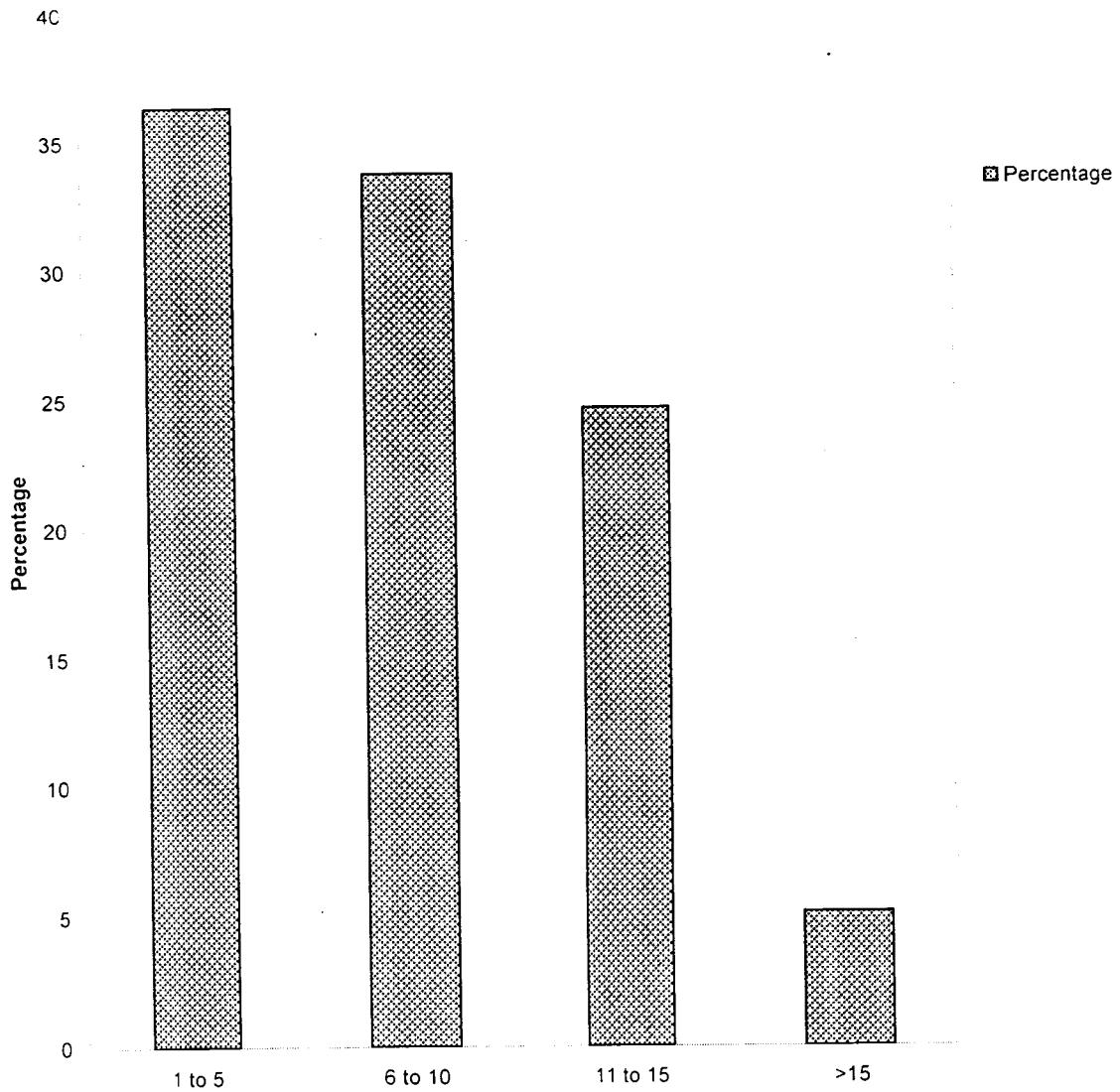


**Fig.18 Percentage of different herdsize pattern of gaur**

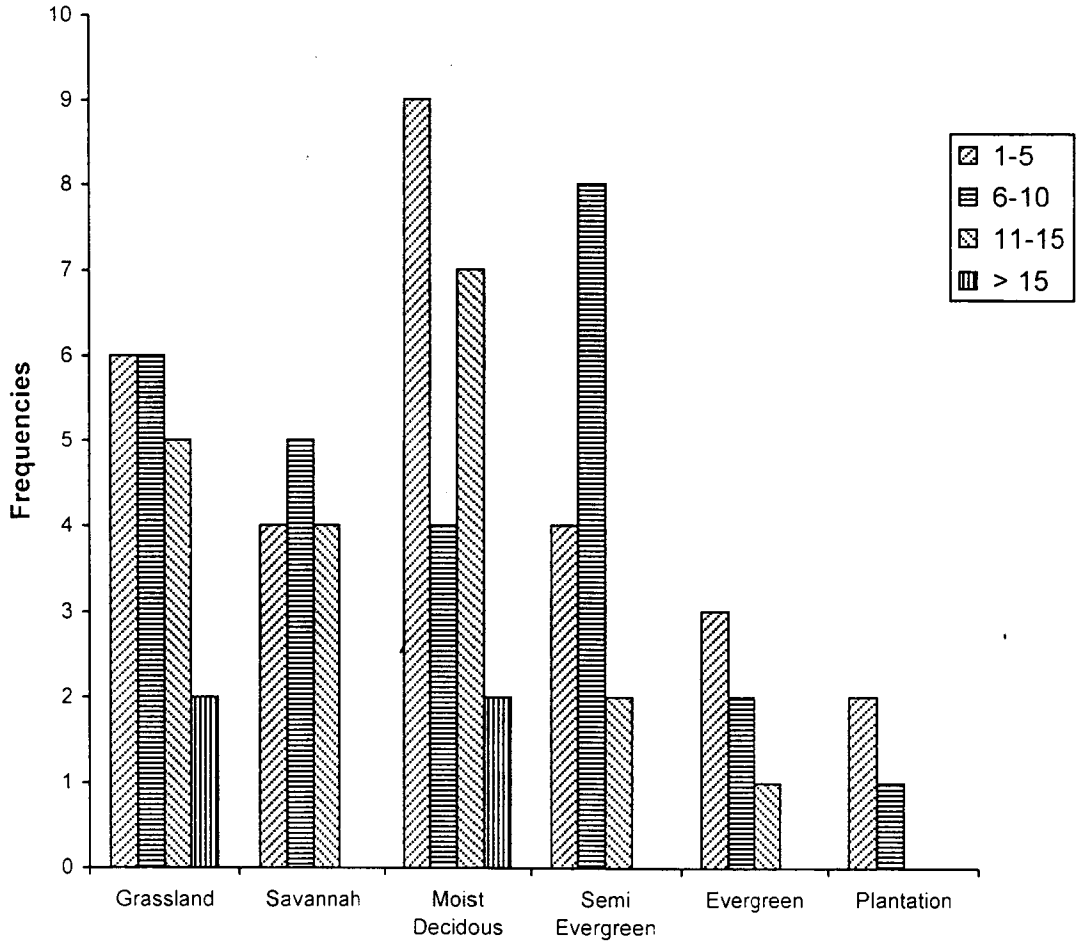


**Fig.19 Herdsize variations of gaur by vegetations**

**Table - 23**

**Herdsize variations of gaur in different vegetations in the study area**

| Class / Habitat | 1-5 | 6-10 | 11-15 | Above 15 |
|---|---|---|---|---|
| Grassland | 6 | 6 | 5 | 2 |
| Savannah | 4 | 5 | 4 | - |
| Moist Deciduous | 9 | 4 | 7 | 2 |
| Semi Evergreen | 4 | 8 | 2 | - |
| Evergreen | 3 | 2 | 1 | - |
| Plantation | 2 | 1 | - | - |
| Percentage | 36.36 | 33.76 | 24.67 | 5.19 |

**Table - 23A**

**Herdsize variations of gaur in different vegetations in the study area**

**Expected frequencies**

| Class / Habitat | 1-5 | 6-10 | 11-15 | Above 15 |
|---|---|---|---|---|
| Grassland | 6.9091 | 6.4156 | 4.6883 | 0.9870 |
| Savannah | 4.7273 | 4.3896 | 3.2078 | 0.6753 |
| Moist Deciduous | 8.0000 | 7.4286 | 5.4286 | 1.1429 |
| Semi Evergreen | 5.0909 | 4.7273 | 3.4545 | 0.7273 |
| Evergreen | 2.1818 | 2.0260 | 1.4805 | 0.3117 |
| Plantation | 1.0909 | 1.0130 | 0.7403 | 0.1558 |

forest. However, the mean group size varied slightly by season, the mean group size was maximum during monsoon (7.2) and post monsoon seasons (7) and minimum during winter and dry months, 6.2 and 6.4 respectively which might be due to seasonal fluctuation in the availability of forage in the study area as showed in Fig. 20.

Bulls were observed with all herds, though maximum number of bulls with herds was observed during summer and post-monsoon months. According to Schaller (1967) 65 % of herds were accompanied by a black bull. On few occasions the herds with more bulls were found splitting into two or three groups and each group moved in different directions with accompanying bulls. Very little data is available about this breaking of gaur herds and their reunion. However this group breaks up seems to be related to the availability of food as observed in elephants.

## VI. 5. HABITAT PREFERENCE

The gaur is a forest animal, coming out to the meadows only to eat and drink during the hot season after its forage in the forest has been burnt and the streambeds are dry (Schaller, 1967). In Periyar gaur was using a variety of habitats namely grassland, savannahs, moist deciduous forests, semi evergreen forest, evergreen forest and plantations. The distribution of the species in the study area has indicated that the gaur preferred both open habitats and forest areas

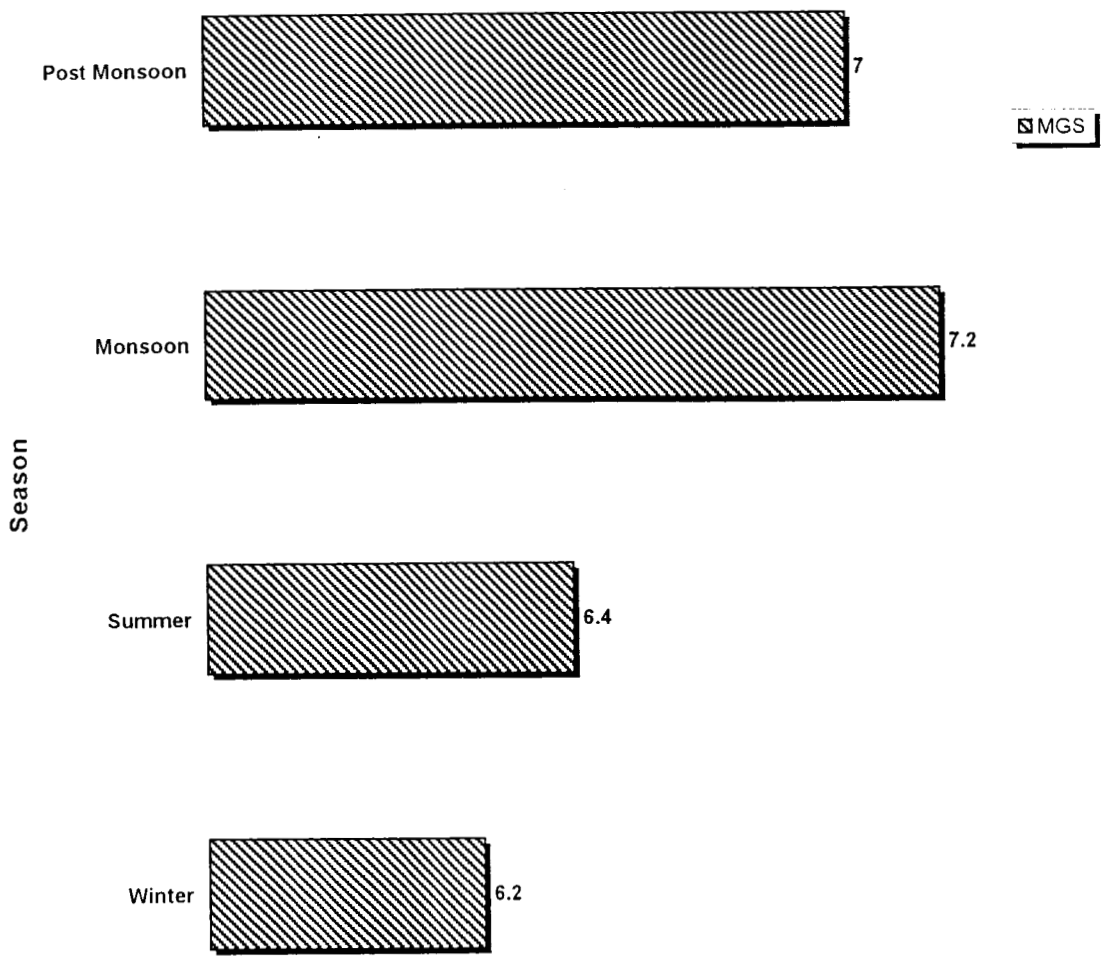


Fig.20 Seasonal variation in mean group size of gaur

however there was no significant association between the utilization of different habitats and season in Periyar ($\chi^2 = 9.0700$, df =15, P > 0.01) though the preference was comparatively more towards moist deciduous forest habitats, observed frequencies and expected frequencies is showed in the table 24 and 24 A.

Of these 77 herds, 19 were observed in grassland and 13 in savannahs. The largest number of herds with a frequency of 22 were observed in moist deciduous forests, where as 14, 6 and 3 herds were sighted in semi evergreen, evergreens and plantations respectively. Thus the percentage of utilization of moist deciduous by gaur seemed to be more than other habitats which comprised 28.57 % followed grassland with 24. 67 % while plantation areas were least preferred with 3.84 %. The preference to dense forest like evergreen and semi evergreen forest constitutes 18.18% and 7.79% respectively. The percentage of preference to savannah comprised 16.88% (Fig.21).

The gaur is an animal of open forest, the moist deciduous forests, in Periyar. The sight records have shown that maximum herds were observed during post-monsoon and monsoon seasons with a peak in post-monsoon months with 13 herds in moist deciduous vegetation. While using the grasslands the gaur-preferred hilltops like Kavalppara and their slopes to those on the lakebed in Periyar (Plate VII), may be due to the relatively less disturbance. Schaller

## Table - 24

## Seasonal variation in the use of different habitats by gaur

| Habitat | Winter | Summer | Monsoon | Post monsoon | % |
|---|---|---|---|---|---|
| Grassland | 3 | 2 | 5 | 9 | 24.67 |
| Savannah | 2 | 1 | 2 | 8 | 16.88 |
| Moist Deciduous | 2 | 3 | 4 | 13 | 28.57 |
| Semi Evergreen | 4 | 3 | 3 | 4 | 18.18 |
| Evergreen | 2 | 1 | 1 | 2 | 7.79 |
| Plantation | - | 1 | - | 2 | 3.84 |

## Table - 24A

## Seasonal variation in the use of different habitats by gaur Expected frequencies

| Habitat | Winter | Summer | Monsoon | Post Mon |
|---|---|---|---|---|
| Grassland | 3.2078 | 2.7143 | 3.7013 | 9.3766 |
| Savannah | 2.1948 | 1.8571 | 2.5325 | 6.4156 |
| Moist Deciduous | 3.7143 | 3.1429 | 4.2857 | 10.8571 |
| Semi Evergreen | 2.3636 | 2.0000 | 2.7273 | 6.9091 |
| Evergreen | 1.0130 | 0.8571 | 1.1688 | 2.9610 |
| Plantation | 0.5065 | 0.4286 | 0.5844 | 1.4805 |

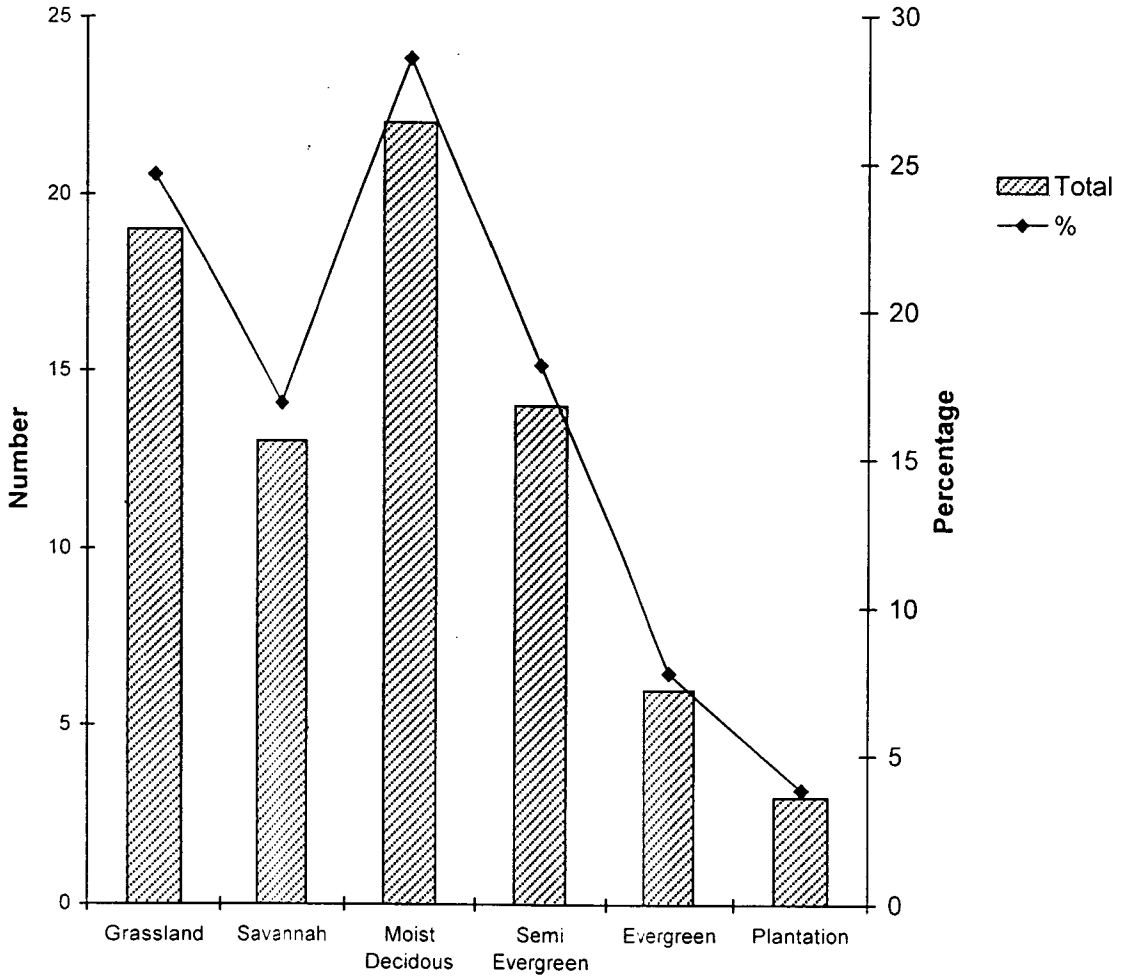


**Fig.21 Number and percentage of occurrence of gaur in various habitats**

## Plate VII

Gaur feeding on the grassland

(1967) also mentions that the gaur apparently preferred hilly terrain. However herds were frequently observed on the lakeshore near places like Edappalayam and Mullakudy in the evening hours especially in the ecotone areas.

Utilization of grasslands and savannahs by gaur during drier months was less when compared to that of the other seasons and during this period they are observed moving towards moist deciduous and semi evergreen habitats where browse species are more. In Periyar, the gaur does not prefer plantations. They spend lot of time for feeding and resting in the interface between forest and grassland. This may give them protection as well as provide them with a variety of food plants, which may be reason for their use of this ecotone and gaur was often feeding with elephants in this type of habitat in the Periyar.

The open habitats like grassland, savannah and moist deciduous forests comprised only in small proportion in contrast to other dense forests habitats. The grassland and savannah having only 1.6% of the total area whereas the utilization of these habitats by gaur was maximum (41.55%). The gaur utilization of moist deciduous forests was 28.57%, while this habitat's proportion was only 12.98%. The less preferred habitats like semi evergreen and evergreen forests consist of 36.42% and 40.39% respectively though the use of these vegetations were minimum with 18.18% and 7.79% in the study area (Table 15 & Fig. 22).

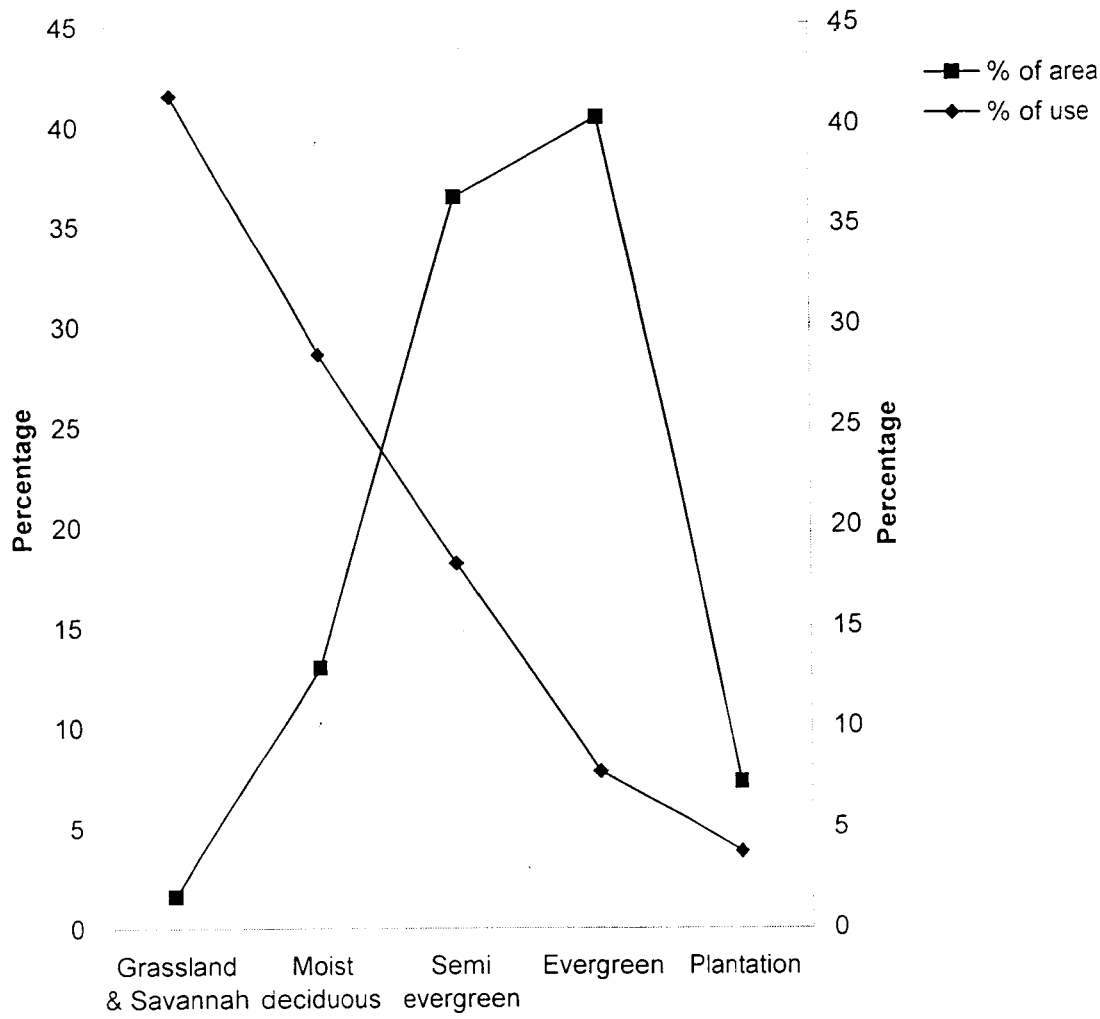


**Fig.22 Proportion of different habitats and percentage of preference to each habitat by gaur**

## VI .6 FOOD HABITS

Observations have shown that the gaur took a variety of food plants as given in the table 25. Of these, largest numbers were grasses 58.10% (n = 43). The percentage of consumption of herbs and shrubs comprised 24.32% (n = 18) and 10.81% (n = 8) respectively. They showed little preference to tree species (6.75%) (n = 5).

Among the grass species, *Chrysopogon spp., Eragrostis bifaria, Garnotia arundinacea, Heteropogon contortus, Imperata cylindreca, Panicum repens, Pennisetum hohenackeri, Setaria intermedia* and *Themida triandra* were mostly taken by the gaur. The most favoured herb species were *Cassia occidentalis, Emilia sonchifolia, Sida humilis, Urena lobata* and shrubs included *Helecteres isora, Solanum sisymbrifolium* and *Solanum torvum.*

The proportion of different types of food plants taken by gaur varied seasonally though the association was not predominant ($\chi^2$ = 9.8412, df = 9, P> 0.01). As given in the table 26, they took maximum grass species during wet months (June- December) and minimum during summer months. Consequently the preference to browse species attained maximum in dry months (52.63%) while it was low (25%) in rainy season in the study area. The proportion of grasses consumed during rainy seasons was 75% and in summer

## Table – 25
## Food plants of gaur in Periyar

| Food Plants | Family | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Achyrathes bidentata* | Amarantaceae | | | | | * | | | | | | | |
| *Ageratum conyzoides* | Asteraceae | | | | | | | | | | | * | |
| *Alloteropsis cimicina* | Graminae | | | | | | | | | | * | * | |
| *Apluda aristata* | Graminae | | | * | | | * | | * | * | | | |
| *Apocopis wightii* | Graminae | | | | | | * | | * | | * | | * |
| *Aristolochia indica* | Aristolcchiaceae | | | | * | | | | | | | | |
| *Arthraxon quartianianus* | Graminae | | | | | | | | | | * | | |
| *Canthium augustifolium* | Rubiaceae | | * | | | | | | | | | | |
| *Careya arborea* * | Lecythidaceae | | | * | * | | | | | | * | * | |
| *Cassia occidentalis* * | Caecalpinaceae | | * | | | | * | | | * | | * | |
| *Centella asiatica* * | Umbiliferae | * | | | | * | | | | | * | | |
| *Cipadessa buccifera* * | Meliaceae | | | * | | * | | | | | | | * |
| *Chrysopogon spp.* | Graminae | * | * | | | | | | * | * | | | |
| *Coix lachryma jobi* | Graminae | | | | | | * | | | | | | |
| *Cymbopogon flexuosus* | Graminae | * | | | | * | | * | | * | | | |
| *Cynodon dactylon* | Graminae | | | | | * | | | | | | | * |
| *Cyrtococcum muricatum* | Graminae | | | | | | * | * | | | * | * | |
| *Cyrtococcum oxyphyllum* | Graminae | | | | * | | | * | * | | | | |
| *Cyrtococcum patens* | Graminae | | | | * | | * | | | | | | |
| *Digitaria sanguinalis* | Graminae | | * | | | | | * | | | * | | * |
| *Dimeria spp.* | Graminae | * | * | | | | * | * | * | | | * | |
| *Elepantopus scaber* * | Asteraceae | * | | | | * | | | | | * | * | |
| *Eleusine indica* | Graminae | | | | | | | | | * | * | * | |
| *Emilia sonchifolia* | Asteraceae | * | * | | * | | | | | | | | |
| *Entada scandens* * | Leguminaceae | | * | | * | | * | | | * | | * | * |
| *Eragrostis bifaria* | Graminae | * | | * | * | | * | * | | | | | |
| *Eragrostis unioloides* | Graminae | | | | | | * | | | | | | |
| *Eragrostis willdenoviana* | Graminae | | | | | | | | | | | | * |
| *Flemingia bracteata* | Fabaceae | * | * | | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Garnotia arundinacea* | Graminae | * | * | * | * | * | * | * | * | * | * | * | * |
| *Globba bulbifera* * | Zingiberaceae | | | | | | | | | | * | | |
| *Grewia tiliaefolia* | Teliaceae | | | | | | | | | | * | | |
| *Helecteres isora* * | Sterculiaceae | * | | * | * | | * | | * | | | | * |
| *Heteropogon contortus* | Graminae | * | * | | * | | * | * | * | * | * | | |
| *Hibiscus barbatus* * | Malvaceae | | * | | * | | | | | | * | | |
| *Hibiscus lobatus* | Malvaceae | | | | * | | | | | | | | |
| *Imperata cylindrica* | Graminae | | * | | | | | * | * | * | | * | |
| *Ischaemum ciliare* | Graminae | | * | | | | | | | | | | |
| *Ischaemum pilosum* | Graminae | | | | | | | | | | * | | |
| *Kyllingia spp.* | Graminae | | * | | | | | | | | | | |
| *Maesa perrottetiana* | Myrsinae | | | | * | | | | | | | | |
| *Manisuris granularis* | Graminae | | | | * | * | | | | | | | * |
| *Memecylon edule* | Melastomaceae | | | | * | * | | | | | | | |
| *Mimosa pudica* | Mimosae | | | | | | * | | | | | | |
| *Olea dioica* | Oleaceae | | * | | | | | | | | | | |
| *Oplismenus burmannii* | Graminae | | * | | | | | * | * | | | | |
| *Oplismenus compositus* | Graminae | | | * | | | | * | | | | * | * |
| *Oryza granulata* | Graminae | | | | | * | | | | | | | |
| *Ottochloa nodosa* | Graminae | | | | | | | | | | * | | |
| *Panicum javanicum* | Graminae | * | | * | | | | | | * | | * | * |
| *Panicum maximum* | Graminae | * | * | | | | * | * | | | | * | * |
| *Panicum repens* | Graminae | | * | * | | * | * | * | * | * | * | * | * |
| *Panicum trypheron* | Graminae | * | | | | | | | | | | * | |
| *Paspalidium flavidum* | Graminae | | | | | | | | | | * | | |
| *Paspalum compactum* | Graminae | * | * | | | | * | * | | | | * | |
| *Paspalum conjugatum* | Graminae | | | * | | | | | * | | | | |
| *Pennisetum hohenackeri* | Graminae | * | * | * | | * | | * | * | * | | | |
| *Pterocarpus marsupium* | Fabaceae | | | | | | * | * | * | | * | | |
| *Randia dumetorum* * | Rubiaceae | | | * | | * | * | | | | | * | |
| *Rottboellia exaltata* | Graminae | | * | | | | * | * | * | * | * | * | |
| *Rottboellia spp.* | Graminae | | | | | | | | * | * | * | * | * |
| *Saccharum spontaneum* | Graminae | | | | | | | | * | | | * | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Setaria intermedia* | Graminae | * | * | * | * | * | * | * | * | * | * | * | * |
| *Sida humilis* | Malvaceae | | | | * | * | | | | | | | |
| *Sida rhombifolia* | Malvaceae | | * | | | | | | | | | | |
| *Solanum sisymbrifolium* * | Solanaceae | * | | | * | * | | | * | | | | * |
| *Solanum torvum* | Solanaceae | | | | * | * | * | * | | | * | | |
| *Sporobolus spp.* | Graminae | * | | | | | * | * | | | | * | |
| *Stachytarpeta indica* * | Verbenaceae | | | | | | | | | | * | | |
| *Synedrella nodiflora* | Asteraceae | | | | | * | | * | | | | | |
| *Themeda cymbaria* | Graminae | * | | | | | | * | * | | * | * | |
| *Themeda triandra* | Graminae | * | * | * | * | * | * | * | * | * | * | * | * |
| *Urena lobata* | Malvaceae | | * | * | * | | | | | * | | | |
| *Urena sinuata* | Malvaceae | | | | * | | | | * | | | | |

* Direct observations

months it was 47.36, which shows a clear preference to graze and browse species in different seasons (Fig. 23).

Out of the total food plants, the dietary overlap with other species, elephant and gaur. Among grasses overlap with elephant was 9.30%, 23.25% with sambar and between these three species constituted 48.83% of overlap. Only 18.60% of grass type food of gaur has no overlap with other herbivores in Periyar (Table 27). Maximum overlaps in shrubs species (75%) between these ungulates is probably due to less number of samples (n = 8). Among the total food plants of gaur (n=74), overlap between these three ungulates was 45.94% while, 29.72% with sambar. Minimum of 10.81% overlap with elephant and 13.51% of food plants are not shared with elephant and sambar.

## Table 26

**Seasonal variations in use of different food taxa of Gaur**

| Type | Winter | Summer | Monsoon | Post monsoon |
|---|---|---|---|---|
| Grass | 21 | 18 | 30 | 31 |
| Herb | 8 | 10 | 3 | 8 |
| Shrub | 5 | 8 | 5 | 5 |
| Trees | 1 | 2 | 2 | 4 |

## Table 26 A

**Seasonal variations in use of different food taxa of Gaur Expected frequencies**

| Type | Winter | Summer | Monsoon | Post monsoon |
|---|---|---|---|---|
| Grass | 21.7391 | 23.6025 | 24.8447 | 29.8137 |
| Herb | 6.3043 | 6.8447 | 7.2050 | 8.6460 |
| Shrub | 5.0000 | 5.4286 | 5.7143 | 6.8571 |
| Trees | 1.9565 | 2.1242 | 2.2360 | 2.6832 |

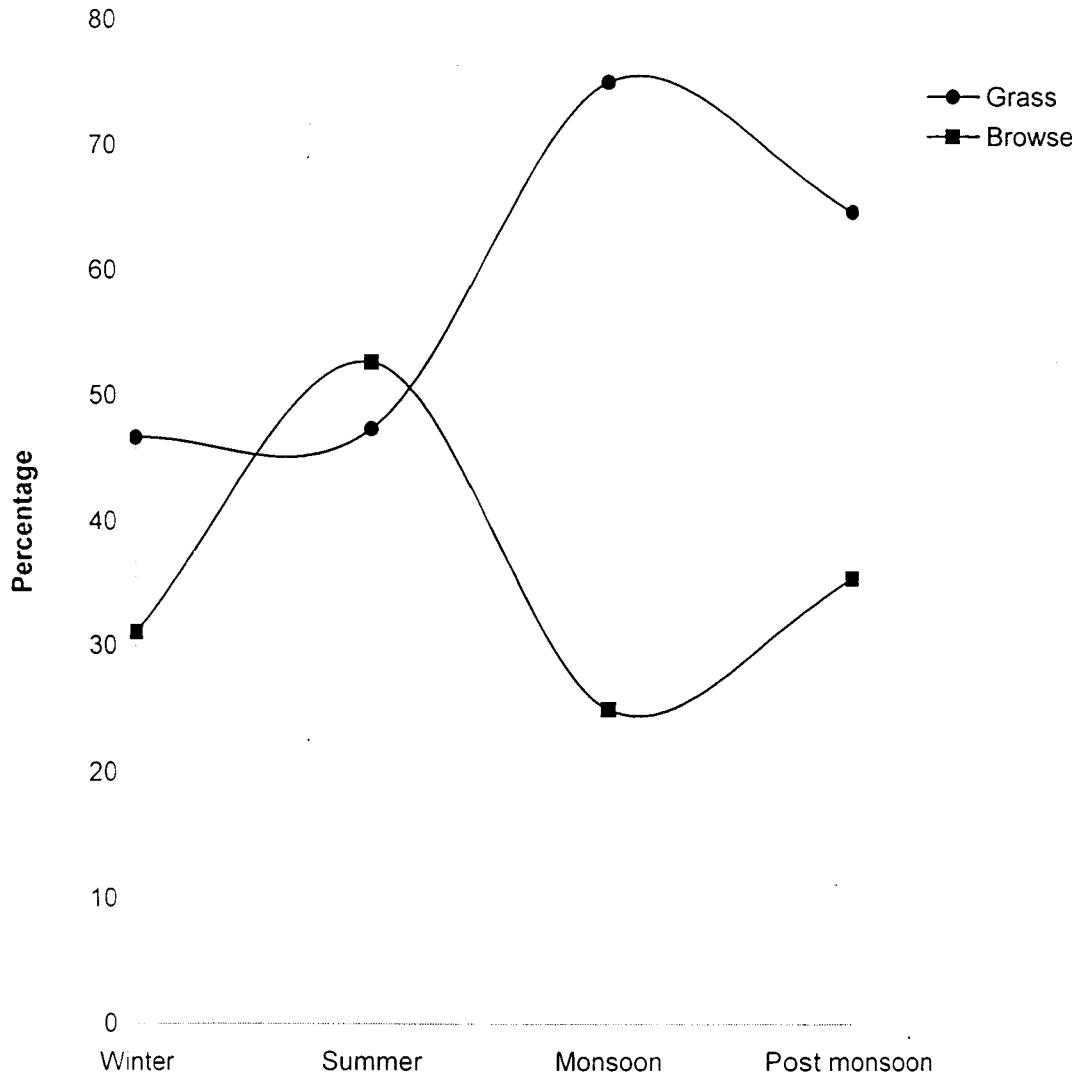


**Fig.23 Seasonal variation in diet of gaur**

## Table- 27

## Dietary overlap of Gaur with other herbivores in Periyar

| Species | Grass | Herb | Shrub | Tree | % |
|---|---|---|---|---|---|
| Gaur | 8 | 2 | - | - | 13.51 |
| Gaur & Elephant | 4 | 4 | - | - | 10.81 |
| Gaur & Sambar | 10 | 8 | 2 | 2 | 29.72 |
| Gaur. Elephant & Sambar | 21 | 4 | 6 | 3 | 45.94 |

# DISCUSSION

Gaur has a matriarchal social set up and it largely focused around the adult females (Wroblenski, 1927). The gaur herd usually consists of adult bull, adult cow, sub adults, yearling and calves (Belsare et al., 1984). During the study period individuals in the gaur herd composition classified as adult bull, adult cow, sub adult and calves. In Periyar the herd was female biased as reported in the bison (Wroblenski, 1927). The proportion of adult females comprises 45.74 % and that of male 12.85 %. Thus the ratio between adult bull to that of cow 1: 3.5 or 28 bulls for 100 cows. Sub adult female have an influence on the herd structure since they come in greater proportions besides adult cows.

The slanted sex ratio favouring the females in Periyar supported the findings of Schaller (1967). The distorted sex ratio favouring females was observed by Vairaveli (1998) during his studies on Parambikulam population. The ratio between males and females by birth assumed to be equal (Schaller 1967) thus, the difference in the male and females mortality could be the cause of this skewed sex ratio in Periyar as attributed by Belsare (1984) that the probable cause for the decrease in proportion of adult males to females may have been selective predation on males or mortality from bull to bull combat. Krasinki (1978) observed that male mortality in European bison about 69 % due to comparatively poor nutrition, particularly

the first year of life. The differential activity pattern of males, dispersal activity than females and need for more food due to its higher metabolic rate could be the factors responsible for the difference in the mortality among gaur population in the study area as described by Klein (1970) in bison. However the effect was not significant on population, due to its slanted sex ratio, because of polygamous nature of adult bulls. The age wise mortality was not estimated during the present study even though hairs of gaur observed in the Tiger scats probably of calves. Hence the predation pressure seems to exert on calves in Periyar, mostly on males due to their independent activity pattern as described by Klein (1970).

The breeding season of gaur varied considerably in different areas and was not confined to one period (Brander, 1923). This supports the present study that the birth of young one has no particular season even though maximum numbers of calves were noticed during late summer and post monsoon months. Stebbing (1911), Brander (1912), and Sanderson (1912) have reported that most mating occurs in December and January and calves are born in April, May, June and it was during November to March (Morris, 1937a). The peak birth season (September - December) in Periyar helps the subsistence efficacy of gaur population since comparatively low temperature, availability of more food resources and forest cover during these months. The higher temperature adversely effects the animals as

described by Brody (1945) that poorly developed homoeothermic mechanism in newborn mammals. The fertility of gaur population was encountered as 0.20 per adult female per year in Periyar. The fecundity of more productive population was in-between 0.20 and 0.25 in Southern India (Sukumar, 1985) since the present Periyar population seems to be more productive.

The most frequently observed herd size was in-between 3 - 10 and the largest herd observed had 38 individuals. The average herdsize of 7 in the study area support the findings of Schaller (1967), Belsare et. al., (1984) and Dwivedi and Shukla (1988). Thus the gaur population has a propensity to become smaller in their herdsize which disagree the findings of Inverarity (1889) that the average herdsize was 12 to 20., , Russel (1900) 10 to 20 and (Sanderson ,1912; Brander, 1923) about 12.

The larger groups observed in the study area could be the aggregations of smaller units since these herds were noticed in grassland and moist deciduous vegetations where adequate supply of forage is available. This kind of aggregations was also described by Dwivedi and Shukla (1988) in gaur and Krasinki (1978) in European bison. The solitary bull constitutes 20.77 % of the total sightings and lone individuals were well builded and healthy, which disagree the concept of Fuller, (1960) on American bison that the solitary bulls were unhealthy with advanced age. Vairaveli (1998) argued that

the solitary bulls he met at Parambikulam were healthy as observed in Periyar during the present study.

Males were observed with all herds though few herds were without adult bulls. More adult bulls were noticed along with herds during summer and post monsoon months. Schaller (1967) reported that 65% herds were one bull accompanied in Kanha. In the study area, 3 herds with more than one bull were found splitting into different groups and each accompanied by a bull. Little observations were carried out on this breaking of gaur herds and their reunion. However this break up seems to be related to the availability of food, since these observations made in the grassland- forest interfaces.

The influence of vegetation on herdsize seems to be insignificant. However larger herds were observed in moist deciduous and grasslands and all herdsize class were maximum in the moist deciduous habitats. The mean herdsize varied with season in the study area, which attained maximum during the month June to December probably due to the availability of lush green forage in this season in Periyar. Thus the forage availability and environmental factors like precipitation seems to influence the herdsize formation of gaur in the study area.

In Periyar, gaur use a variety of habitats and which they show preference to certain habitats over others as described by McNaugton

and Georgiadis (1986). Herbivores are not evenly distributed across a region while foraging, but rather favour certain habitat types over others and the wild ungulates move seasonally in response to their temporal abundance and quality of forages in different portions of their range (McNaughton, 1987). The preference was mainly determined in terms of availability and diversity of forage and water sources in the study area which supported the explanation of Sinclair (1975) and Sinclair et. al., (1979) that the preference of a given habitat type is largely determined by the available vegetation within the area, food, water, minerals, shelter from climatic extremes and cover from predators.

Among the available habitats, moist deciduous type was most preferred by gaur followed by grassland during monsoon and post monsoon months since grass, herbs, and various browse species were abundant in moist deciduous vegetation which comprised the bulk of its diet. The lush foraging conditions besides sufficient shade for resting appeared to be the most important factor influencing the habitat use of gaur in Periyar. The preference of European bison to mixed deciduous and deciduous forests was explained by Krasinki (1978). It is noteworthy that the preferred habitats viz. moist deciduous forests and grassland have proportionately small area in the reserve in contrast to other type of vegetations like evergreen and semi evergreen forest areas.

The time budget study of gaur was not attempted during this study, but they are found to spend considerable time for feeding and which was observed with maximum duration in the mornings and late evening hours, confirming the observations made by Krishnan (1972) in Mudumalai where the animal actively engaged in feeding in the morning and evening hours. This feeding pattern was very conspicuous in places like Edappalayam lakebed and they are found retreating into the forest patches during midday's, probably for resting in the shade. Hence the temperature also seems to be the influencing the feeding activity pattern of gaur in Periyar.

In Periyar all types of habitats were utilized by gaur during wet months with the exception of semi evergreen habitat, which was used more during winter months. The seasonal difference in habitat use by gaur in Kahna and its relation with food and water availability was reported by Schaller (1967). In Periyar they heavily depend on grassland during wet months and this dependency last up to the late post monsoon months. During dry months they retreat into the forests, mostly the moist deciduous forests, support the observations of Krishnan (1972) that the gaur exhibits seasonal movements at the onset of rains and confined themselves to swampy areas in summer. In the study area the seasonal variation in the habitat use was related to the availability of forage, as explained by Krasinki et. al., (1987, 1992, 1995). Movements of bison between summer and winter ranges

was described by McHugh (1958), Meagher (1973) and Van Vuren (1983), while using the grassland the gaur preferred hilltops like Kavalappara and their slopes than those on the lakeshore, may be due to the nature of the terrain and the relatively less disturbance of the area.

The gaur spent considerable time for feeding and resting in the ecotone and this may give them protection and provide them with a variety of forage in these interfaces. Their preference to semi evergreen habitats was more than that of savannah type vegetation and percentage of utilization of evergreen forest constitute only 7.79% while least preference was shown to eucalyptus plantations due to the shortage of forage and disturbances there in. The monoculture plantations unproductive for gaur resulting in extensive habitat loss as described by Conry (1989).

The forest fires have little influence in the movement of gaur in the study area since aggregation of gaur was noticed in the burned areas after the first or second showers. It supports the conclusion of Campbell and Hinkes (1983) that movements of bison can be influenced by fire. The preference of bison for burnt areas to unburnt areas was also reported by Pyne (1984) and Vallentine (1989).

The anatomical and physiological characteristics of the animal, community structure of the plants and its structural and chemical

constituents (Owe-Smith, 1982), and body weight, gut size and the digestibility (Baile, 1975; Bines, 1976) are the factors known to influence the herbivore's diet. The gaur diet includes grasses, herbs, shrubs and trees in the study area, which indicated the polyphgous feeding habits of this species. This polyphagous nature of gaur was described by Schaller (1967) in Kahna and Vairaveli (1998) in Parambilkulam. This polyphagous mode of feeding is advantageous to the animals that can forage instaneaously on temporarily abundant food species (Crawly, 1983).

The food plants identified in the field and by micro histological analysis of droppings has shown that grasses constitute the major portion of the diet of gaur throughout the year, indicate that the gaur is mostly a grazer, obviously depending on grasses for their requirements especially during monsoon and post monsoon months. This seems to be due to the abundance, palatability and high protein content of grasses during afore mentioned period. Tropical grasses have a specialized leaf anatomy, higher growth rate and nitrogen use efficiency (Morton, 1982) and the accumulation of starch and polysaccharides in grasses are easily digestible while tannins and aromatic compounds decrease the palatability of browse species during wet months. The dietary pattern of gaur varied in different months of the year, the maximum grass species are eaten during monsoon and post monsoon months. The browse species on the

other hand are most frequently taken during summer months. The crude protein content of brows species was usually much higher than the grass species during summer months (Hobbs et. al., 1981; Varma et. al., 1982). Thus gaur depends considerably on browse species during drier months in Periyar.

# CHAPTER VII

# POPULATION STRUCTURE AND HABITAT USE OF SAMBAR (*Cervus unicolor*)

## VII. 1. SEX RATIO

The Sambar (*Cervus unicolor*) is widely distributed in the forest of Southern Asia found in a wide variety of habitats and is an animal of high tolerance (Schaller, 1967) In the study area sambar was observed singly and in herds. It spends most of the time in tall grasses, savannas and moist deciduous patches and comes out to feed in the open areas in the late evening hours. This may be a predatory avoidance mechanism as most of the predation on sambar by Wild dogs, the major predators, occurred during daytime. In most of the sightings of sambar, adult female accompanied by another individual. Herds of sambar were sighted at different habitat except in evergreen forests. On the whole a total of 1198 individuals were observed during the study period, which consisted of 220 males and 810 females. (Table. 28 & Fig. 24). Altogether 168 juveniles and fawns were sighted. The sex ratio between males to females was 1:3.6 and 27 males for 100 females. The sex ratio varied significantly which favour the females. The proportion of male was 18.36 % while that of females 67.61% and the proportion of juveniles and fawns consists of 14.02%. Monthly frequencies of different sex group of sambar indicated that the fawns comprised maximum during monsoon months as showed in the figure, 25. The sex ratio was in favour of females in the study area.

## Table - 28

## Population structure of sambar in Periyar

| Age group /Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adult male | 12 | 8 | 9 | 17 | 11 | 32 | 14 | 27 | 49 | 8 | 18 | 15 | 810 | 18.36 |
| Adult Female | 51 | 30 | 17 | 67 | 54 | 98 | 52 | 121 | 134 | 51 | 94 | 41 | 220 | 67.61 |
| Juveniles & Fawn | 6 | - | - | 3 | 2 | 4 | 42 | 64 | 26 | 12 | 8 | 1 | 168 | 14.02 |

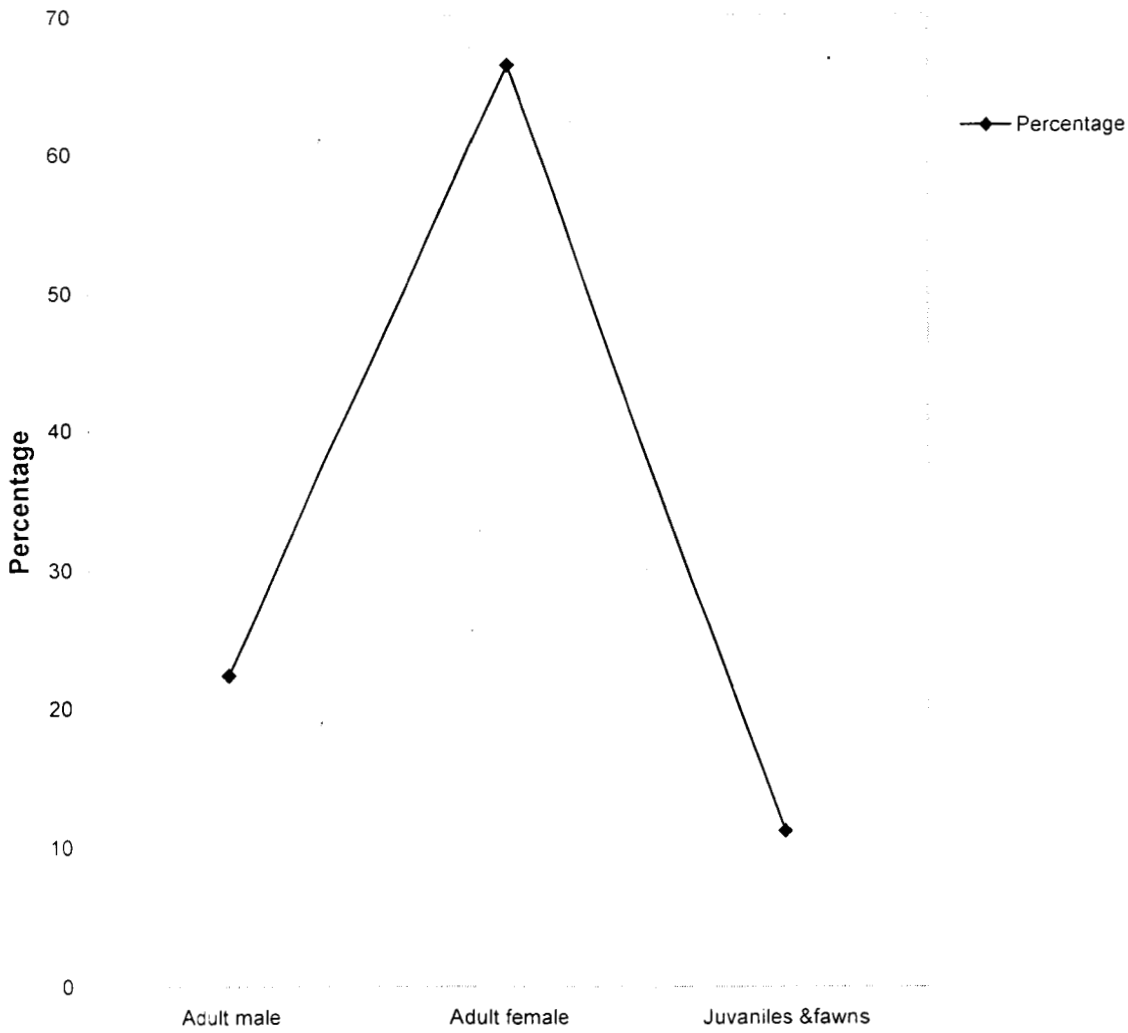


**Fig. 24 Percentage of different age groups of sambar**

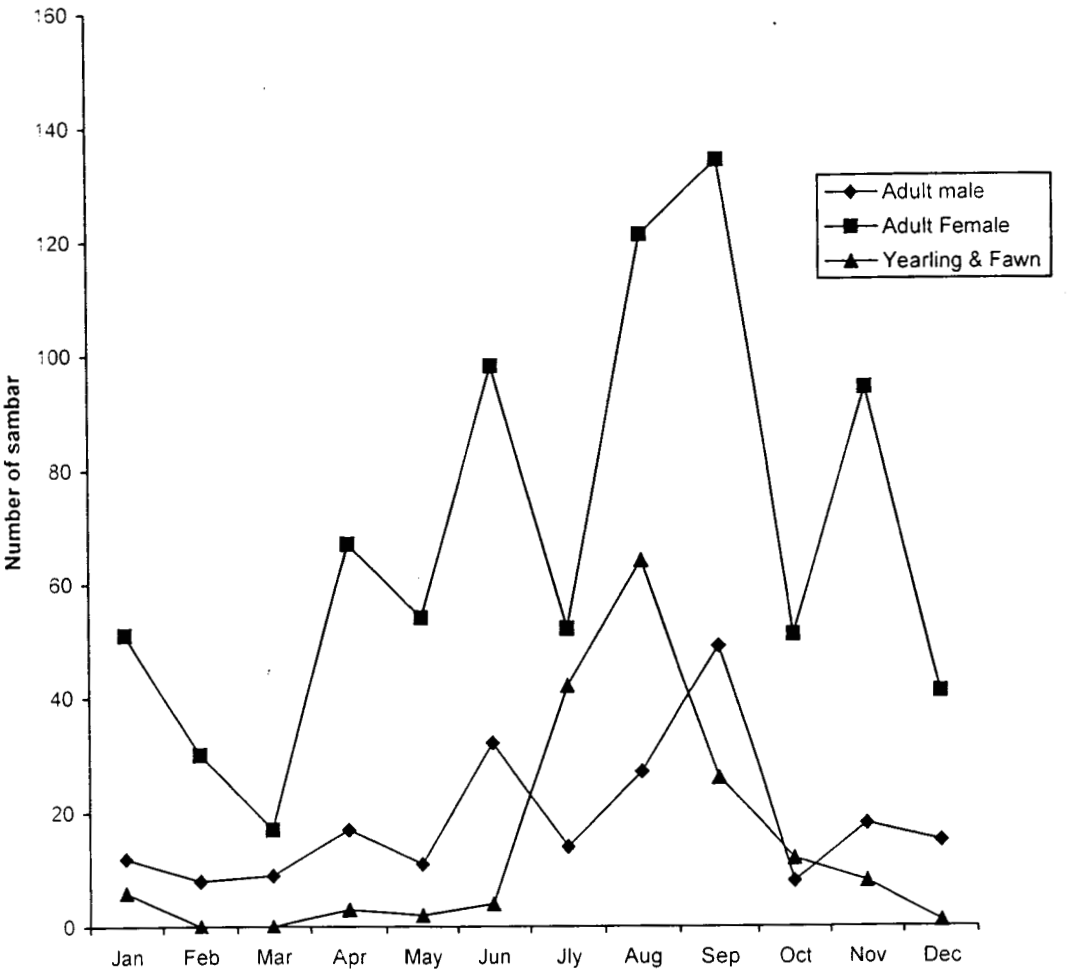


**Fig.25 Proportion of different age class of sambar by month**

## VII. 2 MORTALITY

Predation, disease, poaching and tourism are the factors responsible for the mortality of sambar in Periyar. Of which, predation is the major cause, about 90% of mortality is due to predation, especially by tiger and wild dogs. Kurup (1972) has recorded that there was clear sign of heavy predation on sambar by wild dogs in early 1970s. Besides, in one instance the digestive tract of one of the died sambar was full of Amphistomes during the study period. Several cattle and buffaloes graze in the tourist zone of the reserve, however there was no sign of epidemics like rinderpest, anthrax etc. were noticed in sambar during the present study period.

Only one incident of poaching was recorded during the coarse of the study, sambar was reportedly trapped and killed by a local man. On few occasions, heard shooting sound from the Kurishmalai and Anchuruli areas and the local tribes informed that the sambar was the target. One sambar was electrocuted near Pacchakanam in the Vallakadavu Range. Indirectly tourism has caused death of sambar, on two occasions sambar was run over and hit by motor vehicles at Thekkady, tourist zone, and the animals died after a few days.

## VII. 3. HERD COMPOSITION

Sambar has an uneven distribution throughout the study area. But they avoided dense evergreen forest. The species was seen singly

and in herds of up to 60 individuals but this herds are not stable. Herds are formed at certain times of the day mostly in open areas and disperse. Out of the 290 observations, 30 % were solitary individuals. 24.48 % two individuals. 21.03 % in groups of 3-5, 13.79 % in groups ranging from 6-10 and 10.68 % in groups comprising more than 10 members. All the herdsize classes were sighted in maximum numbers during monsoon and post-monsoon seasons followed by summer and winter months.(Table 29 & Fig. 26). The herdsize ranging from 6 to 10 and above 10 individuals class were maximum during June to December months and consisted of 76 % of the total observations. The aggregation seems to be due to the abundance of forage during rainy season and post-monsoon months.

Out of the total solitary sambar sighted, 45 were males and 42 females comprising 16.20 % and 14.82 % respectively. There was no significant difference in the number of solitary individuals of different sexes in Periyar by season. During monsoon season the sighting of these two sexes are of equal numbers where as in post-monsoon and winter period there was only slight difference in the proportions of the two sex in the study area. The maximum numbers of solitary individuals of both sexes were sighted during monsoon and post-monsoon months.

Table - 29

Monthly frequencies of different herdsize of samabr in Periyar

| Herd size | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solitary | 8 | 3 | 5 | 9 | 3 | 7 | 5 | 14 | 9 | 8 | 9 | 7 | 30 |
| Up to two | 5 | 4 | 3 | 6 | 4 | 8 | 6 | 5 | 12 | 6 | 9 | 3 | 24.48 |
| 3 to 5 | 4 | 1 | 2 | 5 | 5 | 7 | 5 | 7 | 14 | 3 | 4 | 4 | 21.03 |
| 6 to 10 | 2 | 1 | 2 | 3 | 1 | 4 | 7 | 6 | 8 | 2 | 4 | - | 13.79 |
| Above 10 | 1 | 1 | - | 3 | 3 | 6 | - | 5 | 6 | - | 3 | 3 | 10.68 |

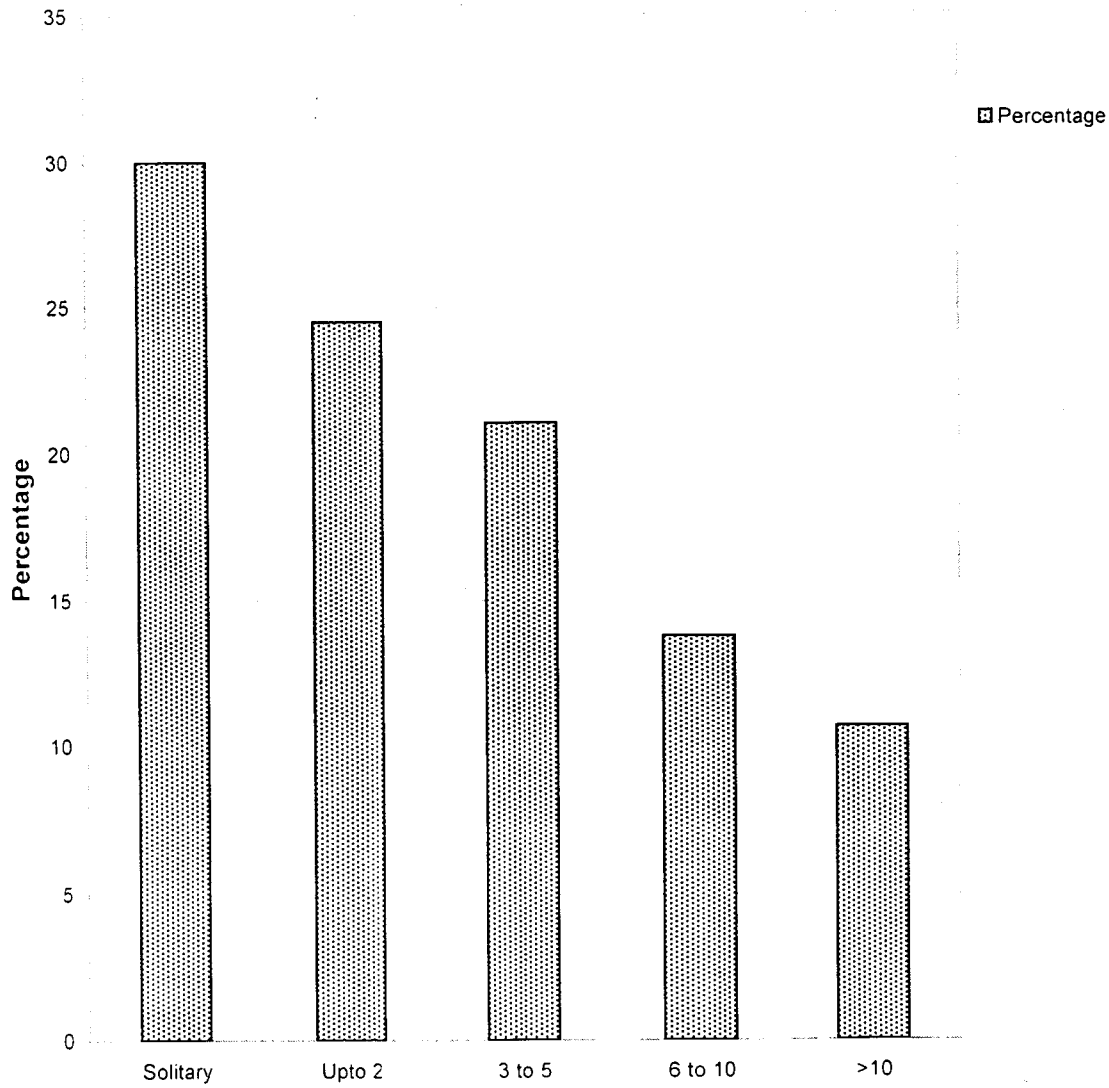


**Fig.26 Percentage of occurence of herdsize pattern of sambar**

The herdsize variations have shown that there were structurally distinct types of herds with different proportions of males and females. Of the total sightings of sambar herds, 87 were of solitary individuals. Of the remaining 203 herds, four herds were without males and observed during rainy season. Two herds with more than 10 individuals without males were observed during this period. Herds with one male sambar were observed 36 times with a proportion of 12.41 % and these herds were mostly smaller in size. Other herds had more than one male with them.

In species like sambar where groups are constantly changing in size, a ' group size' concept however is not applicable. The term 'fluid groups' (Barrette, 1991) would be more applicable to the groups of this species.

The assemblage of sambar observed in certain pockets in the study area like Ayyappankuruku near Edappalayam in the tourist zone especially during evening hours consisted of larger herds of up to 60 individuals. Here the habitat is open and Wild Dog predation is of regular occurrence. Groups are formed, increase in size, last up to several hours and disperse. Since the groups are ever changing, one cannot present the size of the several groups encountered. Barrett (1991) has presented a scale for group size with 10 classes from 1-10, then all groups from 11-20 in a single class, 21-30 in another class and so on. But in this study, the group size have been classified

Table - 30

Herdsize variation of sambar by vegetations

| Vegetation | Solitary | Up to 2 | 3 to 5 | 6 to 10 | Above 10 |
|---|---|---|---|---|---|
| Grassland | 29 | 26 | 25 | 11 | 11 |
| Savannah | 21 | 23 | 20 | 6 | 5 |
| Moist deciduous | 31 | 15 | 8 | 20 | 15 |
| Semi evergreen | 6 | 5 | 6 | 1 | - |
| Plantation | - | 2 | 2 | 2 | - |

into, solitary, two individuals, 3-5, 6-10 and above 10 group sizes. The fluidity and social character is evidently observed. The sambar disturbed by an observer is found running towards another and they in turn to another individual of their species and so on. A search for larger group in the area, a day after they were located, often becomes a futile attempt. Schaller (1967) mentioned a leadership. often an adult hind in the movements, which supports our observations in Periyar.

There was not much influence of vegetation types and season on the herdsize of sambar in Periyar, however Herdsize ranging form 6 to 10 and above 10 were observed maximum (49.29%) in moist deciduous forests as given in the table 30, under tree cover, where they could probably hide from predators a predator avoidance behaviour. Larger herds were seen more often in the grasslands (30.98) especially in the areas near lakebeds where mass defence against predator and the spotting a predator are better. Smaller herdsize were sighted throughout the year though the larger herdsize of 6 to 10 and above 10 classes observed more during monsoon and post monsoon period. As per the observed and expected frequencies table, table 31 and 31A, there was not much association between season and herdsize ($\chi^2$ = 7.2600, df= 12, P > 0.01). Eventhough the percentage of the larger groups constitute 39.43% and 36.61% during the monthy June August and September to December

## Table - 31

**Occurrence of various herdsize classes of sambar in different seasons**

| Season | Solitary | Up to 2 | 3 - 5 | 6-10 | Above 10 |
|---|---|---|---|---|---|
| Winter | 11 | 9 | 5 | 3 | 2 |
| Summer | 17 | 13 | 12 | 6 | 6 |
| Monsoon | 26 | 19 | 19 | 17 | 11 |
| Post-monsoon | 33 | 30 | 25 | 14 | 12 |

## Table - 31A

**Occurrence of various herdsize classes of sambar in different seasons**

**Expected frequencies**

| Season | Solitary | Up to 2 | 3 - 5 | 6 - 10 | Above 10 |
|---|---|---|---|---|---|
| Winter | 9.1901 | 7.5000 | 6.4437 | 4.2254 | 2.6408 |
| Summer | 16.5423 | 13.5000 | 11.5986 | 7.6056 | 4.7535 |
| Monsoon | 28.1831 | 23.0000 | 19.7606 | 12.9577 | 8.0986 |
| Post-monsoon | 33.0845 | 27.0000 | 23.1972 | 15.2113 | 9.5070 |

(Fig. 27), while it was 16.90% and 7.04% during summer and winter months. The mean herdsize of sambar varied in different months and maximum mean herdsize was obtained during monsoon (4.9) and post monsoon months (4) while it was 3.5 and 3 during winter and summer months respectively (Fig. 28) and this variation seems to be influenced by the quality and quantity of forage and other ecological requirements, the abundance of precipitation, sambar tend to increase their herdsize during wet months in Periyar.

## VII. 4. HABITAT PREFERENCE

The sambar is an animal of high adaptability since it is found in a wide variety of habitats. Its habitat utilization patterns are broader and present a wide range of habitat types, which it could utilize consistently (Eisenberg and Lockhart, 1972). The preference of sambar to grasslands in the study area was 35.17 % and moist deciduous habitat 30.68 % and followed by savannah habitat with 25.86 %. They showed least preference to semi evergreen forest and Eucalyptus plantations 6.20 % and 2.06 % respectively (Fig. 29).

This species' preference for open habitats, which include grassland, savannahs and moist deciduous types, comprised 91.71 % and to other types (semi evergreen and plantation area) was 8.26 %. Sambar is hence essentially an animal of open habitats and Periyar during different months of the year is given in the table 32.

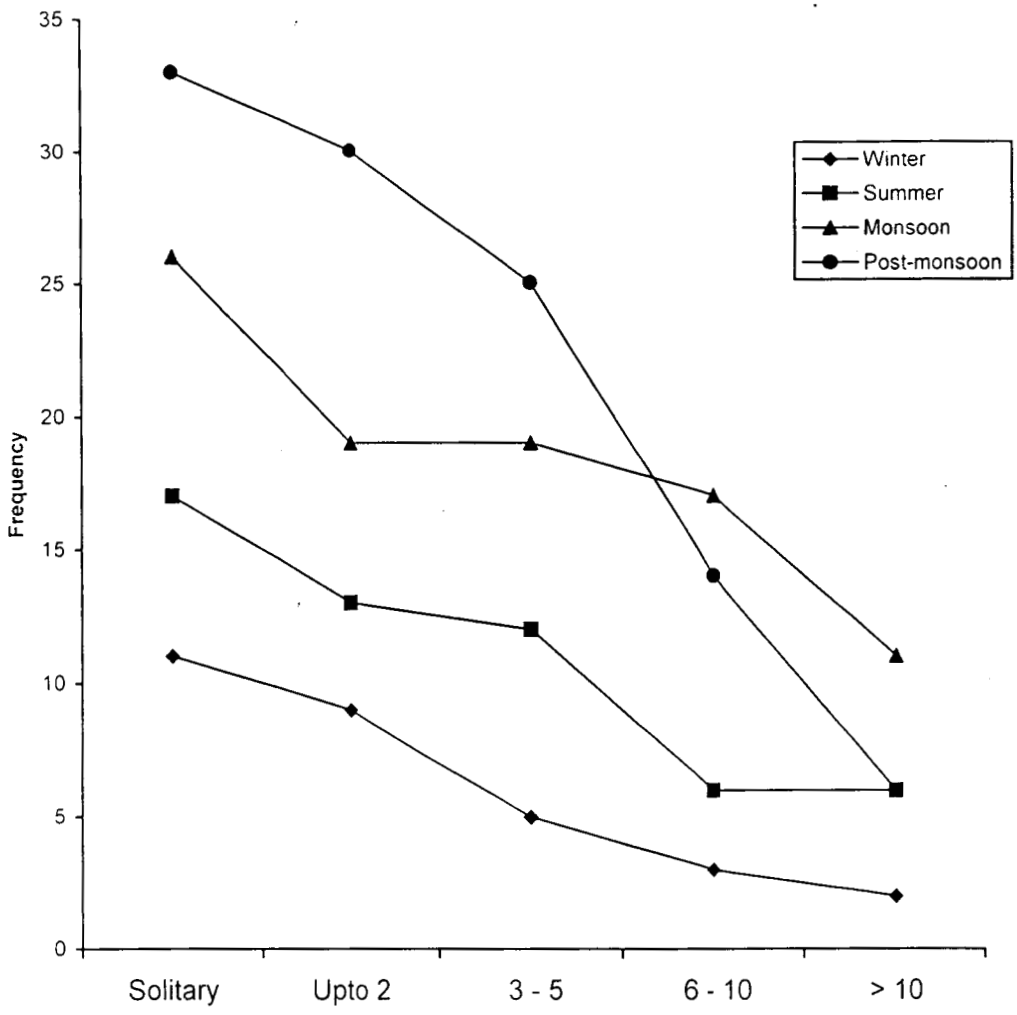


**Fig.27 Groupsize frequencies of sambar in various seasons**

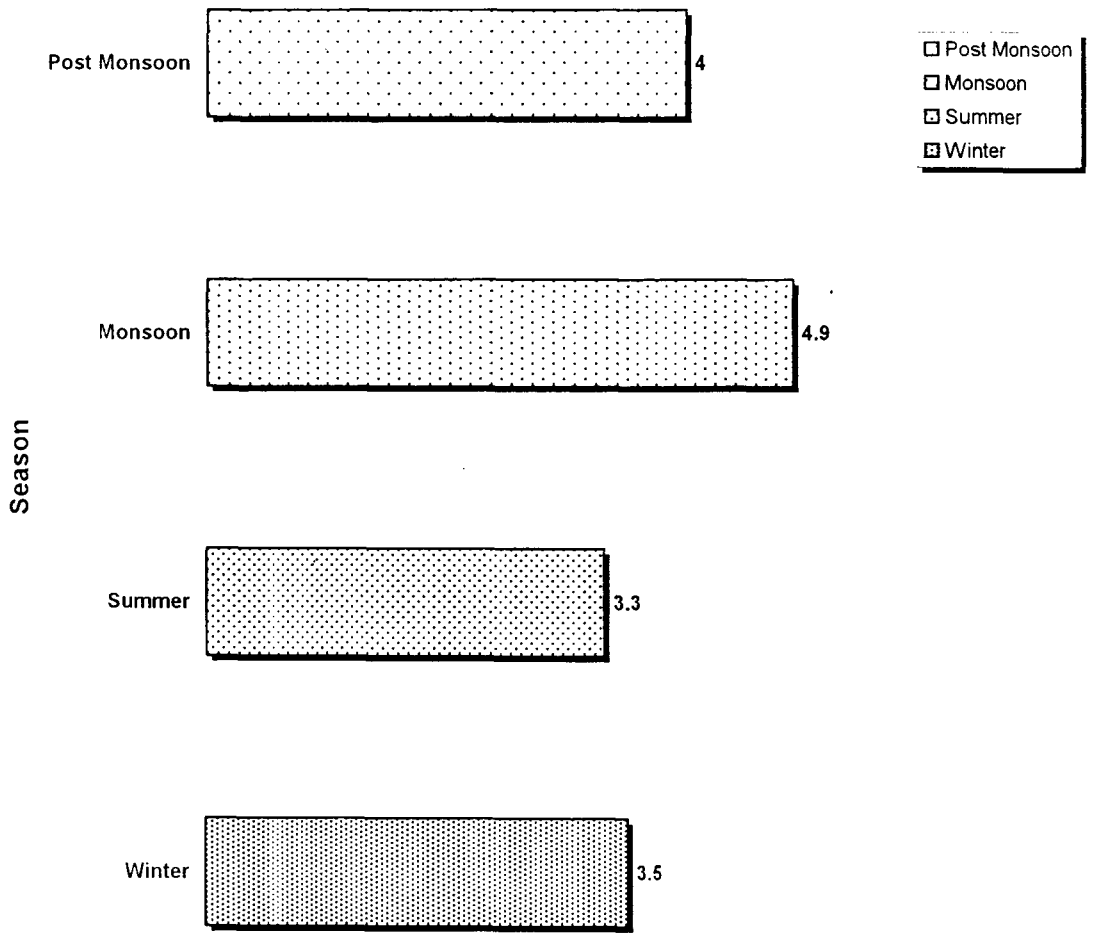


**Fig.28 Seasonal Variations in the mean group size of sambar**

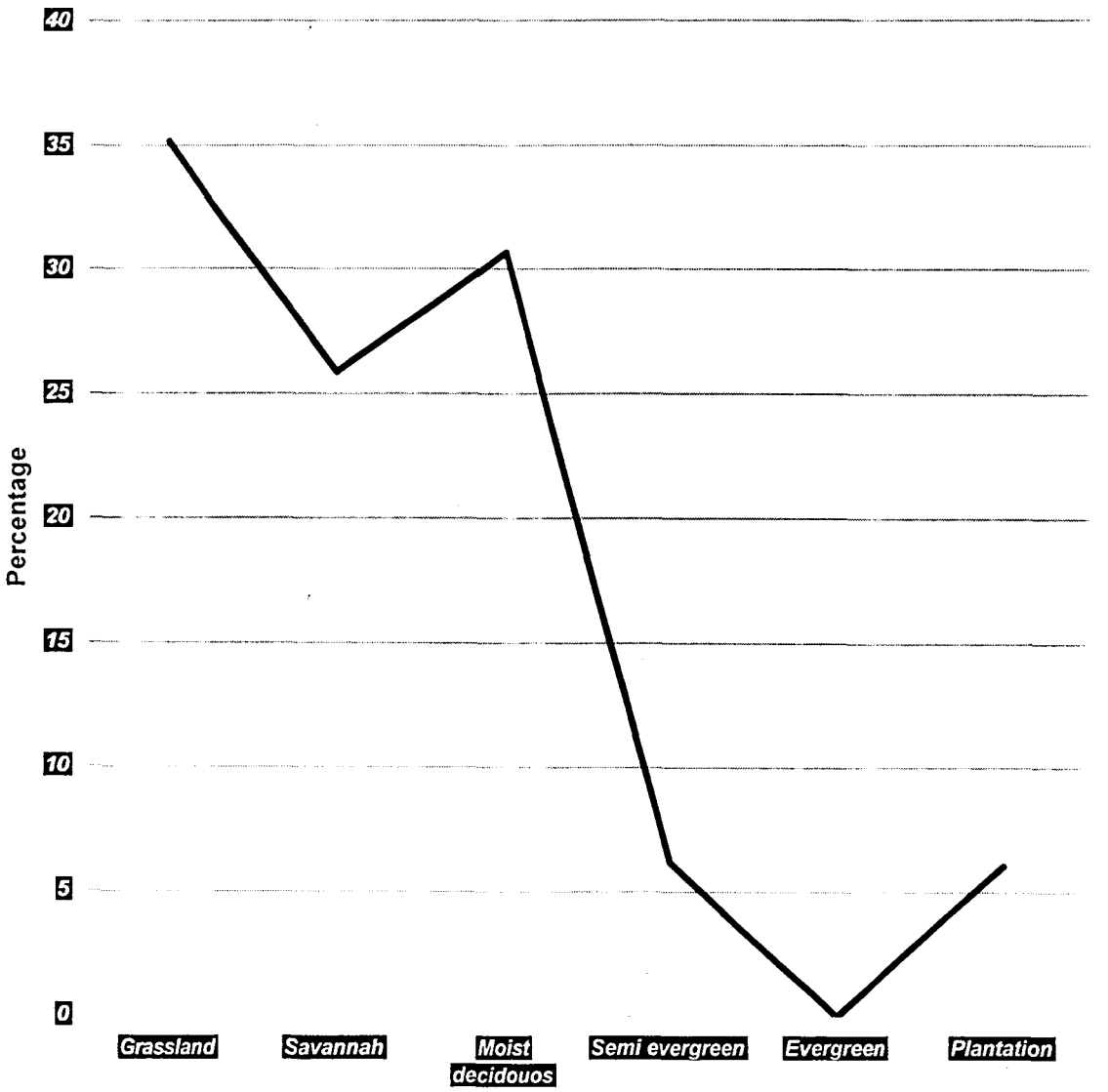


Fig.29 Habitat preference percentage of sambar

Table - 32

Monthly Habitat preference of sambar

| Habitat | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grassland | 8 | 7 | 5 | 8 | 5 | 14 | 10 | 8 | 7 | 12 | 8 | 10 |
| Savannah | 11 | 2 | 1 | 6 | 4 | 10 | 5 | 9 | 12 | 2 | 11 | 2 |
| Moist deciduous | - | 1 | 5 | 8 | 4 | 8 | 8 | 13 | 26 | 4 | 8 | 4 |
| Semi evergreen | 1 | - | 1 | 4 | 2 | - | - | 4 | 4 | 1 | - | 1 |
| Plantation | - | - | - | - | 1 | - | - | 3 | - | - | 2 | - |

avoiding areas of dense tree growth. Habitat preference of sambar in

As per the present study, sambar is observed in grassland throughout the year, (Plate VIII), with maximum sighting during monsoon and post-monsoon periods where as the use of savannah type and moist deciduous forest was mostly from April to November, late summer and wet months (Table 33 & 33A) eventhough their utilization of various habitats in Periyar not influenced significantly with season ($\chi^2 = 21.6704$, df = 12, $P > 0.01$). During the months from December to March every year the wild fire usually occur in Periyar and most of the grassland areas are burnt. However grasslands in the lakebed are not prone to forest fire in the study area. Two to three days after the fire, grass shoots, herbs and shrubs sprout mostly with the first during pre-monsoon shower. The tender lush green sprouts attract sambar to congregate on grasslands and burnt areas. Observations have shown that the sambar is the first animal entering a burnt area, a day or two after the fire, to feed on the sprouting tender shoots of plants.

Of the different habitats available in the reserve, grassland and savannahs constituted only 1.6 % of the total area but 61.03 % of sambar sightings were recorded in this type of habitat. In contrast, the moist deciduous forest that consists of 12.98 % of the total area, recorded only 30.68 % of the sightings. The semi evergreen forest constituting extensive areas with 35.40 % had only 6.20 % of herds

## Plate VIII

Herd of Sambar on the grassland - Hilltop

## Table - 33

**Seasonal variation in the use of different habitats by sambar**

| Habitat | Winter | Summer | Monsoon | Post-monsoon |
|---|---|---|---|---|
| Grassland | 15 | 18 | 32 | 37 |
| Savannah | 13 | 11 | 24 | 27 |
| Moist deciduous | 1 | 17 | 29 | 42 |
| Semi evergreen | 1 | 7 | 4 | 6 |
| Plantation | - | 1 | 3 | - |

## Table 33A

**Seasonal variation in the use of different habitats by sambar Expected frequencies**

| Habitat | Winter | Summer | Monsoon | Post-monsoon |
|---|---|---|---|---|
| Grassland | 10.5517 | 18.9931 | 32.3586 | 40.0966 |
| Savannah | 7.7586 | 13.9655 | 23.7931 | 29.4828 |
| Moist deciduous | 9.2069 | 16.5724 | 28.2345 | 34.9862 |
| Semi evergreen | 1.8621 | 3.3517 | 5.7103 | 7.0759 |
| Plantation | 0.6207 | 1.1172 | 1.9034 | 2.3586 |

of sambar sightings (Fig.30). Hence it seems that the preference of habitat by sambar in Periyar is not proportional to the area of different habitats in Periyar.

## VII. 5. FOOD HABITS

The diet of sambar includes a variety of plants such as grasses, herbs, shrubs and trees as given in the table 34. Of the total plants identified food the grasses constituted the major part of their diet (43.47%) followed by herbs (30.43%). The shrubs and trees contributing 26.08%. The intake of grass species didn't vary too much seasonally, even though the animal's diet mostly consisted of grass species in monsoon and post monsoon than winter and summer months.

The food selection of sambar varied insignificantly in different seasons in the study area, the summer diet included more herbs, shrubs and tree species. Of the total 55 species of summer food plants identified the percentage of grasses was 40% and that of the browse species was 60%. Monsoon diet consisted mostly grasses with a percentage of 54.71 and 45.28% of browse species as shown in table 35 and fig.31.

The sambar also showed seasonal preference to certain food plants. They didn't take *Flemingia strobilifera, sida humilis, Heckeria subpeltata* etc. during winter months. The plants such as

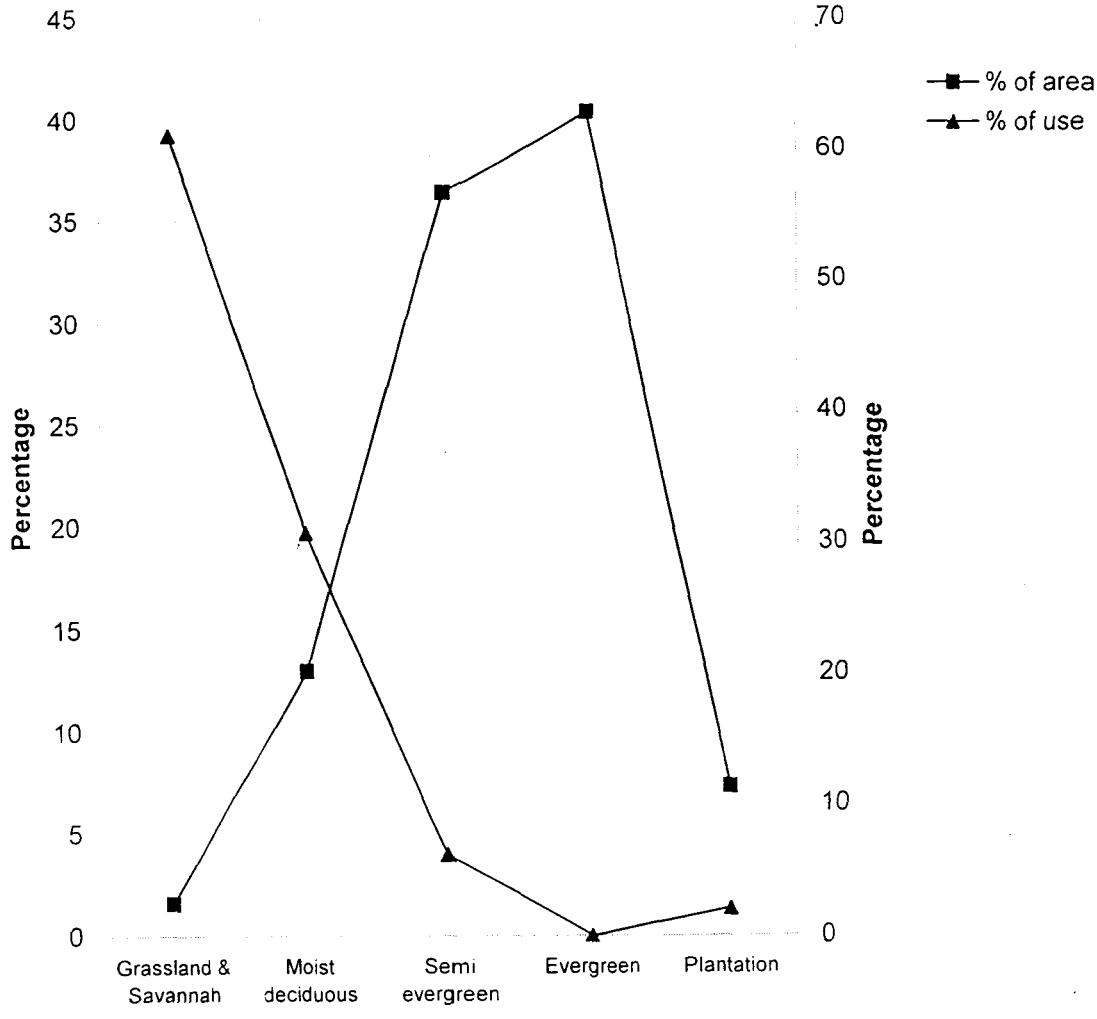


**Fig.30 Proportion of different habitats and percentage of preference by sambar**

## Table 34
## Food plants of sambar in Periyar

| Name of Food Plants | Family | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Alloteropsis cimicina* | Graminae | * | * | | | * | * | * | | | | | |
| *Apluda aristata* | Graminae | * | * | | * | * | | | | * | | | |
| *Apocopis wightii* | Graminae | * | | * | | | | | | | | | * |
| *Aristolchia indica* * | Aristolochiaceae | * | | | * | * | | | | | | * | |
| *Arthaxon quartianianus* | Graminae | * | | | | | | * | * | * | | | * |
| *Artocarpus gonezianus* * | Moraceae | | | * | | | | | | | | | |
| *Canthium angustifolium* | Rubiaceae | | | | | | | | * | | | | |
| *Carya arborea** | Lecythidaceae | | | * | * | | | | * | | | * | |
| *Cassia occidentalis* * | Caesalpinaceae | * | * | * | | | * | | | | * | | |
| *Centella asiatica* * | Umbilferae | * | | | * | * | | | * | | | | * |
| *Chrysopogon spp.* | Graminae | * | | | | * | | | * | | | * | |
| *Coix lachryma jobi* | Graminae | * | * | | | | | | | | | | |
| *Crotalaria pubescense* * | Leguminaceae | | * | | * | | | | * | | * | | |
| *Cymbopogon flexuosus* | Graminae | * | * | | * | * | * | | * | | | * | * |
| *Cynodon dactylon* | Graminae | * | * | | | | | * | * | * | | | * |
| *Cynoglossum furcatum* * | Boraginaceae | | | * | | | * | * | | | * | | |
| *Cyrtococcum oxyphyllum* | Graminae | * | | | * | * | | * | * | * | * | * | * |
| *Desmodium triflorum* | Fabaceae | | | | | * | | * | * | | | | |
| *Digitaria sanguinalis* | Graminae | * | | * | | | * | * | * | * | | * | * |
| *Dimeria spp.* | Graminae | * | | | | * | | * | * | | | * | |
| *Elepantopus scaber* * | Asteraceae | * | | | * | * | | * | | * | | * | |
| *Eleusine indica* | Graminae | * | * | | | * | * | * | * | * | | * | * |
| *Emblica officinalis* ** | Euphorbiaceae | | * | * | | | | | | | | | |
| *Emilia sonchifolia* * | Asteraceae | | * | | * | | * | | | | | | * |
| *Entada scandens* * | Leguminaceae | | * | | | * | * | | | | * | | |
| *Eragrostis bifaria* | Graminae | | * | | | | | * | | | | * | * |
| *Eragrostis unioloides* | Graminae | | | * | | * | | * | | | | * | |
| *Eragrostis willdenoviana* | Graminae | * | | * | | * | * | | | * | | | * |
| *Ficus hispida* * | Moraceae | | | * | | | | | * | | * | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Flemingia strobilifera* | Fabaceae | | | | | * | | | * | | | | |
| *Garnotiai arundinacea* | Graminae | | | * | | * | * | | | * | | | * |
| *Grewia tiliaefolia* | Tiliaceae | | | * | * | | | * | * | * | * | | |
| *Heckeria subpeltata* | Piperaceae | | | * | * | | * | | | | | | |
| *Helecteres isora* | Sterculaceae | | | | * | | | * | * | * | | | |
| *Heteropogon contortus* | Graminae | | | | | | | | * | | | * | * |
| *Hibiscus lobatus* | Malvaceae | | * | | | | | | | | * | | |
| *Justicia procumbens* | Acanthaceae | | | | | * | | | | | | | |
| *Knoxia mollis* | Rubiaceae | | | | * | | | * | * | | | * | |
| *Lantana camara* | Verbenaceae | | | | | | | * | | | | | |
| *Maesa perrottetiana* | Myrsinae | | | | | | | | | * | | | * |
| *Mangifera indica* ** | Anacrdiaceae | | * | | | | | | | | | | |
| *Manisuris granularis* | Graminae | | * | * | | | | | * | * | | * | * |
| *Memecylon edule* | Melastomaceae | | | | * | | | | | | | | |
| *Oplismenus compositus* | Graminae | | | | * | | | * | * | | * | * | * |
| *Ottochloa nodusa* | Graminae | | | | | * | | | * | * | | | |
| *Panicum repens* | Graminae | * | * | * | * | * | * | * | * | * | * | * | * |
| *Panicum trypheron* | Graminae | | | | | | | | * | * | | * | |
| *Paspalum compactum* | Graminae | * | | * | | | | | * | | | | * |
| *Passiflora subpeltata* | Passifloraceae | | * | | | | | | | | * | | |
| *Pennisetum hohenackeri* | Graminae | | | | | | * | * | * | | | | * |
| *Polygonum chinense* | Polygonaceae | * | | | | | | * | | | | | |
| *Psidium guajava* ** | Myrtaceae | | | | * | | | | | | | | |
| *Psychotria nigra* * | Rubiaceae | | | * | | * | | | | | | * | * |
| *Pterocarpus marsupium* | Fabaceae | | | * | | | | * | * | | | | |
| *Randia dumetorum* * | Rubiaceae | | | | * | * | | | | * | | | |
| *Rottboellia exaltata* | Graminae | | | | | | | * | * | | | | |
| *Rubia cordifolia* | Rubiaceae | | | | | | * | | | | | | |
| *Saccharum spontaneum* | Graminae | | * | | | | * | * | | | | * | |
| *Setaria intermedia* | Graminae | | * | | | * | | * | | * | | * | * |
| *Sida humilis* | Malvaceae | | | * | | | | | | | | | |
| *Solanum sisybrifolium* * | Solanaceae | * | | | * | * | | | | * | | * | * |
| *Solanum torvum* | Solanaceae | | | | * | | | | | | | | * |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sporobolus spp.* | Graminae | | | | * | | | * | | | | * |
| *Stachytarpheta indica* * | Verbanaceae | * | * | | * | * | | | | * | | |
| *Synedrella nodiflora* | Asteraceae | | | | | * | * | | | | | |
| *Themeda cymbaria* | Graminae | * | | | | | * | * | | | * | * |
| *Themeda triandra* | Graminae | * | | * | | | * | * | * | | * | * |
| *Urena lobata* | Malvaceae | | * | * | | | | | | * | * | |
| *Urena sinuata* | Malvaceae | | | * | * | | | | | | | * |

* Direct Observations ** Fruits

**Table -35**

**Seasonal variations in plant taxa eaten by sambar in the study area**

| Type | Winter | Summer | Monsoon | Post monsoon |
|---|---|---|---|---|
| Grass | 15 | 22 | 29 | 29 |
| Herb | 10 | 17 | 15 | 15 |
| Shrub | 2 | 8 | 5 | 6 |
| Trees | 2 | 8 | 4 | 4 |

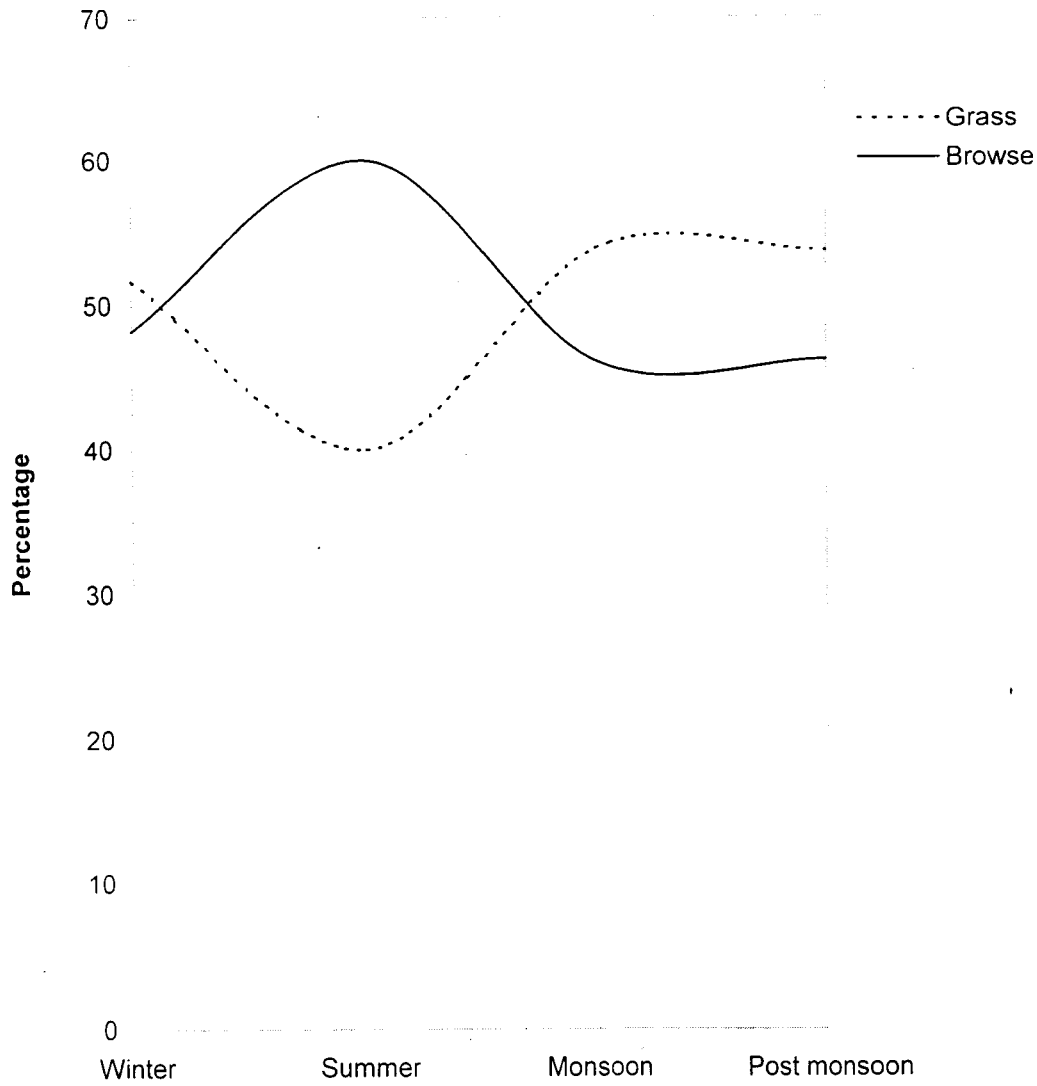


**Fig.31 Seasonal diet variation of sambar**

*Urena lobata, Urena sinuata, Bidens humilis* are do not preferred during the period from June to August. Its diet consisted of 9 species of trees, which was only 13.04%. Fruits of *Emblica officianalis, Psidium guajava, Mangifera indica* and *Artocarpus spp.* were taken during winter and summer months.

The food overlapping among herbivores was observed in the study area. The percentage of overlap of sambar's food with elephant was 10.14% and with gaur 27.53% and overlapping between these herbivores was 49.27%. 14.49% of forage of gaur have no overlap with other species The maximum of overlap was in grass species followed by shrubs and the overlap was minimum among tree and herb species.

# DISCUSSION

The sambar is an animal of high adaptability since it is found in a wide variety of habitats (Schaller, 1967). Its habitat utilization patterns are broader and present a wide range of habitat types, which it could utilize consistently. The vegetations of the study area has a mosaic complex of grassland, savannah, moist deciduous forests, plantations, semi evergreen and evergreen forests in which the grassland was the most preferred and heavily used habitat in Periyar followed by moist deciduous forests. In Periyar, they usually avoid dense forest areas and least preference towards plantation areas. Thus the sambar is considered as an animal of open forest as described by Ngampongsai (1977).

Several factors affect the habitat suitability of sambar in Periyar, the important being the availability of graze and browse species, access to water and cover. The utilization of favoured habitats was maximum during wet months and less during summer months presumably due to the availability of green palatable forage. Their preference to moist deciduous forests seems to be related to abundance of both graze and browse and obviously due to the presence of more shade in these habitats as explained by Bharucha and Asher (1993) in the Black buck.

The less use of grasslands by sambar during summer months is determined by the shortage of palatable grasses. The occasional pre monsoon showers were found to bring sambar herds in grasslands in late summer months. Thus forage appears to be the major factor in habitat utilization by sambar. They most often occurred in certain areas on the lakeshore like Ayyappankurukku near Edappalayam, indicate the selective use of habitat in the study area where optimum availability of forage.

The wild fire usually occur during December to March period in Periyar and majority of the grassland areas are burnt every year, however the grassland on the lakebed are not prone to forest fire, they utilize consistently on the grasslands on the lakebed during fire season. After the forest fire, plants sprout in a few days, often coincide with the first pre monsoon shower. The delicate lush green sprouts attract the sambar to congregate in the burnt areas. Evidently sambar was the first animal entering the burnt area, a day or two after the fire, to feed the sprouting tender shoots of plants.

The sambar herds varied from one to sixty individuals in Periyar, and the larger aggregations observed was not stable. Majority of herds were of small size. The herds of above 10 individuals were 10.68 %, which disagree with the findings of Ramachandran et al., (1987) that the herdsize seldom exceed eight individuals. However the sambar has a propensity to be in smaller groups.

The seasonal variation in the mean group size of sambar was noticed in this study. The mean group size was highest during monsoon season with 4.9 while it was 3.3 during drier months. It is therefore seems that aggregations of sambar is influenced by the availability of forage. The lack of significant seasonal variations in the group size of sambar has been documented by Eisenberg and Lockhat (1972), Dinerstein (1980), Mishra (1982). The group size in species, which exhibit open membership and social structure. may show temporal variations not only on a seasonal basis but also during different times of the day (Sharathchandra and Gadgil, 1975; Barrett, 1991).

The sambar has a tendency to aggregate in certain habitats in the study area and the distribution of larger herds was maximum in grassland and moist deciduous vegetations presumably due to the availability and abundance of forage and protection from predators. These aggregations were mostly noticed during rainy months. Hence the habitat types seem to be an influencial factor on the herdsize pattern of sambar in the study area. Similar observations were reported in Axis axis by Barrette (1991) and various other species (Leuthold and Leuthold, 1975; Takatsuki, 1983; Santiapillai et al., 1984). Occurrence of larger groups in open areas is interpreted as an anti-predator strategy, where animals use each other as cover (Altman, 1974; Jarman, 1974; Pulliam and Carco, 1984) and this seems to be

applicable in the case of sambar in the study area too. Hamilton (1971), Vine (1971). Jarman (1974), Sarthchandra and Gadgil (1975), Khan and Vohra (1992) described that the food availability, predation risk and rutting activity are the main factors responsible for seasonal changes in sambar groups. The similar impacts on mean group size of sambar in Gir forest have been reported by Berwick (1970). According to Sharathchandra and Gadgil (1975) the increase in group size is related to the high food availability but Dinerstein (1980) considered that predator detection to be the prime reason for increase in group size, which is also caused, by the increase in plant cover and density. Khan et. al., (1995) argued that the increase in the plant cover and density would cause the herds to fragment not only due to primarily structural reason (Barrett, 1991) but also because bigger group size would benefit stalking predators. The congregation of sambar was most frequently noticed in certain open areas like Ayyappankurukku and Edappalayam where the wild dog predation was of regular occurrence. Hence the predation seems to be an another factor promoting the formation of larger groups of sambar in Periyar.

The larger aggregations of sambar however were not stable, the groups are found constantly changing in size. A group size concept is hence not applicable here. Barrett (1991) used the term "fluid group" on the groups of Axis axis, he studied. Sambar herds could also be called fluid group since the group may disperse after few

hours of aggregation. Group size variation in different times of the day was also reported by Sharathchandra and Gadgil (1975). The aggregation was maximum during evening hours presumably because of predation since more predation was recorded during evening hours.

Different herd compositions were observed during the present study in which the solitary animals sightings constituted maximum. Small herds with one male and mixed heterosexual herd were also observed in the study area.

The sex ratio of the sambar was slanted and favouring females. The proportion of males to females was 1: 3.6. The yearlings and fawns were observed throughout the year and the fecundity was documented as 0.20 per adult female per year since the population is said to be a productive one. The fecundity of more productive population is in between 0.20 and 0.025 in south India (Sukumar, 1985). In Periyar mating of sambar seems to take place mostly in winter months and adult stags are found with females during this period unlike other months of the year when they move alone. Fawns were observed throughout the year though the maximum birth was notised during the rainy season that might be a survival strategy of this species. Krishnan (1972) reported the occurrence of young fawns during March in Mudumalai. According to Schaller (1967) the young are born in between November and December in Kanha. The desparity in sex ratio has been attributed by several factors in

ungulates such as misclassification of individuals (Sharathchandra and Gadgil, 1975; Mishra, 1982), higher mortality of male fawn (Schaller. 1967; Johnsigh, 1983) and selective predation on males (Schaller. 1967; Berwick, 1974; Johnsingh, 1983; Karanth and Sunquist. 1992). Among the African ungulates, the subsistence of sub adult males on low quality forage as a result of their exclusion from established territories and harassment by dominant males have been discussed as a major factor for higher mortality of males (Leuthold et. al., 1975). In southern Asian ungulates, the solitary habits, lacks of alertness during rut and dispersal behaviour are factors, which makes males more vulnerable to selective predation (Karanth and Sunquist, 1992). In the study area the sambar form the principal prey species of wild dogs and tiger since the predation seems to be the reason for the desperate sex ratio of sambar. Kurup (1971) reported that there was a heavy predation on sambar by wild dog in early 1970s.

Sambar probably subsists on a wider variety of plants (Schaller, 1967) and the diet of herbivore are controlled by several factors such as anatomical and physiological characteristics of animal, plant community structure and chemical constituents of plants (Owen - Smith, 1982), the ability of the animal to digest and metabolise, digestive capacity (Westoby, 1974) body weight, gut size and digestibility (Baile, 1975; Bines, 1976). The popyphagous and

bimodal nature of feeding was observed in Periyar since their diet chart includes a variety of food plants namely grass, herbs, shrubs and tree species in which grass and herbs contribute major portion of its diet in the study area. The polyphagous feeding strategy of sambar give higher advantages to the animal as explained by Crawly (1983) that the animal can feed on the available forage species when available. The animal can select a number of food items of unequal nutritive value that provide a nutritionally adequate mix of essential nutrients.

The most frequently used food plants among grasses were *Cymbopogon flexuosus, Cynodon dactylon, Eleusine indica, Eragrostis willdenoviana, Manisuris granularis, Oplisiminus burmani, Panicum repens, Paspalum compactum* and *Themeda triandra* in which panicum repens is heavily eaten while they are in the lake beds. The utility of grassland was maximum during wet months probably due to the palatability of the species. During summer they switch on to browse species. The important food plants consumed during summer season were *Centella asiatica, Emilia sonchifolia. Helecteres isora, Hibiscus lobatus, Stachytarpeta indica, Synedrella nodiflora, Urena lobata* and *Grewia tiliaefolia.* The habitat type, plant species availability and season are the major factors operating on the preference of sambar in Periyar. The seasonal difference in the use of food plants may be due to the difference in

their nitrogen content (Colmam and Lazenly, 1970), lignin content, digestibility and solubility ratios (Short, 1970) and crude protein (Lyttleton, 1973). The higher amount of crude protein in browse species than grass during summer months is often viewed as a protein supplement to wild animals (Hobbs et. al., 1981). The difference in the nutritional requirements in different stages of life such as fawn period, lactation period and during antler formations have been described by Ullrey et. al., (1969) and French et al., (1976) in white-tailed deer.

Fruits of certain species like *Artocarpus gonezianus; Emblica officinalis* and *Mangifera indica* were eaten during the months from January to May in Periyar and the feeding on fruits seem to be subjected to their availability. Fruits have high lignin content and probably were passed rapidly and represents a source of high-energy food for deer species, this could be the reason for the selection of fruits, as explained by Vangillder (1979) and Vangilder et. al., (1982).

# SUMMARY

The larger herbivores, elephant, gaur and sambar have a wide distribution in south India, in the western ghat country, where they share the same habitats. The population of these herbivores seemed to be declining within their range due to habitat degradation, fragmentation, poaching and epidemics.

The population of all these species is biased to females; adult females formed major portion of this population. Among elephants the adult males females ratio was 1:141. The sex ratio in other age groups is also unbalanced. The skewed sex ratio is evidently due to high poaching pressure.

In gaur and sambar the ratio between males to female were not so pronounced as in elephants. However, selective predation on males or mortality from bull to bull cambat may be the probable reason of the present uneven ratio in these ungulates. The dispersal activity of males and poor nutrition of male calves during their infancy might have also contributed to the mortality in males of these ungulates.

There was no specific breading season for elephant, gaur and sambar in Periyar. However maximum birth was observed during wet months might be a survival strategy with abundant food supply

and sufficient cover. The fecundity of elephant was only 0.08/adult female/year due to the shortage of adult tuskers. However the fertility of other two species was better.

The herbivores have a tendency to become smaller in their herdsize and the most frequently observed herdsize of these species was below ten. The mean herdsize varied by season in Periyar. The aggregations were common in open habitats like grassland, savannah and moist deciduous vegetations particularly during monsoon and post monsoon months due to the constant supply of forage.

The sightings of lone animals were more in sambar though solitary elephant and gaur were also noticed occasionally. Among elephants more solitary individuals were females, might be due to the peculiar social structure of this species and larger number of females in the population.

Larger herds of these herbivores could be the aggregations of smaller units and these aggregations were predominant in grassland and moist deciduous forest. The tendency of formation of larger group in ungulates in open habitats seems not only due to the diet diversity but also to escape predation. Availability of variety of forage in the ecotone areas tends them to aggregate in these areas in Periyar. However larger groups of sambar were not stable and found to disperse after several hours. Hence the term ''fluid groups'' could

be attributed to the sambar herds in Periyar, which were more conspicuous in certain fringes of the reserve especially in late evenings.

In Periyar, the larger herbivores used a broad spectrum of habitats though grassland was most preferred habitat of elephant and sambar. Gaur however showed preference towards moist deciduous forest. Utilization of evergreen forest and semi evergreen forest and eucalyptus plantations was less in the reserve. Dietary diversity, disturbance, percentage of cover are seem to be major components influencing the use of habitats by herbivores in Periyar.

Utilization of grassland by herbivores was optimum with the onset of monsoon and lasted up to the late post monsoon months. During dry months they moved towards moist deciduous forest and adjoining areas, while utilizing grasslands, the gaur preferred hilltops and slops than those on lakebed. The sprouting tender shoots attracted this species, which led to their congregation in the burnt areas after fire seasons. In fact, sambar is probably the first animal enter a burnt area immediately after the first pre monsoon shower.

Grass formed the major share of the diet of larger herbivores throughout the year. However the polyphagous feeding nature is advantageous to the animals since they can switch over temporarily to other species. The palatability and high crude protein content of grass during wet months tend them to take more grasses during this

period. Since grasses formed bulk of their diet they could be called grazers than the browsers in Periyar though they feed a variety of herbs, shrubs and trees species.

During summer months they used more browse species due to the decreased amount of crude proteins and other mineral contents in grasses. Apart from leaves, their diet includes fruits and barks. The elephant consumed barks of *Grewa tiliaefolia, Telia gamblia, Randia dumetorum, Careya arborea, Helecteres isora* and *Ficus spp.* The three species however took fruits of *Mangifera indica, Emblica officinalis, Psidum guajava* and *Artocarpus spp.* during their fruiting seasons.

The larger herbivores, elephant, gaur and sambar shared a number of food items and their dietary pattern has indicated that there was overlap between these species in their forage. However competition between them is minimised by selective feeding on different plant parts and feeding at different times of the day. According to Lamprey and Stewart (1984). ungulates living together use different resources that could be determined from their food habits. Maximum overlap was observed in grass species and it seemed to be greatest in the dry season when forage is least available as stated by Hansen et. al., (1985) which lead to competition (Field, 1972; Abrams, 1980). Such condition is not cause high mortality among ungulates in drought years (Hillman and Hillman, 1977; Sinclair et. al., 1979).

The forage overlap of herbivores in Periyar is very significant since these species have higher dependency on open habitats that constitute only in a small proportion of the study area. This may likely to cause optimum pressure on these habitats and forage. According to French (1982), in prolonged periods of unfavourable conditions particularly in smaller areas, the survival of the whole population of large herbivores will be most endangered. Therefore it seems that herbivores require much larger areas for forage.

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