Social Organization and Dispersal of Asiatic Lions

&

Ecological Monitoring of Gir

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INTRODUCTION

Project titled 'Social Organization and dispersal of Asiatic lion' was initiated in 2002 by the Wildlife Institute of India in collaboration with the Gujarat Forest Department. Continuous record of lion demographic and population parameters, ungulate density and distribution, livestock-ungulate interaction and the study of male ranging patterns and resource utilization with the help of radio- telemetry have been some of the achievements of the project in the past five years. The project had established two research-bases at Sasan Gir (West Gir) and Tulsi Shyam (East Gir) respectively to meet the added project objective of project "Ecological monitoring of the Gir" in 2003. This component included studies on livestock-wild ungulate interaction, Maldhari-lion interaction, refinement of protocols for lion monitoring and mapping of peripheral areas of Gir which were considered important by the Gujarat Forest department and The Wildlife Institute of India.

Male lions have a very large annual home-range and the study of their movement patterns and resource utilization strategies requires radio-telemetry. Permissions for radio-collaring 20 lions were granted by the MoEF in 2003. The Chief Wildlife Warden sanctioned the collaring of 6 lions in early 2005. Two lions were collared in December 2005 and one in January 2006 with normal VHF, GPS-satellite VHF and GPS VHF collars. However, the technology and ruggedness of the HABIT Research collars failed and the collars had to be replaced. The delays in obtaining radio-collaring permissions, deployment and the failure of technology have been a major impediment in achieving the full sample size of the project.

The Wildlife Institute of India proposes to continue its research and monitoring work in the Gir PA in collaboration with the Gujarat Forest Department. Future work would include continued monitoring of the radio collared lions and vegetation exclosures. We shall also undertake a detailed study of the peripheral populations of the lions in areas adjoining to the Gir PA by deploying satellite/ GPS/ VHF collars on lions near Savar Kundla, in coastal areas and in Girnar. Sub-adult lions nearing dispersal age would also

be collared within and outside the Gir protected area to better understand dispersal in lions—a crucial ecological aspect extremely relevant for conservation management.

The project report includes chapters on lion demography, lion habitat preference, diet, social organization, preliminary finding of ranging of radio-collared male lions, ungulate densities, chital and livestock ecology, the contribution and availability of livestock for the resident carnivores in the park. Other parameters for long term ecological monitoring of the Gir are also discussed.

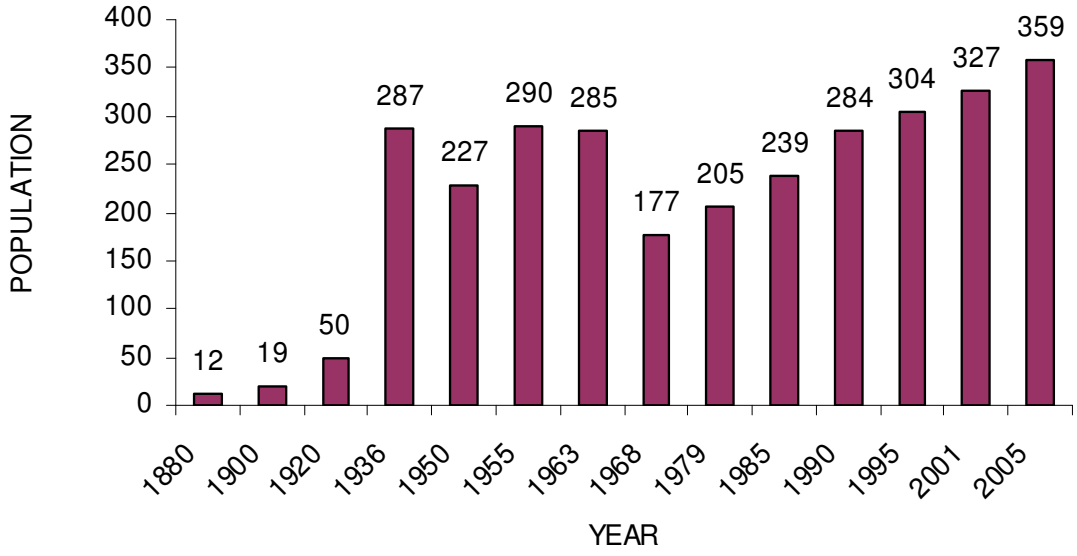
Asiatic Lions: Distribution and Status

The only surviving free-ranging population of the Asiatic lion (*Panthera leo persica*) exists in the Gir forest, Gujarat, India. Historically, the range of the Asiatic lion once extended from Syria across the Middle East to Eastern India (Kinnear 1920, Joslin 1973). Lions inhabited the entire North and Central India and were found in large numbers in the states of Punjab, Haryana, Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat and western Bihar (Fenton 1908, Dalvi 1969). Indiscriminate hunting wiped out lions from the rest of India 1880 (Pocock, 1936). Within the Saurashtra region, they were found in Dhrangadhra, parts of Jasdan, Chotila, Alech hills, Barda hills, Girnar and Gir. By the turn of the 19th century, large tracts of cultivation came to separate Gir, Girnar, Alech and Barda hills. As a result, lions came to be isolated and ultimately limited to the Gir forest (Dalvi 1969). Lions were still known to move out of Gir in post monsoon and monsoon season (Singh 1997). In recent years a lions, totaling about 50 has taken permanent residence in the coastal forests of Kodinar, Girnar and Mitiyala forests (Soni 2000).

While the distribution of lions has consistently shrunk and has been limited to a single pocket in Gir, the population numbers within the area has also fluctuated widely over the years. The numbers of lions in the Gir was very small, believed to be as low as 12 animals in 1880 and very close to extinction (Wynter-Blyth and Dharmakumarsinhji 1950). Owing to the timely protection measures taken by the Nawab of Junagadh, the lion population got a brief respite from hunting and recovered to a number of 70. However, a

famine that occurred between the years 1901 and 1904 brought the lions in direct conflict with the people thereby ending the earnest attempt to protect them. Yet again the lion population declined to a mere 20 at the end of the famine in 1911. This brief period under the British and the following period under the new Nawab, the lion population was again resurrected from the brink of extinction. The 1936 census indicated a population of 287 (Dalvi 1969). Lion count in the following years, in 1950, 1955 and in 1963 showed stable population figures of 227, 290 and 285 respectively (Wynter Blyth and Dharmakumarsinhji 1950, Wynter Blyth 1956, Singh 1997). The population of lions has since then been increasing (**Figure: 1**).The current estimated population size is 360 lions, including those living outside the park.

Figure 1: Estimated Population of Gir Lions (Source: Gujarat Forest Department)



There has also been a substantial increase in the wild ungulate population (Khan 1996). The Gir today has a very high density carnivore population. There is also high density growing population of over 250 leopards within Gir.

However, the Gir is also impacted upon by a growing human population: There are 97 peripheral villages with over a Lac human population and over 95,000 livestock;

over 5000 Maldharis with 10,000 livestock in 54 nesses across the Gir PA and about 4500 people in 14 forest settlements with a livestock of nearly 4200 (Singh and Khamboj, 1996)

The above changes have resulted in increasing incidences of human-animal conflict. On the one hand, there a substantial increase in sugarcane and mango cultivation around Gir and has resulted in an increase in incidences of crop damage by wild ungulates (Pati, 2000) and on the other, there is an increase in encounters with an expanding carnivore population. In the last eight years there has been an increase in attacks and injuries by lion and leopard around the Gir PA.

In recent years, lions have started dispersing out of the Gir PA and taken permanent residence in certain areas. Lions have been recorded in Girnar, coastal areas and areas from Palitana to Savar Kundla to Mitiyala. The 2005 census has estimated a population of 68 lions in these peripheral areas.

Review of past research in Gir PA

Gir has a long history of research and the studies conducted so far include both the animal and plant component of Gir. Berwick (1971, 1976) studied the conflict between wild ungulate and livestock population and the role of predators. Joslin (1973) looked at studied the reasons responsible for decline in the population of the Asiatic lions and suggested appropriate management recommendations. Sinha (1987) studied the ecology of wildlife with special reference to lions in the Gir and looked in detail at ranging patterns and diet of lions and also interactions with local graziers. Khan (1993) studied the ungulate-habitat governing the distribution of major ungulate species in the Gir Sanctuary and its management implication. Chellam (1993) studied the ecology and predation range of the Gir Lions. The study made by Chavan (1993) gives a good account of tree associations, feeding ecology of ungulates, forage distribution, production utilization and nutrition. Sharma and Johnsingh (1995) studied the vegetation composition and investigated the impact of maldharis on vegetation and the habitat

utilization by ungulates. Dharaiya *et al.*. (1999) studied the feeding niche differentiation among lion and leopard in Gir. Jhala *et al.* (1999, 2004) validated the use and applicability of the vibrissae spot method for individual identification and population estimation of Asiatic lions. Jhala *et al.*. (2004) developed monitoring protocols for long term monitoring of lions and their prey population. Pati (2000) studied impact of livelihood practices of Maldhari tribe on wildlife habitat of Gir PA.

OBJECTIVE OF STUDY

The overall objectives:

The main objectives of the project are to investigate factors that influence social organization in Asiatic lions and determine the dispersal patterns of sub adult males, using radio-telemetry. A component also addresses the issue of long-term ecological monitoring of lions. The observed movement patterns of male lions, dispersal patterns of sub adult males and habitat-use patterns of lions will be analyzed with respect to increasing lion densities, anthropogenic pressures of livestock grazing and resource utilization.

Objectives addressed till date:

- Aspects of social organization: lion density, population structure and demographic information on survival, seasonality of reproduction of Asiatic lions in the Gir protected Area
- Minimum Home Range and territory use by male lion coalitions of adjoining territories.
- To study behavioral interactions of males within and between coalitions and also with pride members. Availability of mate-resource within the home ranges of the study animals and the mating opportunities for each male lion.
- Measure of reproductive success by assessing tenure period and reproductive contribution by the male lions.
- Refinement on long term monitoring methodology for lions.

- Predation ecology of lions and their dependence on livestock.
- **Ungulate monitoring and chital ecology**
    - Food habits, Habitat use and Activity patterns of chital
    - Evaluation of livestock grazing impact on demography and density of wild ungulate community.
    - Evaluation of the body health condition of chital in areas of different livestock grazing pressure.
    - Estimation of seasonal grazing circuits.
- **Livestock Monitoring**
    - Food habits, Habitat use and Activity patterns of livestock (cattle and buffalo) in East Gir
    - Estimation of seasonal grazing circuits and their impact zones.
    - Seasonal livestock survey
    - Monitoring of predation of Maldhari livestock in Sanctuary-East.
    - Habitat use and grazing zone estimation.
- **Vegetation monitoring**
    - Establishment of permanent vegetation monitoring plots and exclosures in areas of prominent livestock grazing and devoid of livestock grazing.
    - Evaluate the vegetation community in the foraging areas of different Maldhari Ness sites.
    - Assessment of palatable browse and grass species availability and abundance in the intensive study area.
- **Monitoring of Ness**
    - To evaluate the importance of domestic livestock to the diet of lions and leopards.
    - To study the mortality pattern of livestock in selected nesses within the Intensive Study Area of Gir (East).
    - To estimate the financial losses faced by the Maldharis by livestock depredation.

Objectives to be addressed:

- Demography and ranging patterns of peripheral lion populations
- Dispersal in lions within and outside the Gir Protected Area
- Monitoring of vegetation exclosures for evaluating impact of livestock and wild ungulate foraging on vegetation trends
- High resolution mapping of study areas within and outside of the Gir PA.

ESTIMATING DENSITY OF ASIATIC LION

Introduction:

Several methods have been tried over years for estimating large carnivore numbers. These include pug marks (Choudhury, 1970; Gore *et al.*. 1993; Panwar, 1979; Smallwood and Fitzhugh, 1995, Sharma *et al.*. 2005); track counts (Palomares *et al.*. 1996), mark recapture (Trolle and Kery, 2003, Karanth *et al.*. 2004; Chauhan *et al.*. 2005, Jhala *et al.*. 1999, 2004) and radio telemetry. A census for estimation of lion population using baits was regularly conducted every five years from 1963 to 1995 (Dharmakumasinhji, 1968, Jhala *et al.*. 1999, Singh 1997).

Methodology:

Field Method for Individual Identification of Lions:

For estimating the lion population within the Intensive Study Ares (ISA) of Gir (West), Gir (Central and Gir (East) sight-resight framework of population estimation was used (Pollock *et al.*. 1990). Lions were individually identified based on vibrissae pattern (Pennycuik and Rudnai (1970), Jhala *et.al.* (1999, 2004).Whisker patterns of individual lions were calibrated on a graph paper using a spotting scope. Lions were intensively searched on foot and by vehicle systematically in different areas of the intensive study site. Data on the location of the lion, age group, sex, pride composition and interaction

and any additional identifiable marks on the body like ear notches (both left and right), permanent scars or spots in the body were recorded (Jhala *et al.*. 2004).

A software has been designed (enclosed) to facilitate the storage, search and analysis of individual lion records for long term monitoring and population estimation (Badoni et al 2005).

Statistical Analysis:

The capture histories of the individual lions generated from the sample survey were used to make an X matrix (Pollock *et al.*. 1990). Since population estimation using mark-recapture is statistically alike to estimating species richness (i.e. number of individuals replacing species) (Chao and Huggins 2005), species richness can be used for population estimation (Chao and Huggins 2005) and a robust estimation of the standard errors. The data obtained herein were analyzed using the Program **Estimate S Version 7.5** (Colwell, 2005) and **CARE—2** (Chao, 2002) which calculates various estimates of species richness including the jackknife and sample coverage approach.

In order to get a robust population estimation model, non-parametric methods provided by the Program Estimate S were used. Burnham and Overton (1978) proposed the use of jackknife estimators up to the fifth order for estimating the population size. Jackknife estimators were developed as a general technique to reduce the bias of a biased estimator.

Since trapping was conducted over a fixed period of time and captures (or sightings) of individuals occurred at any time during the data collection part, hence our experiment was considered as a discrete-time capture-recapture experiment (Chao and Huggins 2005) with each sampling day as one session. Assuming the lion population to be a closed population within the time frame of sampling and our experimental set-up being a discrete model, a Windows 98 (or later) executable program written in C language **CARE-2** (for CApture-REcapture) (Chao 2002) has been used to get the population sizes for three different areas of Gir. Various estimates for the models were analyzed without covariates. The population estimates obtained from two programs were compared to get the more robust estimation.

The density of the lions in the study areas was estimated as the population size (obtained from the estimates given the Program **CARE-2** and **Estimate S**) divided by the

effective sampled area, which was estimated by creating a polygon over the trapping stations (A) and a buffer width ($\hat{W}$) estimated as half the mean maximum distance moved (1/2 MMDM) by recaptured lions added to A (Karanth and Nichols 1998) **(Plate: 1)**

$$\check{D}=\check{N}/ (A (\hat{W}))$$

Where, $\check{D}$= Estimated Density, $\check{N}$= Estimated population Size and (A ($\hat{W}$)) = Effectively Sampled area.

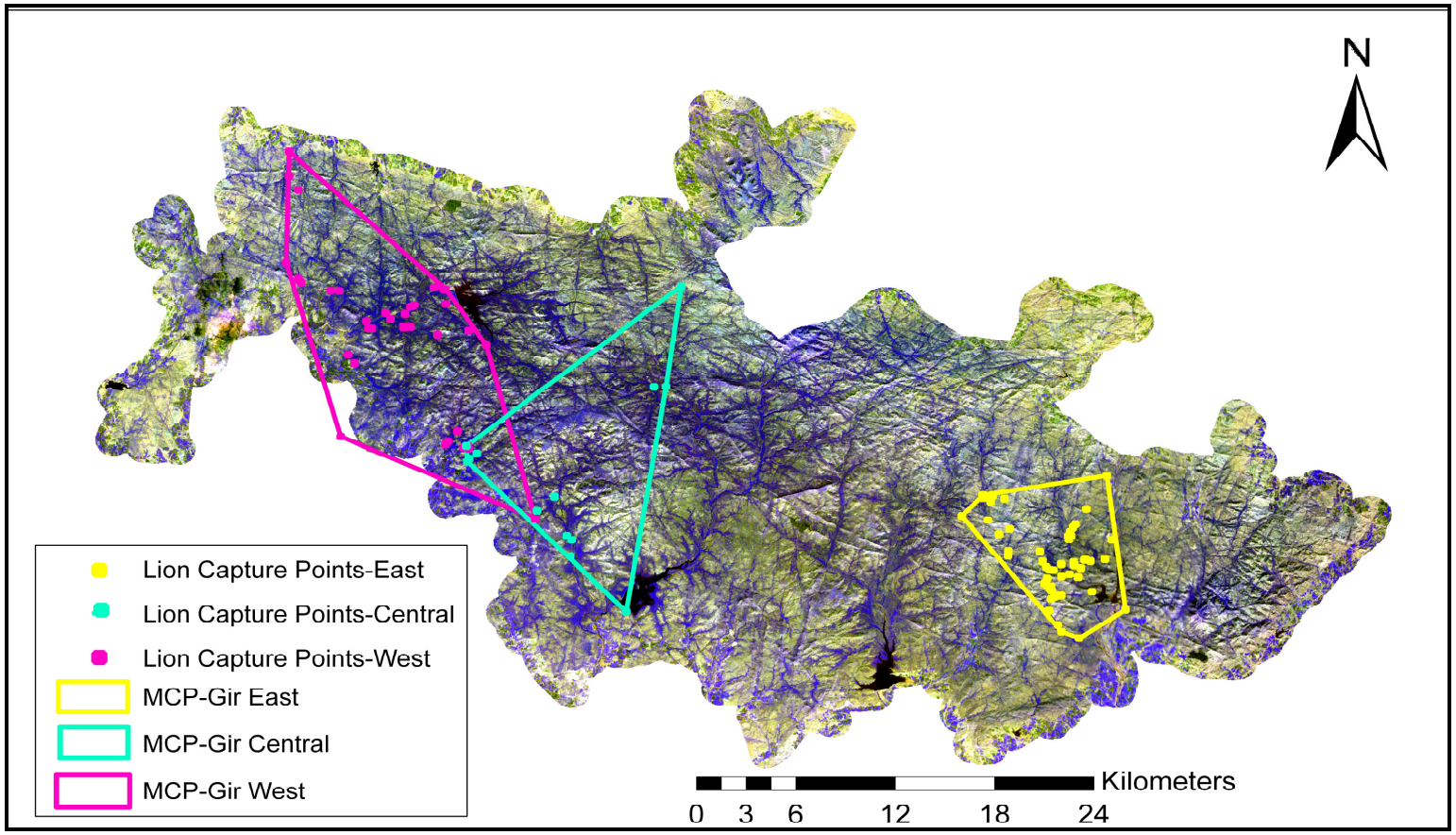


Plate 1: Lion Distribution, capture points and effectively sampled areas in different parts of Gir

Results:

Total number of distinct individuals along with the number of capture occasions is summarized in **Table 1**. Lion sightings when plotted against number reached an asymptote for all 3 sampled locations **(Fig 2 – Fig 4)**

Figure 2: Saturation Curve of Lion Sightings in Gir (West)

Figure 3: Saturation Curve of Lion Sightings in Gir (Central)

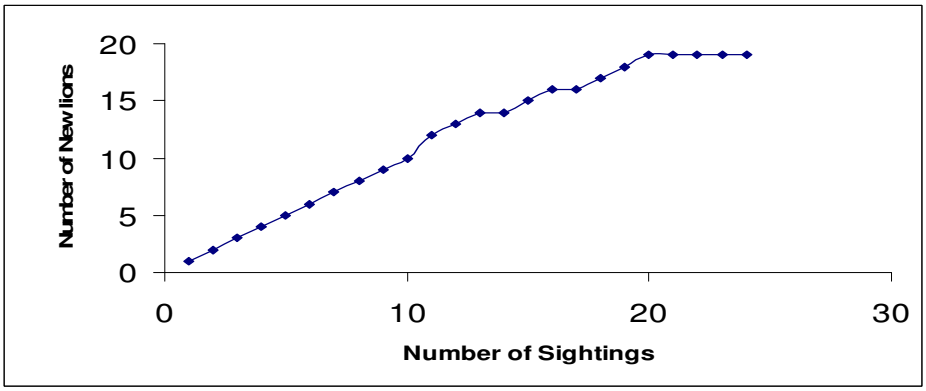


Figure 4: Saturation Curve of Lion Sightings in Gir (East)

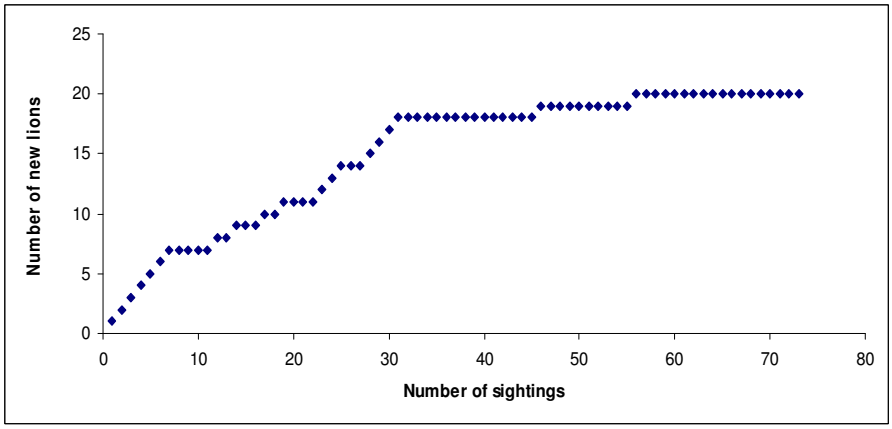


Table1: Summary of Capture-recapture Statistics for lions obtained from different regions of Gir

	Gir (West)	Gir (Central)	Gir (East)
Total number of distinct individuals	29	18	20
Number of capture occasions	58	24	36

Population size of lions computed by various estimators was similar **(Table 2)**.

Density of lion calculated on the basis of Jackknife 1 population estimators showed the maximum density of lion in Gir (East) [16/100Km^2, SE= 3.08], followed by Gir (West) [12/100Km^2, SE=1.92] and Gir (Central) [8/100Km^{2}SE=3.05] **(Figure: 5).**

Figure 5: Comparative Density of Lions in Gir (West), Gir (Central) and Gir (East)

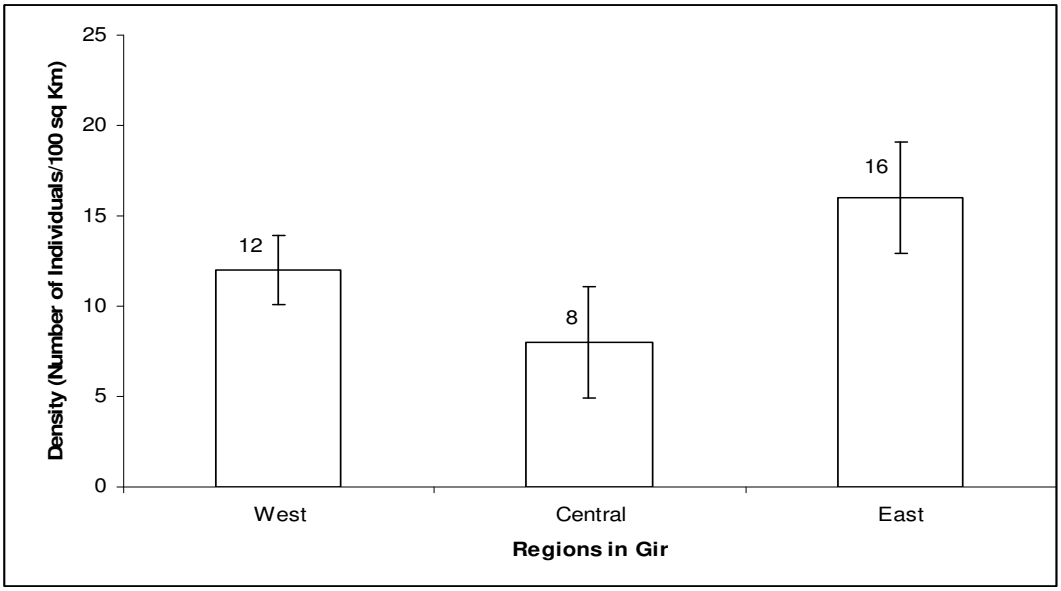


Table 2: Population Estimates estimated by the Program CARE-2 for Gir (West), Gir (Central) and Gir (East).

Region	Estimator	Population Estimate	Boot_s.e	Asy_s.e	95%CI (log transfer)	95%CI (Percentile)
Gir (West)	Mh(SC2)	50	12.31	12.07	36-90	35-73
	Jackknife 1	45	5.75	5.52	37-60	38-49
	Mh(IntJk)	46	15.21	5.91	33-106	39-82
Gir (Central)	Mo(CMLE)	37	18.57	11.85	22-113	24-91
	Jackknife 1	31	4.75	4.96	24-44	26-35
	Mh(IntJk)	67	25.8	18.3	37-147	25-97
Gir (East)	Mo(CMLE)	21	2.66	1.26	20-36	21-25
	Jackknife 1	23	3.57	2.61	20-39	20-28
	Mh(IntJk)	23	3.32	2.61	21-37	20-28

As evidenced from our study on ness monitoring that livestock contributes about 48% of the lion's diet, therefore removal of such a prey base might have a detrimental for the lions to survive. Central Gir with the legal demarcation of a National Park is totally free of livestock population and hence with the minimal lion density compared to Gir (East) or Gir (West). It was thus clear that wild ungulate population alone was not enough to support the lion population in the central part.

Lion densities are thought to have increased in Gir in recent years causing populations to establish outside the park. The following relevant management concern is whether the lion densities are in fact high and at the same time, are they high in all areas within the park. In other words, do lions establish equally well in all areas of the park. How does the core-National park area compare with the sanctuary area in terms of lion

densities? A reconnaissance study on this aspect was started during the winter season. Lion locations, ungulate and livestock surveys were conducted.

Lion sightings for central (national park) and sanctuary-west and re-sightings of individuals within these areas were separated for further analysis. Total area surveyed was estimated using minimum convex polygon model (Mohr 1947) using **Calhome** (Kie 1994). Comparative lion densities were then calculated. Additions of new lions across the season were plotted and appropriate models were fitted to understand the apparent trends. The results are as shown in **Table: 3**

Table 3: Lion Densities in different areas of Gir

Areas of Gir	**Number of lion sighting**	**Number of unique lions**	**Area (MCP) In Sq Km**	**Buffer width (SE)**	**N̂ Population Estimate (SE)**	**Density (SE)**
Gir West	58	29	135	2.97(0.53)	45(5.75)	12(1.92)
Gir Central	24	18	134	3.46(1.6)	31(4.75)	8(3.05)
Gir East	36	20	43	2.37(0.46)	23(3.57)	16(3.08)

LION DEMOGRAPHY

METHODS:

Intensive search and location of lions, record of location, sex, age category and activity of animals.Description and identification of animals based on distinct body markings and vibrissae spot pattern method (Pennycuick & Rudnai 1970).

Data based on above methods, collected from April 2002 to July 2006 has been scrutinized to identify individuals in the study area. Demographic changes related to birth,

mortality, immigration and emigration of lions has been recorded for three years Profiles of individual animals based on repeated sightings are continued to be maintained. In the absence of telemetry this data would be the second best alternative to study lion ranging patterns, land tenures and turnover rates within the area studied.

Group composition

Joslin (1973) reported female group sizes to range from 1-11 with average group size being 2.1 (n=58). Male groups ranged from 1-4 with an average of 1.6 (n=58). Ravi Chellam (1993) reported the mean group-size for females to be between 1-11 and the average group size to be 4.5 (n=109). The mean group size for males ranged from 1-5 and the average group size was 2.2 (n=72).

In the current study, female groups ranged between 1-4 with the average group size being 1.3±0.53 (n=291). Group size of males was 1.4±0.50 (Range 1-3, n=283). The gradual shift to smaller groups over the years likely reflects the change in the average prey size of lions from large bodied livestock to smaller wild prey in Gir west and National Park.

Males did not associate with females moving and feeding independently. Only 12% of total sightings were of male-female associations (n = 487) of these 70% sighting were of mating pairs.

Age Structure:

The majority of the lion sightings were of prime reproductive age group **(Figure6-Figure 9).** The representation of large cubs in the lion sightings was low (2%) in 2002, this could be an artifact of sampling or the result of infanticide by pride takeovers just prior to the commencement of the study.

Figure 6: Age Structure of lion sightings in Gir in 2002

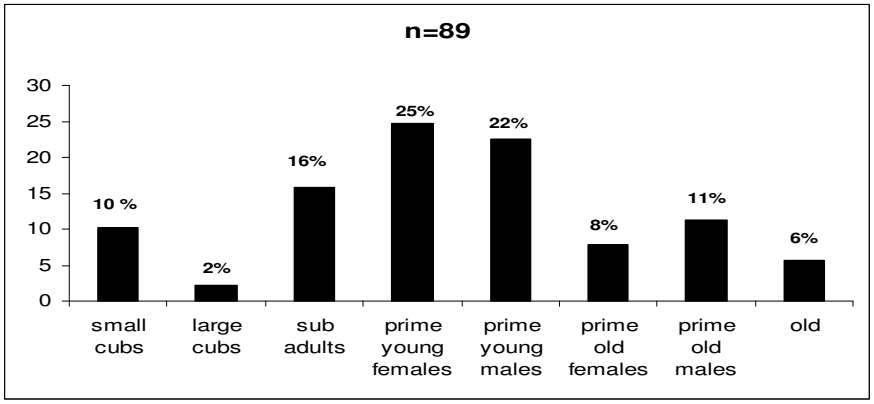


Figure 7: Age Structure of lion sightings in Gir in 2003

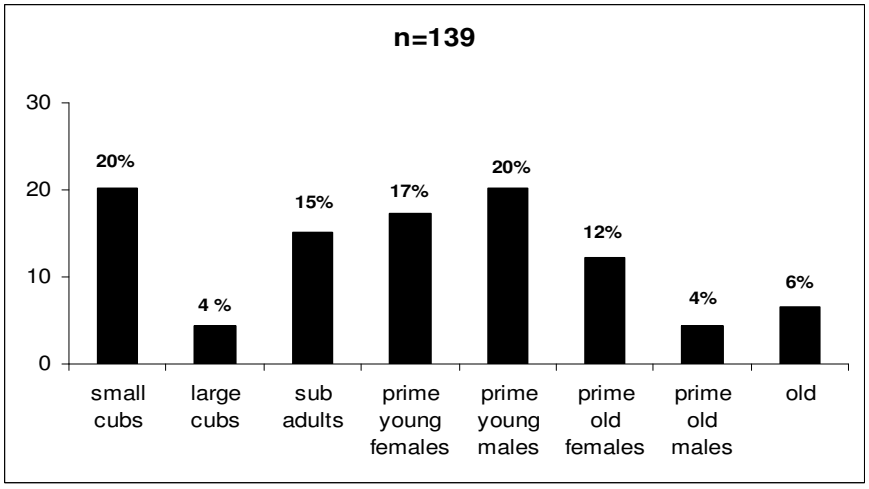


Figure 8: Age Structure of lion sightings in Gir in 2004

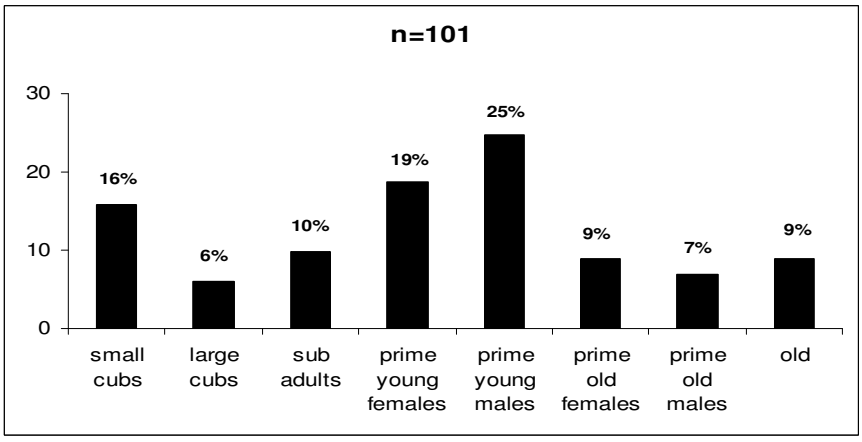
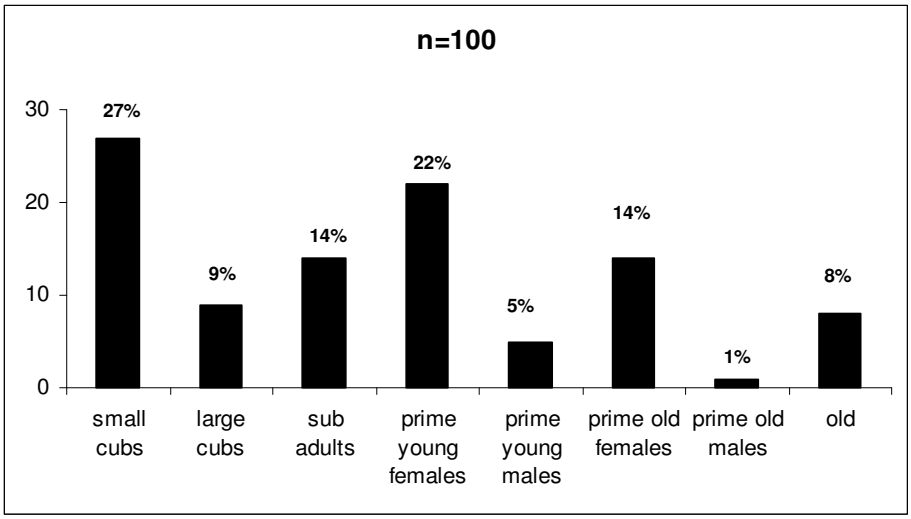


Figure 9: Age Structure of lion sightings in Gir in 2005



Mating

At the age of three, a sub adult female is either recruited into the pride or driven out of it depending upon the existing adults in the population (Bertram 1975). Females have a life span of 18; they start breeding at 3-4 years of age and breeding rate starts to decline from 11 years of age (Packer *et al.*. 1988). Females do not appear to have a regular estrus cycle in the wild and come into estrus at variable intervals ranging from three to few months (Bertram 1975). Females come into estrous synchronously and have their litters about the same time. Therefore, cubs are borne not in relation to time of the year but more in relation to the birth of other cubs in the pride (Bertram 1975). Gestation in lions is about 110 days and the mean litter size is 2-3 ranging from 1-5, (Schaller 1972). Females cease lactation when their cubs are 5-8 months old (Schaller 1972) but do not resume sexual activity until their cubs are about 18 months old (Bertram 1975, Packer and Pussey 1983). However, females that lose their cubs generally resume sexual activity within days or weeks of the loss (Schaller 1972, Packer and Pussey 1983). In the case of cub-loss the lionesses gave birth to a second litter within 7-13 months (Joslin 1973).

In the case of Asiatic lions, mating occurred through out the year, but there were peaks and most mating happened during winter **(Figure 10 & 11).** Cub birth did not necessarily follow each mating episode.

Figure 10: Seasonality of mating

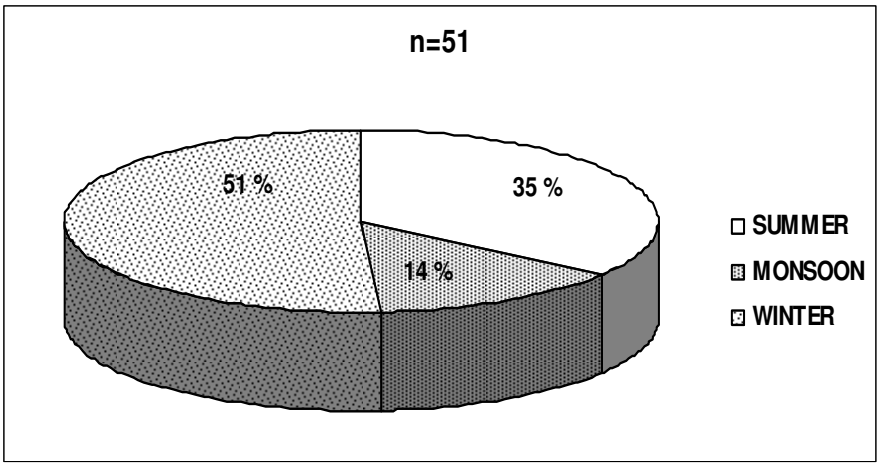
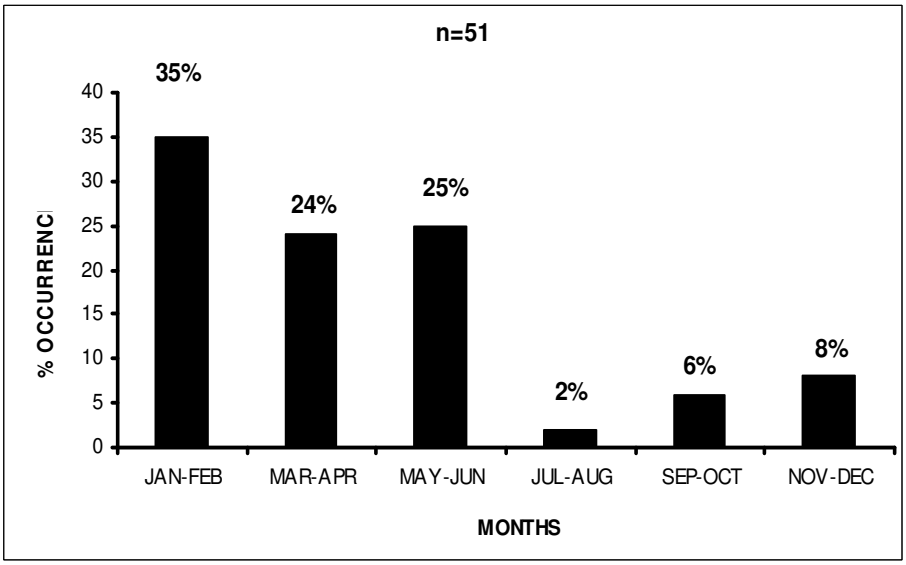


Figure 11: Mating Episodes across the Year (N= 51)



Cub Birth

Cubs are dependent on the mothers till they are two years of age. During the first month they are vulnerable to predation and hence are kept hidden. Although they begin to eat meat when they are 2-3 months old, they continue to suckle till they are 6-8 months old (Bertram 1975). Mortality at this age is high, about 80%, due to starvation during season of low prey availability, male takeovers and predation (Bertram 1975).

Birth peaks were during end winter again, during the beginning of summer. In the Sanctuary west and Central Gir, cub to female ratio was 0.45 for data from 2002 – 2003 (N = 380). There was also a second birth peak during the beginning months of monsoon (**Figure 12 and Figure 13**). The reported mean litter size of Asiatic lion is 3.0 with a birth interval of 24 months. Although it was not possible in the wild to observe cubs in the first few weeks of birth it was possible to locate cubs within the first month of birth. The present study recorded a mean litter size of 1.9 (range 1-3, 43 cubs in 23 litters).

Figure 12: Cub birth pattern in different seasons

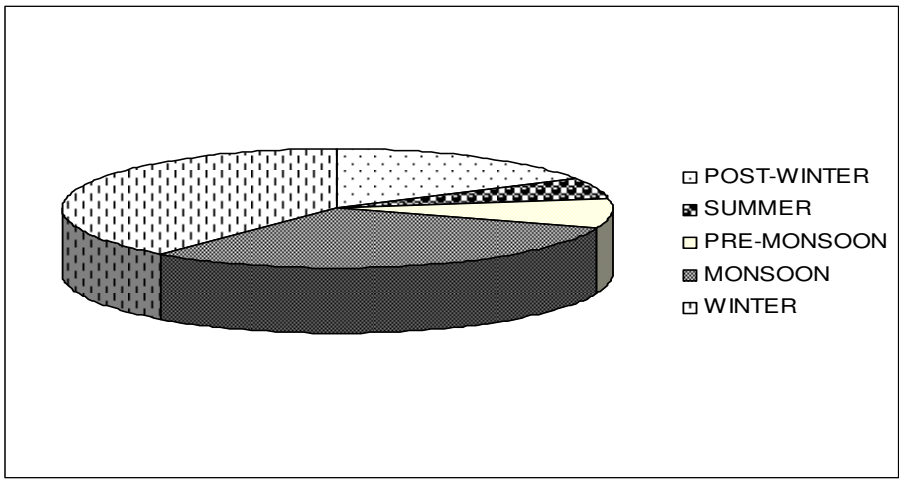
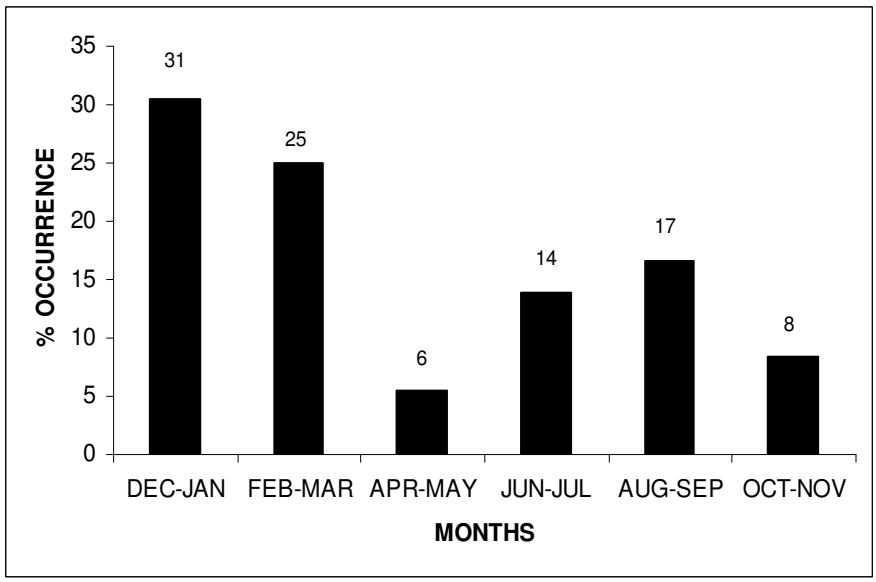


Figure 13: Cub Birth across the year



Cub Mortality

Cub mortality was high during the first year of birth especially due to infanticide. During the study two tenure takeovers have been recorded with one takeover resulting in mortality of resident, dependent cubs. The survival chances of cubs improved beyond the first year of birth. It was possible to monitor 14 cubs in seven litters of females that were monitored regularly. The percentage of small cubs (< 1 year) that became large cubs (1-2) was 36% and the percentage of large cubs reaching the sub adult stage was 60%. Thus, cub survival in the first year was low as reported in the case of African lions (Schaller 1972). Interestingly, male lions were responsible for more than 50% of the cub-mortality in the first year.

Adult Mortality

Majority of cases of adult mortality in the past three years were due to natural causes though a small percentage of the death were due to accidents. On scrutinizing official mortality records of the forest department for the past five years, there seemed to be on an average of 10 lion deaths per year under natural circumstances. About 4 animals per year die due to accidents; 3 out of 4 such cases are outside the protected area.

Diet

The average daily requirement of meat per day for a lioness is 5kg and that of a male is 7 kg and would need 2,724 kg and 3,813 kg meat per year (Schaller 1972). There has been a remarkable increase in the wild ungulate population from the 1970s (Berwick 1974, Joslin 1973) to the 1990s and a consequent in increase in the wild ungulate biomass in the Gir PA (Khan *et al.* 1996). The available ungulate biomass varies across the three management zones of the park, namely Sanctuary- west, National park and Sanctuary east. While the National park area has a higher wild ungulate biomass, Sanctuary east has the highest overall prey (including livestock) biomass (Khan *et al.* 1996). Chital contributes more than 70% of the wild ungulate biomass in all the three zones. As a consequence of this increase in prey base, there has been a marked alteration in the diet of

the Asiatic lion. While 79% of the diet consisted of domestic prey in the 1970s (Joslin 1970), wild ungulates constituted 74% of the diet in the late 1980s (Ravi Chellam 1993).

The present study has also collected data on ungulate densities in different management zones, livestock density and diet of the Asiatic lion both by intensive search and location of lion kills as well as laboratory examination of lion scat. Scat analysis was done on protocols standardized by Mukherjee *et al.* 1994. The observation on lion kills included the name, age and sex of the prey species. The habitat features of the kill site as well as the nature of kills (hunting and feeding behavior) of lions were recorded.

A survey of resident livestock was undertaken. 20 nesses which had about 165 Maldhari families accounting for a population of 1408 and had a livestock holding of 4583 **(Figure 14A and Figure 14B)**. It was found that livestock was still an important prey-base available to the lion population and predation on livestock is maximum during monsoon (**Figure 15)**. There were a greater proportion of cattle kills compared to buffalo kills (**Figure 16**). The survey indicated a death of 316 livestock in the year 2004, of this 60.4% was due to carnivore predation. The data of lion kills consisted of 19% lion kills in the peripheral area (n= 202). Thus, although, the number of livestock lost by Maldharis in a year seems less, the kills of livestock from peripheral villages account for the greater contribution of livestock from scat. The data on lion kills revealed 52% livestock kills. Scat analysis revealed 35 to 40% of livestock remains in lion scats **(Figure 17).**

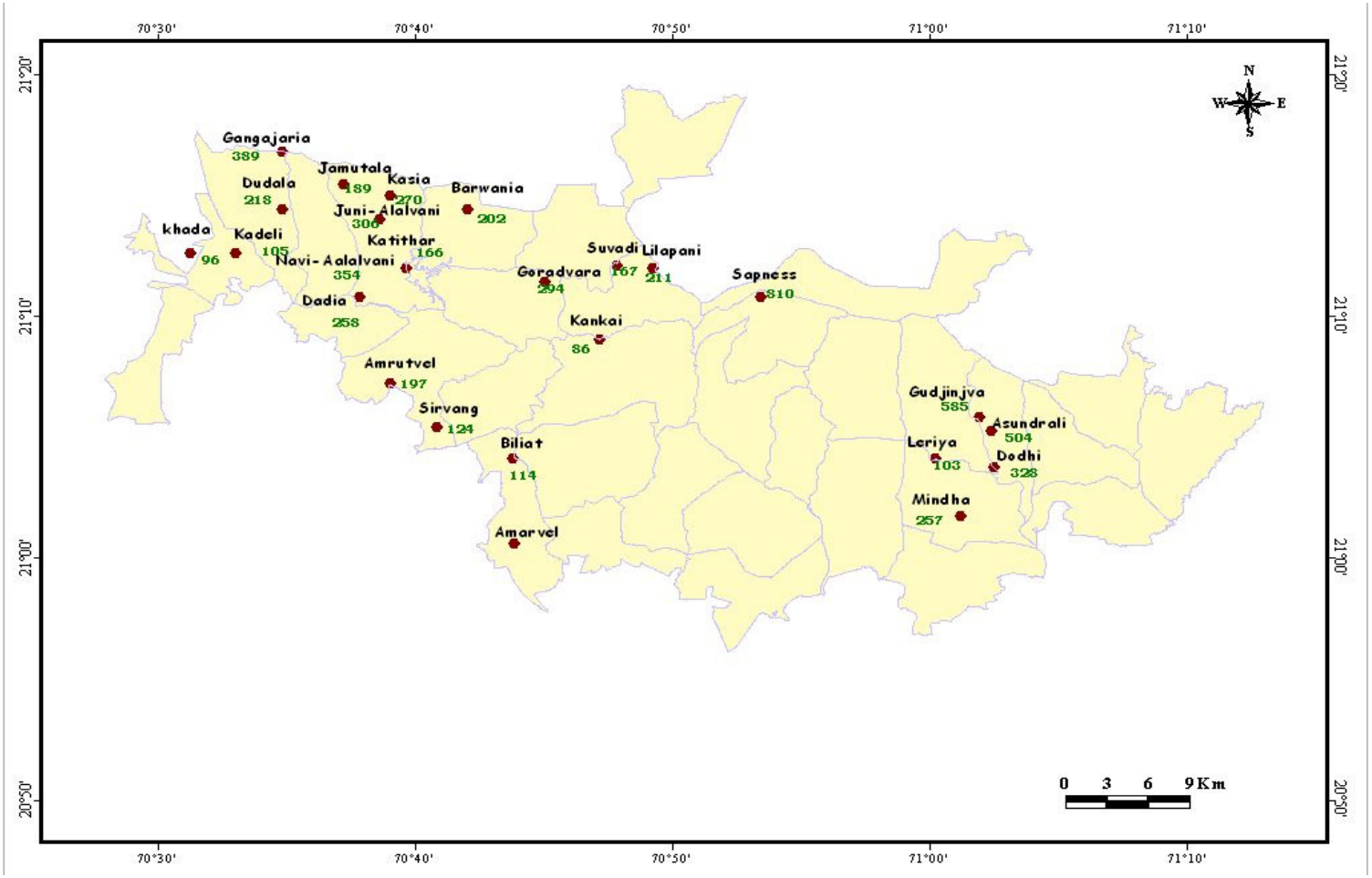


Figure 14 A: Distribution of sampled Nesses and number of the livestock in Gir Protected Area

Figure 14B: Population Structure of Livestock in Nesses in Sanctuary West and Central Gir

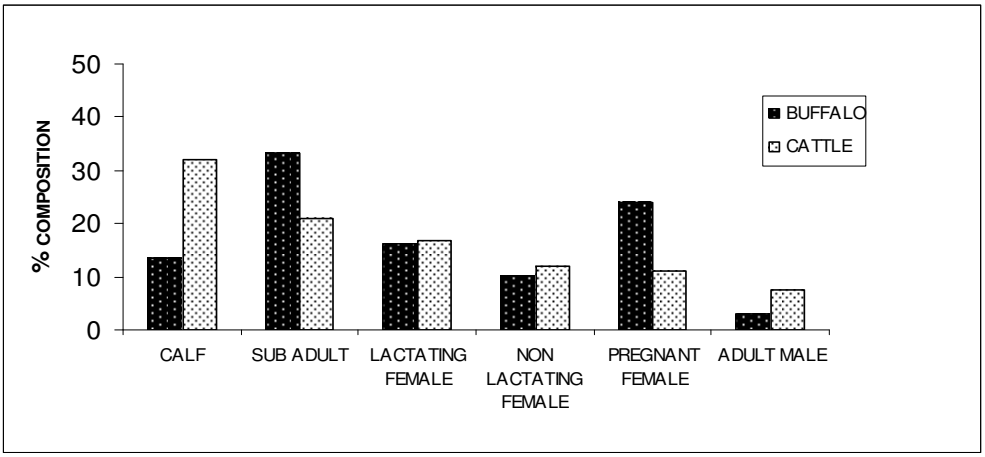


Figure 15: Composition of Lion kills across season (n= 206).

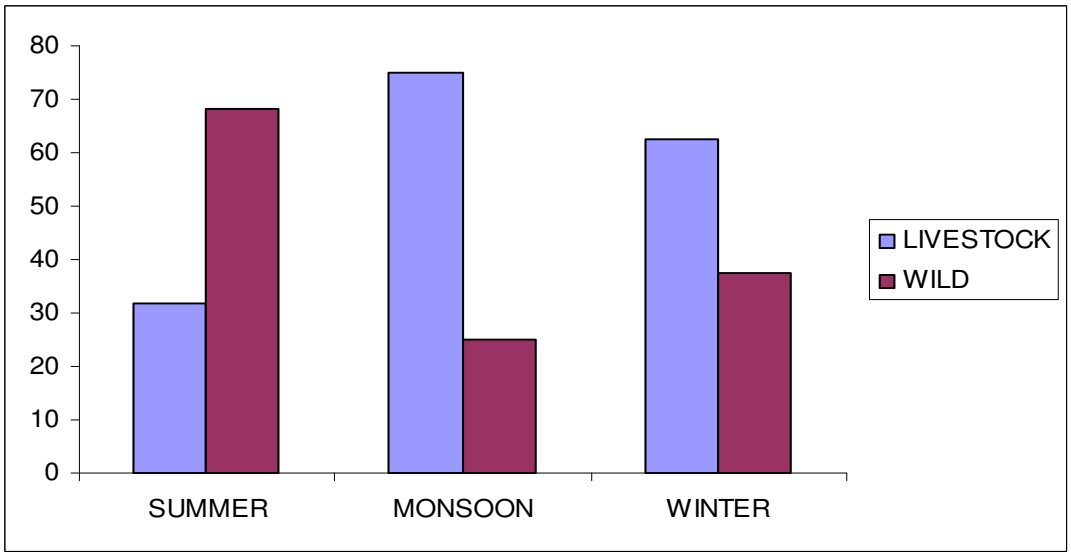


Figure 16: Age-wise classification of lion kills in Sanctuary-west and central Gir (n=145)

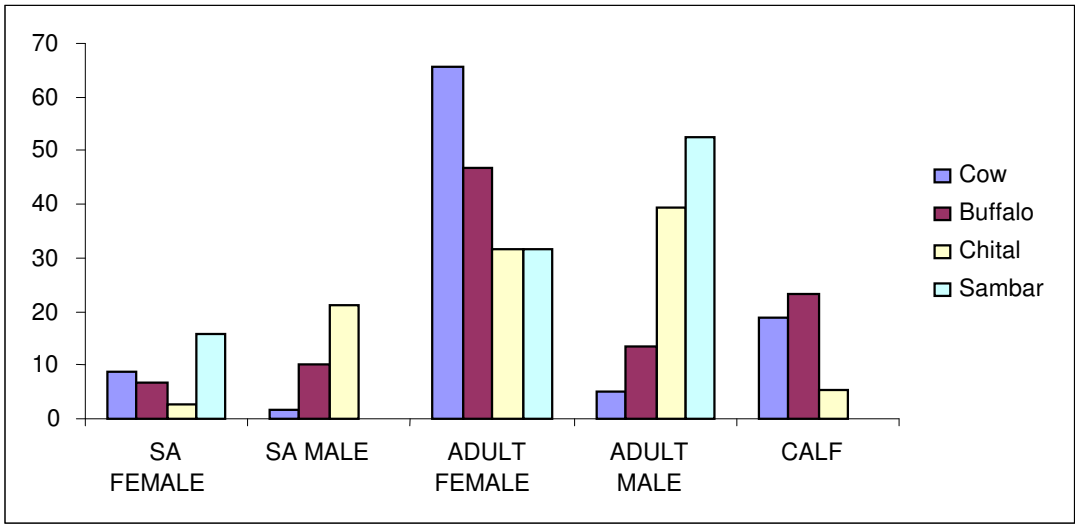
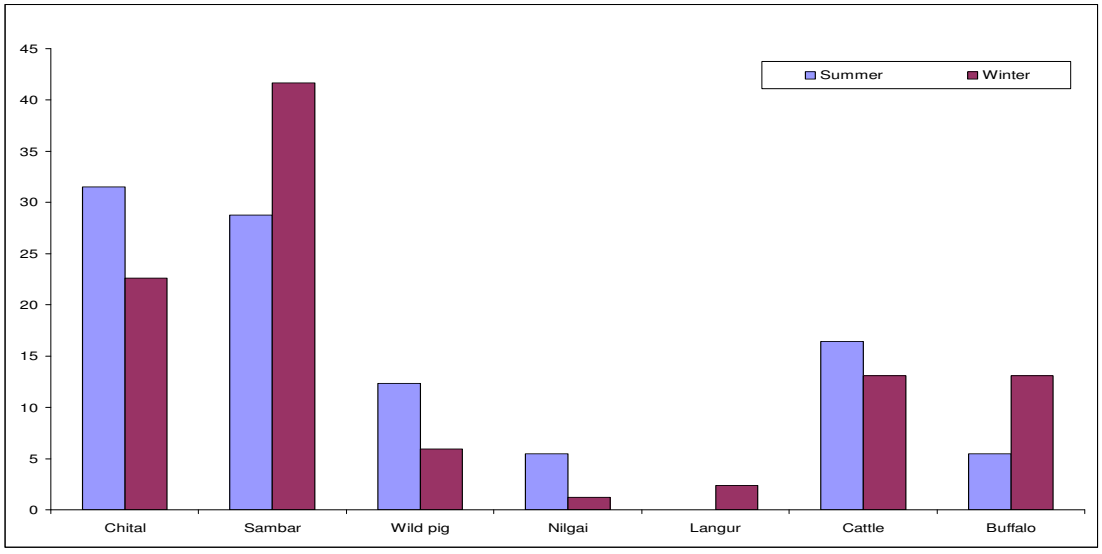


Figure 17: Food Habits of lions as frequency of occurrence of prey items in lion scats.



Characteristics of male lion coalitions in the Gir PA

Coalition formation and subsequent takeover and control of pride females are important determinants of male reproductive success. Hence, male lions need to guard their territory to ensure their continued association with the pride (Packer and Pussey 1997). The tenure period is also essential for stability of prides and successful recruitment

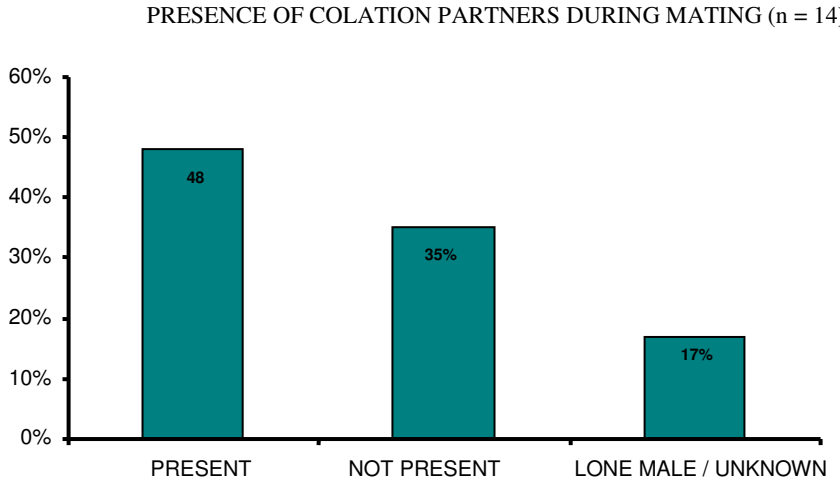
to the population. The male African lions have been termed as companions that move, rest and feed with female prides during their tenure. Yet, such an association has been described as casual except during courtship (Schaller 1972).

In the case of Asiatic lion the association of the males with pride females is much weaker. Adult male and female associations are rare. Between April 2002 and August 2004, only 29% out of 114 sightings of groups were of male-female associations of this 76% were of mating pairs. Males rarely rest or move with female groups. Males may tolerate the presence of resident females over a kill. On four occasions males have been found to interact and tolerate the presence of females and their cubs. On one occasion a male was found to spend three days entirely in the company of the female and her three cubs. On another occasion male spent five days in the company of female and her dependent cub.

The members of a pride may be of variable age and may include one or more adult females, sub-adults and dependent cubs. However, male-male associations are among males of similar age (N= 55 m-m) sightings.

Ad libitum behaviour observations have shown that there is no dominance among the male partners and aggression during feeding or mating. The first male among the partners to gain access to a female in estrous becomes her mating partner through that particular mating period. The associate male has been found to remain in the vicinity and joins back with his coalition partner at the end of the mating period **(Figure 18).**

Figure 18: Presence of coalition partners during mating



Distribution of territorial males in the intensive study area

Kamleswar, Kheramba, Pilipat, Kokra, Devadungar and Janvadla are prime areas around which territorial males operate. Data on male lion movement, territorial behaviour, tenure and takeover had been monitored since 2002. The movement patterns of five male lion groups have been presented below:

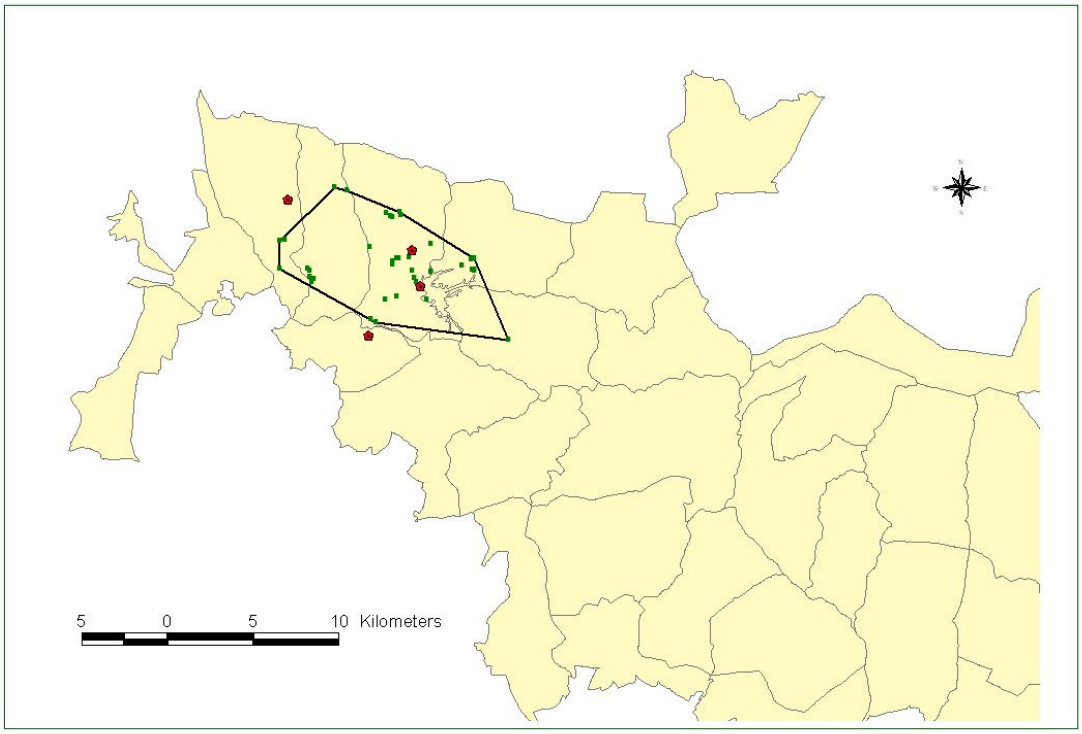
Observations on male lion coalitions in Gir PA

Kamleswar males:

The natal territory of Kamleswar males was in Chodavadi (Mukherjee,S. *pers. comm.*) In summer 2002, the males became resident in Kankai area about 10 km from their natal territory. In January 2003, they ousted the resident male and gained control over Kamleswar area 21 km from Chodavadi. During this period they were even sighted well away from the Kamleswar area in Khuthni and Jamutala, two areas controlled by other males.

In May 2004, one of the partners had to be retained in captivity due to injury. In the following two months, the associate male stayed on in the same area and later moved on closer to his natal territory. Currently this male has a new coalition partner and his current range has altered **(Figure 19 and Table: 4).**

Figure 19: Home Range of Kamleswar Radio Collared Male



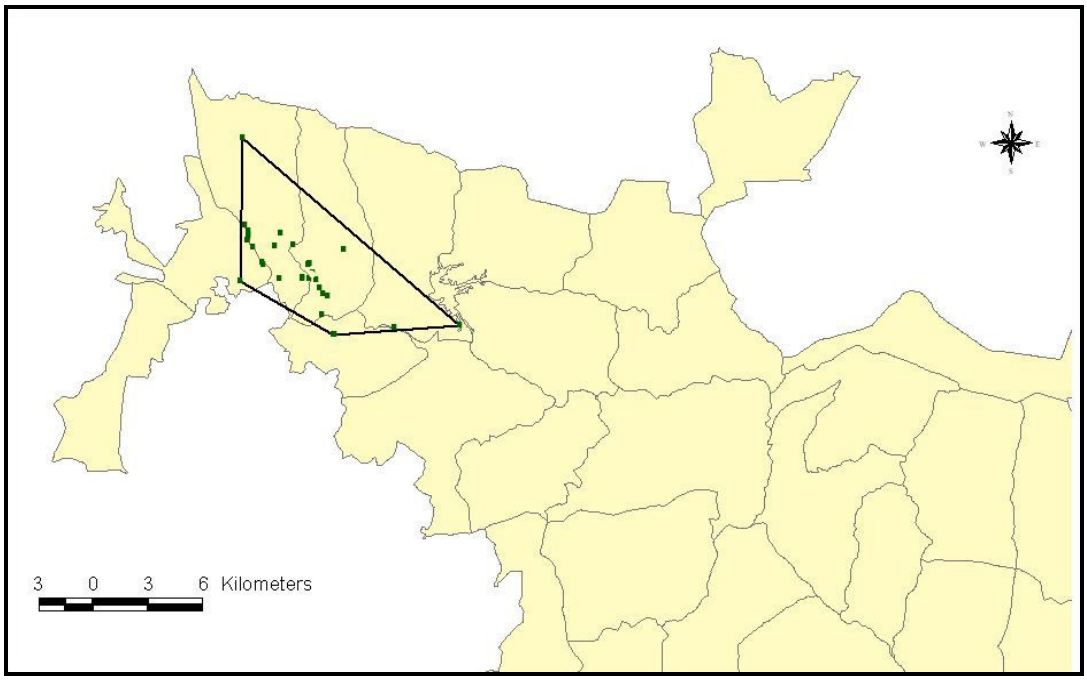
Pilipat male:

At the time field study was initiated in 2002, the Pilipat male had lost his partner and was the resident male of Kamleswar area. He was ousted in January 2003 and after that his range altered. The males that took over killed the dependent cubs and came to be called the Kamleswar males.

The range of the *Pilipat male* overlapped with that of the Kheramba males and also marginally with that of the *Kamleswar males*. In spite of being old and without a partner, this male holds prime territory defending it effectively against territorial males. On a few occasions there have been aggressive encounters with the Kheramba males when the Pilipat male proved to be more dominant.

Presently (2005 -2006), another coalition has taken over, the Pilipat male ranges in the edge of former territory in areas such as Karsangad, Nanava, Periphery of Sasan village with occasional entry in areas such as Panchari, Paravia and Juni-Raidi (**Table:4 Figure:20**).

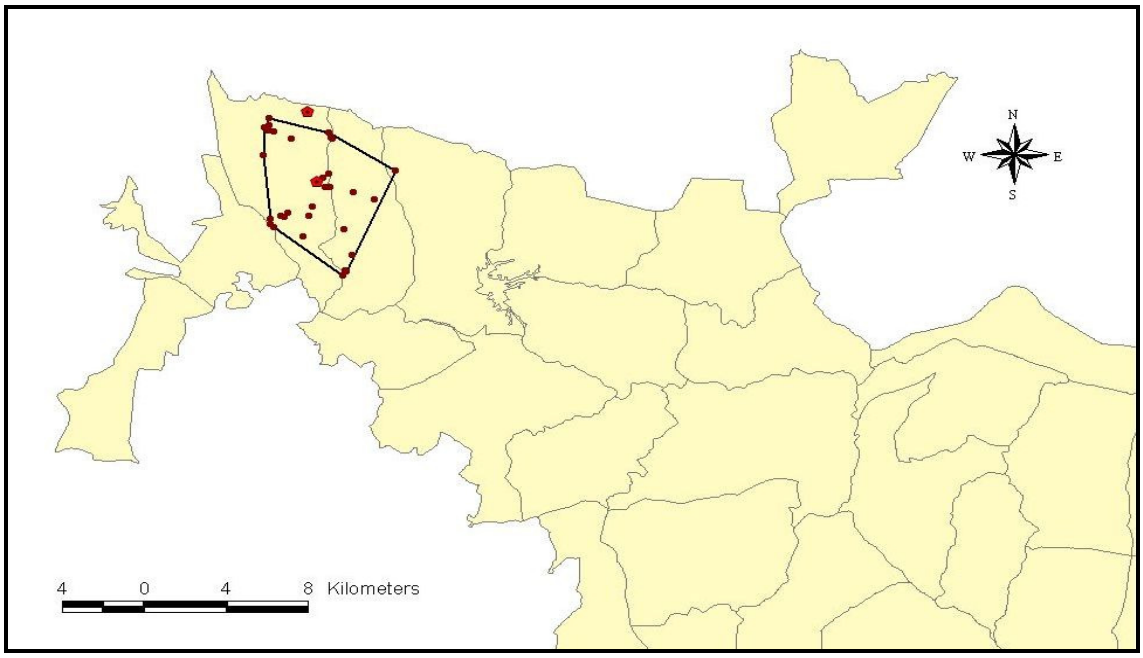
Figure 20: Home Range of Pilipat Male



Kheramba males:

According to available records, the Kheramba males established in their natal territory itself. Since the study commenced in 2002, these males have been monitored and have been observed to operate within a defined area for over three years without much deviation. During this time they are also known to have sired many cubs. In June 2005, one of the males died and till last observed the associate was still resident in the same area. **(Table: 4 Figure: 21).**

Figure 21: Home ranges of Kheramba Males

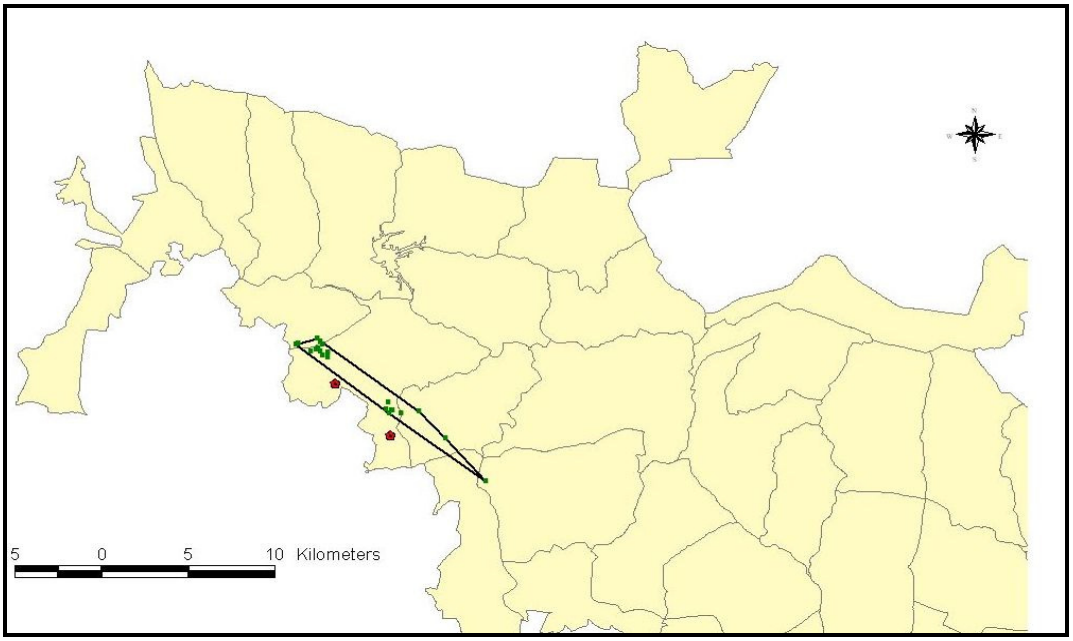


Kokra males

The Kokra males have taken residence in the area in December 2003. Their area of operation overlaps with that of the Janvadla males in Devadungar. An encounter with the Janvadla coalition in March 2005 resulted in death of three cubs sired by one of the males.

Between April 2002 and Febuary 2003, the same area was occupied by another male coalition that dispersed from the area. In 2005, one of the males died, the lone Kokra male still holds territory (**Figure: 22 Table: 4).**

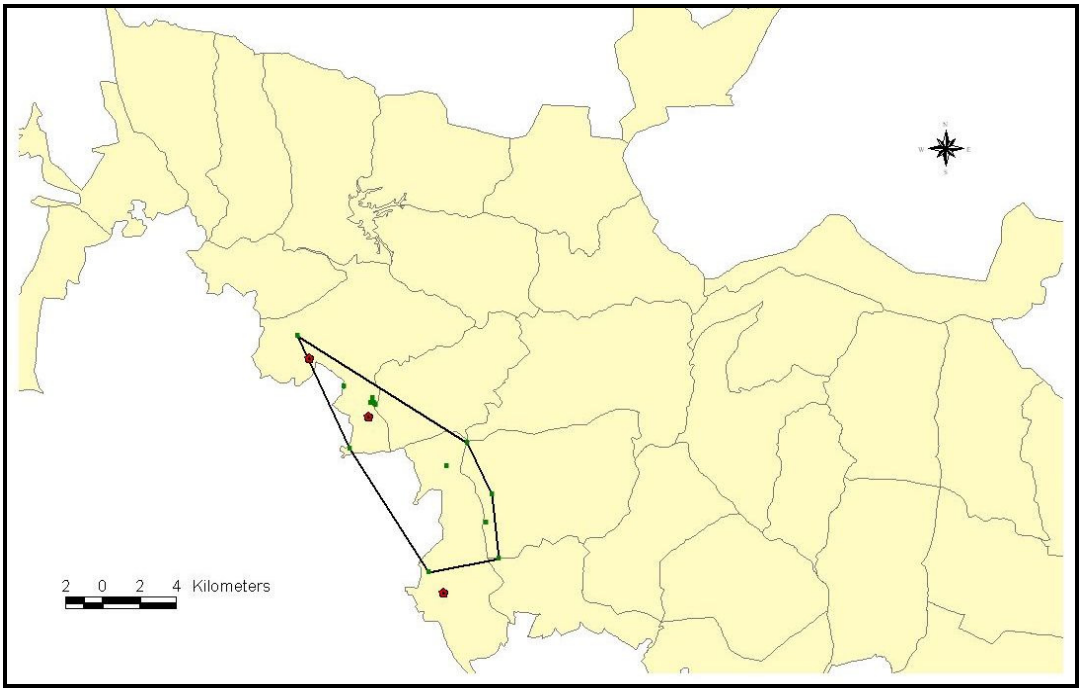
Figure 22: Home Ranges of Kokra Males



Janvadla males:

The Janvadla male coalition includes three individuals over ten years of age. Their 2002 range included Kokra, Siruvang and Devadungar. But in the following years, they were sighted more in the national park area of Janvadla, Mundachowk and Singoda. Thus these males have been holding a very large area for over four years and have been observed to have aggressively defended this area many times. One of the males died in 2005. The other two males range in the border areas of their former territory (Rasulpara – Akolwadi) **(Figure: 23 Table: 4).**

Figure 23: Home Ranges of Janvadla Males



Alavani male

Prime (old) male was captured from Chachai-Pania sanctuary. He was brought to the hospital in Sasan, treated and released back on fourth November 2004. I re-located him in Alavani on 19th November 2004 over 30km form the area where he was resident. Since then he has taken residence to an area close to Sasan. This perhaps means that the lion has lost his holds over his territory while undergoing treatment. It is not clear if he is currently a "nomadic" or has taken permanent residence as a territorial male. This male was involved in aggressive encounter with other territorial male. The recurring injury had resulted in making the male very aggressive. The male was captured yet again treated and released. This time the range was much wider covering areas from Balsel to Kasia. The male died during 2006 monsoon in captivity.

Patriyala Males:

A coalition of two sub-adult males in their natal area and Central Gir were located and tagged with Satellite-GPS-VHF radio collar in December 2005. The satellite part of HABIT collar subsequently malfunctioned. However, the GPS collar has provided excellent data on the movement and ranging pattern of the sub-adult males. Patriyala males explored a large range during the past 7 months covering areas from Leelapani to Sirwan and Sasan (**Figure: 24, Table: 4**).They currently continue to reside within the natal area and should likely to hold a reproductive territory soon.

Figure 24: Home Range of Patriyala Males

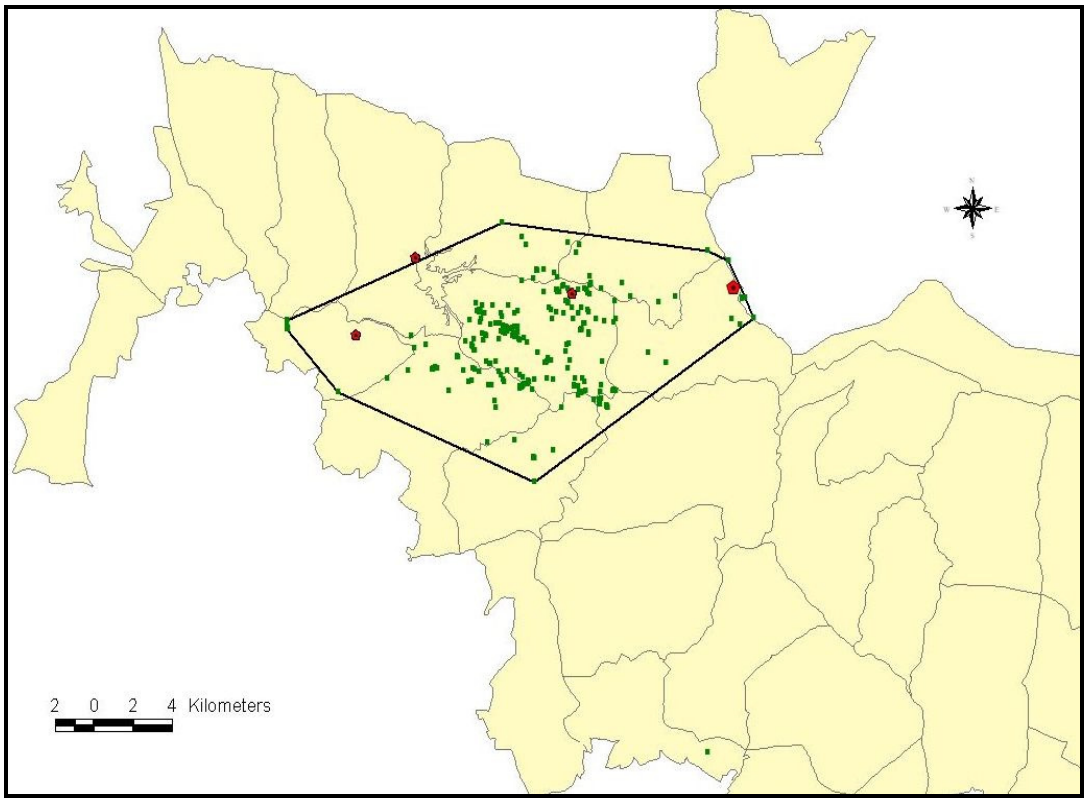


Table 4: Details of coalition male lions monitored during the study

ID	Associates	Status	Monitoring Period	No of Locations	Area
Pilipat male	single	Non-radio collared	2002-2006	34	57.5 km²
Janvadla male	Three (presently single)	Non-radio collared	2002-2006	25	56.38 km²
Short tail male	Two	Non-radio collared	2002-2006	28	46.27 km²
Kheramba male	Two (currently single)	Non-radio collared	2002-2006	37	35 km²
Kokra	Two (currently single)	Non-radio collared	2002-2006	26	12 km²
Kamleswar male	Two	Radio-collared	2005-2006	38	68 km²
Patriyala male	Two	Radio-collared	2005-2006	302	174 km²

Three male lions from different coalition pairs and area were radio-collared and are being intensively monitored for data on ranging patterns and resource utilization.

POTENTIAL FOR FOOD COMPETITION BETWEEN CHITAL AND LIVESTOCK

The presence of high densities of free ranging cattle and their likely impact in the forest lands of India have been commented on by Kothari *et al.* (1989), Prins (1992), Fleischner (1994), Noss (1994) and Voeten (1999). Many authors draw attentions to the deleterious effects of grazing and associated lopping of trees on forest parameters such as canopy cover, ground cover, regeneration and wildlife density (Saharia, 1984; Ram Prasad and Bhatnagar, 1988; Lal, 1989). Most wildlife protected areas in India support various forms of land use such as agriculture, livestock grazing and collection of minor forest produces (Mishra, 2001). Kothari *et al.* (1989) report livestock grazing in as many as 73 % wildlife sanctuary and 39 % National Parks in India (of the 101 and 14 surveyed protected areas respectively in those categories) with livestock densities reaching up to 150 per sq.km. Livestock grazing is especially widespread and livestock holdings form an important component of the local pastoral community and agricultural economy (Mishra, 2001).

Realizing the importance of the chital population as a keystone species in the Gir ecosystem, it is essential to monitor population density (Khan *et al.*. 1996; Khan and Vohra, 1992), demographic parameters (Schaller, 1967) nutritional condition (Rhiney, 1962) and behavioral adaptability (Changappa, 1971). Another important ecological aspect relevant to the conservation and management of Gir is the potential impact of livestock on sympatric chital population to understand and evaluate if there is any impact of livestock grazing on chital population.

On comparison of vegetation data obtained from areas sympatric with livestock grazing and devoid of livestock can help in understanding the interface between chital and livestock. Also information on food habits, diet niche overlap and habitat use of chital and livestock can provide information on impact of livestock grazing on chital population.

Understanding of prey-predator relationship is a prerequisite for effective lion conservation. Chital constitutes the majority of the wild prey biomass of Gir, compared to other ungulates. According to Khan (1995) and Khan *et al.* (1996), total ungulate

population estimation in Gir was around 55,000 of which chital accounted for around 51,000.

In Gir, there are 54 Maldhari nesses in the sanctuary having about 361 families living in it. Beside that there are 14 forest settlement villages covering an area of 52 sq.km. with the human and live stock population 4,494 and 4,200 respectively. They have legal access to the sanctuary for grazing and firewood collection for their own purposes. In addition, there are 97 villages, with 1, 52,000 humans and 95,000 livestock, within a distance of 6 km from the boundary of sanctuary. The main occupations in these villages are agriculture and animal husbandry. Some of them are illegally grazing their livestock and collecting the firewood from the sanctuary area.

Berwick (1974) studied the food habits of wild and domestic ungulates during dry and hot season of the year. In his study he did not record any competition between wild ungulates and domestic livestock though; he admitted that the potential for forage competition is high during monsoon. He also mentioned that wild prey would not increase if domestic livestock were removed to alleviate overgrazing, since wild and domestic preys do not eat the same forage. From the time of Berwick (1974) till date (Khan, 1993; Singh and Khamboj, 1996) wild ungulate densities have increased several folds. Simultaneously, there has been a reduction in the total livestock population in Gir due to the creation of a national park and removal of some resident *Nesses.* However, it is unclear whether this increase in wild ungulate population is due to decreased competition with livestock or a result of increased understorey productivity as a consequence of the cyclone of 1983.

The debate on whether local human use of wildlife reserves should be modified, curtailed or encouraged continues to be fuelled by activism rather than by ecology (Mishra & Rawat 1998). The present study is an effort to understand the interface between wild and domestic ungulates in Gir.

Methods

Habitat availability and Habitat use

Specific habitat requirements of species need to be determined for their effective management and conservation (Eisenberg and Seidensticker, 1976; Bhatnagar, 1988). Habitat use by a particular species can be best understood by monitoring its movement pattern, which ultimately would reflect its behaviour or response to the habitat (Rongstad and Tester, 1969; Shea *et al.*. 1990).

Availability of different habitat types to chital and livestock were computed plotting their grazing routs on the GIS map. A minimum convex polygon was generated using ARCINFO software program, to obtain the area being used by chital and livestock in the intensive study area. Percent coverage of each habitat types in the ISA was computed for the habitat availability.

Habitat Preference

Habitat selection by ungulates is a function of several factors, amongst which food availability, mate availability, predation are of major importance (Jarman, 1974). Chital primarily prefers open habitats and forest edges (Schaller, 1967). To understand and justify the habitat use of chital and livestock for various activities, habitat preference index was computed. Ivlev's electivity index was computed for habitat preferences of chital, cattle and buffalos during different seasons (Ivlev, 1961). This index of preference measure is simple and easy to interpret and still widely used in practice.

Activity patterns and Activity budgets

To investigate the time activity budget, foraging behaviour and habitat use Scan Animal Sampling technique (Altmann, 1974) was used for chital as well as livestock. Fortunately chital is inclined to be diurnal (Fuchs, 1974) hence the data collection on behaviour was carried out during the daytime from dawn to dusk. The scan exercise was carried out with an interval of 10 minutes between observations which was fixed after preliminary observations to standardize the technique for the study area. The total effort made for scan sampling was 6 to 8 scan days per season for each i.e. Chital and livestock.

The field observations on chital were carried out with the aid of 10×40 binocular and 10× to 35× spotting scope. The observations on activity pattern of livestock have been made during continuous monitoring of livestock herd from morning when they leave their corral till their return to respective *Nesses* in evening using same technique as used for chital. The livestock herds of Maldhari are comprised of buffalos mixed with several cattle. Here observations were made separately for buffalos and cattle.

Grazing circuits

Chital herds habituated to human presence around Maldhari ness were followed continuously from early morning to late evening. Observations were recorded from a distance of 10 to 50 m. from the animals. Care was taken to avoid the influence of observer's presence on chital behaviour. The herd movement was mapped using a hand held GPS unit. Same exercise was also followed for livestock herds of four adjacent Maldhari settlements of eastern Gir i.e. Dodhi, Asundrali, Leria and Tulsishyam.

Food Habits

Chital is a plastic species capable of considerable adaptive response within varied forest ecosystems (Ables, 1974). According to Smith (1974), chital are grazer by choice, however they are not restricted to a grass diet and are capable of changing to forbs or browse with ease. Understanding food habits is an essential component of research efforts addressing such issues like assessments of productivity of the local habitat and extrinsic factors that influence reproductive success (Litvaitis *et al.*. 1996). The food habit study was carried out by direct observations. Direct observation has been widely used for estimating food habits of large herbivores (Wallmo and Neff, 1970; Jhala, 1997). Individual free ranging animals were selected and watched through binoculars or a spotting scope as they graze or browse and the type and the frequency of bites of plant parts and species consumed were recorded in different habitats in different seasons. Observations were quantified as bite counts (number of bites of a particular food item) (Berwick, 1974; Smith, 1974; Jhala, 1991 and 1997; Schaller, 1967).This exercise was carried out for chital, buffalos and cattle in different habitat types known to be used by chital and livestock during different seasons through continuous scan sampling.

The detailed food habits of all three herbivores were computed for different seasons. The actual contribution of each food item to the total seasonal diet were derived using the dry weight per bite of each food item, proportional contribution to the total bites observed during direct observations and proportionate habitat use for foraging.

Diet Niche Width and Overlap

The basic approach to understand the prevalence of interspecific competition between sympatric species in terms of resource utilization pattern is to evaluate the niche breadth (Pianka, 1986; McDonald *et al*, 2000) and niche overlap (Reynolds and Meslow, 1984; Thill and Martin, 1986; Major and Sherburne, 1987)

The most common resources measured in order to calculate overlap are food and space. Since, the food is one of the most important dimensions of the niche; the analysis of animal's diet is closely related to the problem of specification (Krebs, 1989). The comparison of niches of sympatric population might give an insight to the understanding of potential for the competition. Several measures of niche overlap have been proposed (Hurlbert, 1978; Abrams, 1980; Linton *et al.* 1981). Here, we used the Percent overlap indices (Schoener, 1970), which is the simplest measure of niche overlap to interpret.

Impact of livestock grazing on vegetation

To quantify the impact of livestock grazing on the vegetation, 10 exclosures have been established in the intensive study area of Gir east. These exclosures would either restrict both livestock and wild ungulates i.e. exclosures located in grazing radius of Maldhari livestock; or only livestock i.e. exclosures located in area were no livestock grazing was observed; or be available for foraging by both plots sampled just outside the exclosures. Long term vegetation sampling in these exclosures and study plots would help in quantifying the impact of livestock grazing on the plant species composition and pattern. This experimental design will enhance the understanding of the impact of livestock grazing on long term vegetation trends and wild ungulate community especially the chital population.

Impact of livestock grazing on ungulate population

Estimation of population size of wildlife species is a difficult task. Line transects sampling schemes represent a potentially useful methodology. Density estimates from line transect sampling are practical efficient and inexpensive for many populations (Anderson *et al.*. 1979).

To evaluate the impact of the livestock grazing on ungulate population, entire Gir PA was systematically sampled for ungulate density estimation. For the administrative purpose the Gir PA is divided into 34 forest blocks. To systematically sample the entire park, the forest block was considered as an individual sampling area and line transects measuring 2 to 3 km in length were laid in each block and walked at least twice during winter 2006. Besides that the intensive study area in Gir east was seasonally sampled for ungulate densities. Guidelines for designing and conducting line transect study were presented by Anderson *et al.* (1979) and Burnham *et al.* (1980) were adhered to for conducting this study. The Gir PA is divided into three different management and ecological zones i.e. Gir east sanctuary, Gir west sanctuary and Gir National park. Analysis of transect data was done for these zones separately i.e. Entire Gir PA, Gir West, Gir East and Gir Central. These zones differs in livestock grazing pressure from no grazing in Gir National Park and to high grazing pressure in Sanctuary east (Khan *et al.*, 1996). The data collected therein were analyzed using a computer software program **'DISTANCE'** (Buckland *et al.*. 1993; Laake *et al.*. 1999).

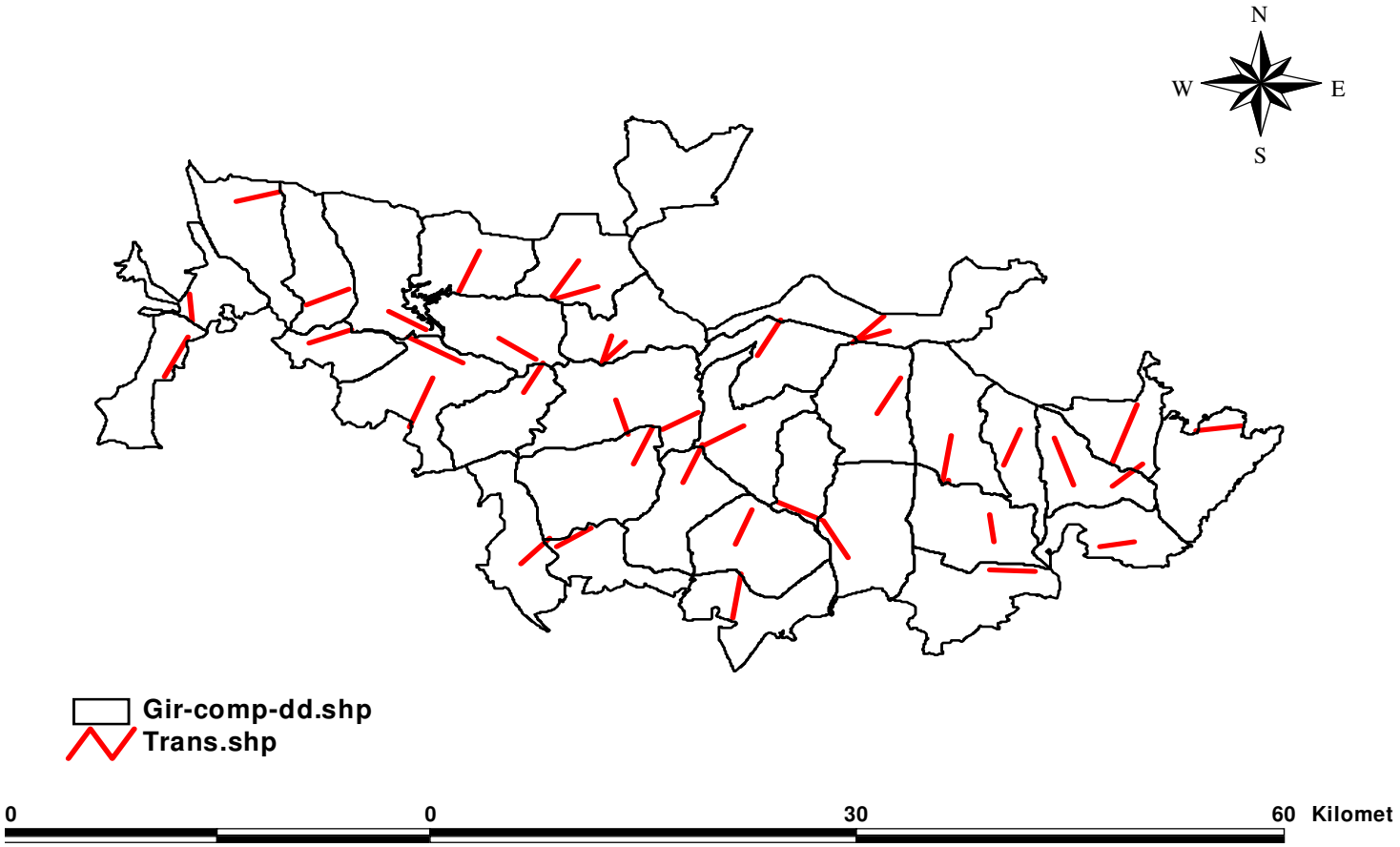


Plate 2: Habitat types and Line Transects for estimating ungulate density in Gir PA.

Results and Discussion

Activity Budget of Chital:

The Activity Budget of Chital has been worked out for major activity patterns found during seasonal observations made during scan animal sampling. Among all observed activity of chital across the day length, overall, chital devoted more time on foraging than other activities. Foraging as a whole includes grazing as well as browsing.

The activity budgets during three major seasons i.e. Monsoon, Winter and Summer, reveal that chital is a grazer by choice, as observed difference between grazing and browsing proportion is higher during winter months. The forest floor is well covered with palatable grasses and herbs during winter which offers wide preference of forage species to chital. The rainfall in monsoon months accelerates the vegetative growth of tree species which makes new tender shoots of nutritionally rich browse species available to herbivores. This subsequently causes the increased browsing during monsoon. Hence during monsoon this difference between grazing and browsing is lowest i.e. browsing proportion increases comparatively.

The social interactions including positive and negative intra-specific interactions were found more during winter (5.3 ± 0.5 %) than summer (4.8 ± 0.2 %)and monsoon (3.1 ± 0.6 %) respectively. Fawning occurs during winter when interactions between doe and fawn were observed maximum. While, rutting peak of chital was observed during summer, when male-male and male- female interactions are frequent which reflects in the proportion time spent in social activity during winter and summer. During monsoon male chital are found in velvet when they avoid conflict with other males and remain isolated from mixed herds and therefore less social interactions were observed. Chital were found more alert during summer (8.6 ± 0.8%) as they spend much time dense riverine patches to avoid the extreme hot temperature during late morning to late afternoon hours. The time spent on movement was less during winter (10.2 ± 0.7 %) as they have more availability of forage around compare to monsoon (13 ± 1.3 %) and summer (12.6 ± 1.1%). Chital used to spend prolonged time on ruminating during day time in summer and monsoon mostly between afternoon hours of summer and rainy hours of monsoon (Figure 25-27).

Figure-25: Proportion of time spent in various activities by Chital during summer.

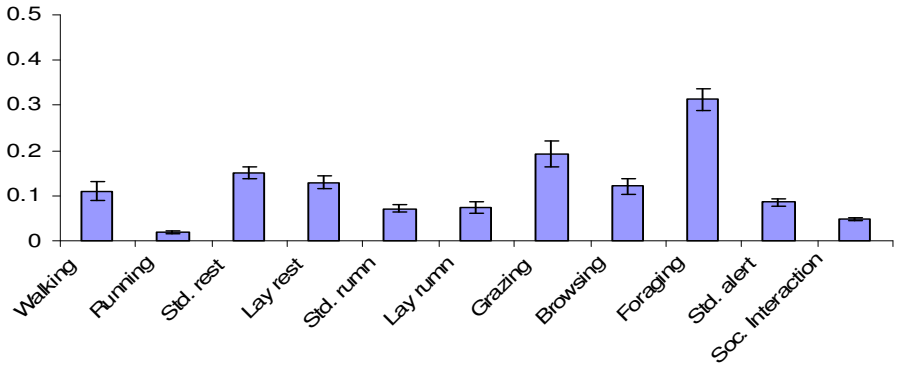


Figure-26: Proportion of time spent in various activities by Chital during winter.

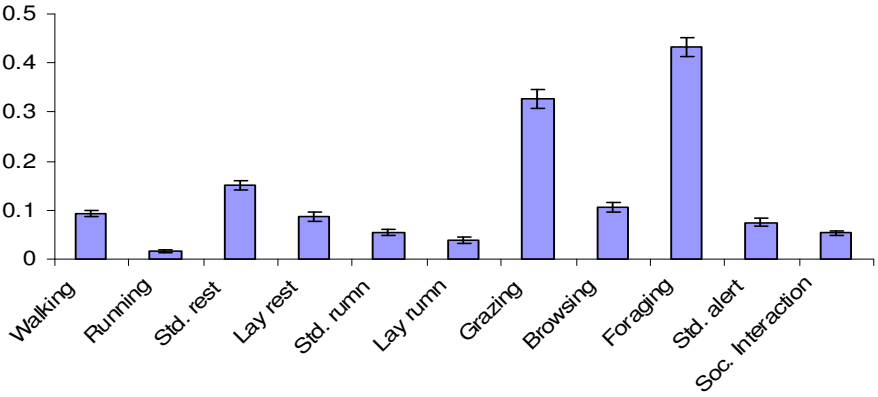
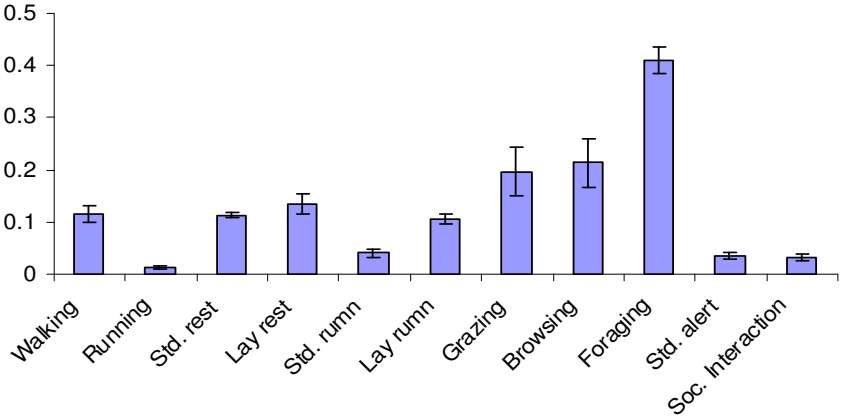
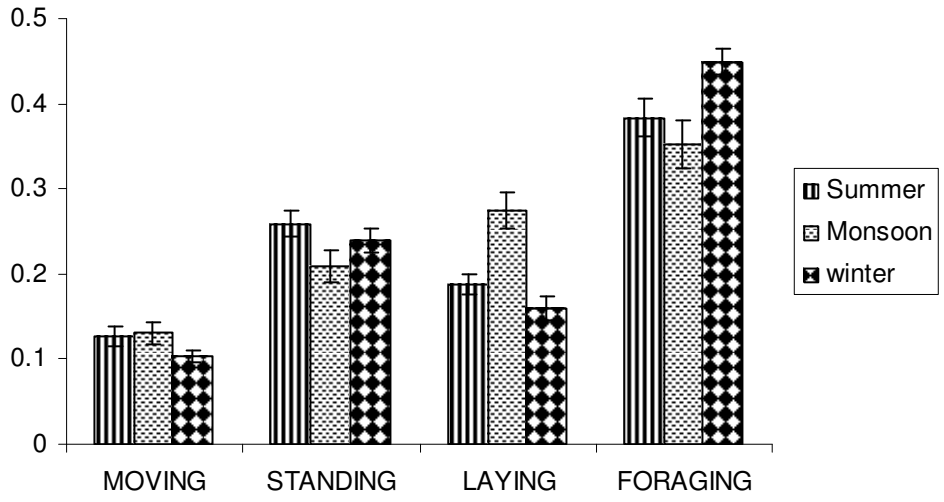


Figure 27: Proportion of time spent in various activities by Chital during monsoon.



The comparison for broad activity patterns i.e. Foraging Moving Standing and Laying, among seasons reveals that proportional time spent for foraging is higher during winter (45 ± 1.5%) as it is the recruitment period for chital and hence females need nutritious forage to bring up new born fawns and also build up body reserve for the lean summer **(figure 28)**. While time spent on standing was higher (25.9 ± 1.5 %) during summer as they spent prolonged hours in dense thickets of riverine habitat where the chances of predator presence is also high hence standing position is safer to escape from such sudden attack from lion and leopard. The time spent on foraging was reduced as an energy saving strategy. Where as during monsoon they rest in open shady areas where they can sense predator from safe distance. The 'movement' was lowest during winter (10.2 ± 0.7 %) as forage availability is good comparatively.

Figure 28: Seasonal comparison of broader activity patterns of chital.



Activity Budget of Livestock

There is no major difference was observed in activity pattern between Buffalos and cattle as they go as a common herd for foraging. The striking difference was observed during resting time in afternoon hours, where buffalo spends more time in sitting (0.44 ± 0.05 % in monsoon; 16 ± 0.7 %, in summer; 10 ± 0.8 %, in winter) in watery places while cattle generally stand in shady areas (12 ± 0.2 %, in monsoon; 19 ± 1.4 %, in summer; 15 ± 0.8 % in winter) **(Figure 29 and 30).**

Figure-29: Seasonal comparison of broader activity patterns of cattle.

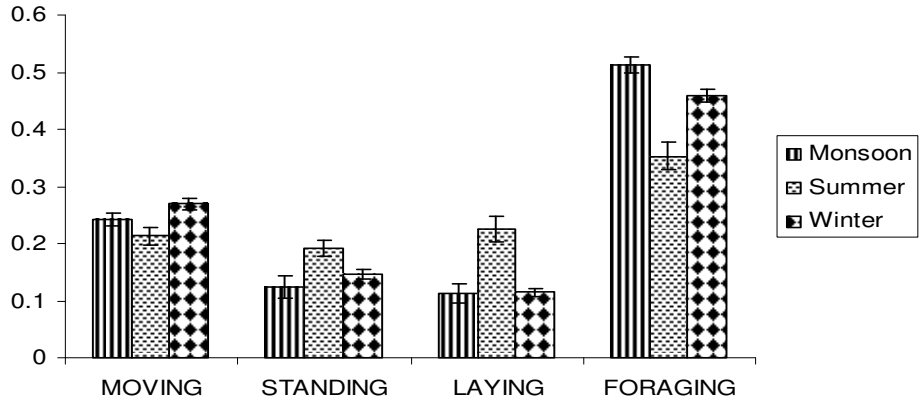
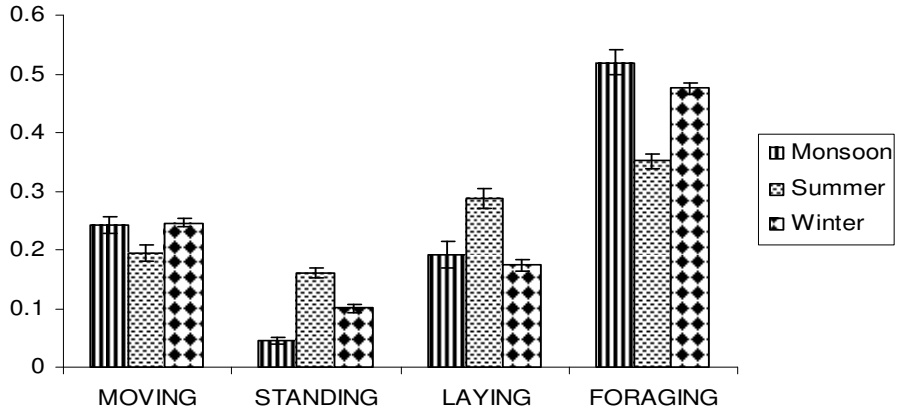


Figure 30: Seasonal comparison of broader activity patterns of buffalo.



Detailed Activity Budgets of Buffalo and Cattle

Buffalos and cattle were found spending less time in walking (18 ± 2.0 %, 19.2 ± 2.4% respectively) in summer compare to monsoon (24 ± 0.1 %, 23 ± 1.3 % respectively) and winter (26 ± 0.1%, 28 ± 1.3 %). Limiting factor for their movement could be the availability of water, extreme temperature and low forage quality during summer months might compel them to conserve energy by moving less. Also low forage quality and quantity during summer might take more time for gut passage for ruminant herbivores. Buffalo was observed mostly grazing and occasionally browsing through out all seasons.

Cattle were also found to graze by and large but comparatively they spent more time on browsing than buffalos. Browsing proportion was high during monsoon after rainfall for both of the domestic ungulates, as new browse becomes available after rainfall and Maldhari*s* lopped good quality browse to feed their livestock. As buffalos are more susceptible to heat, they spent afternoon hours resting, either sitting or standing, in water. Buffalo spends prolonged time on ruminating during summer afternoon hours (Laying ruminating 14.9 ± 2.0 %, standing ruminating 4.9 ± 0.4 %). **(Figure 31-33).**

Figure 31: Proportion of time spent in various activities by cattle and buffalos during summer

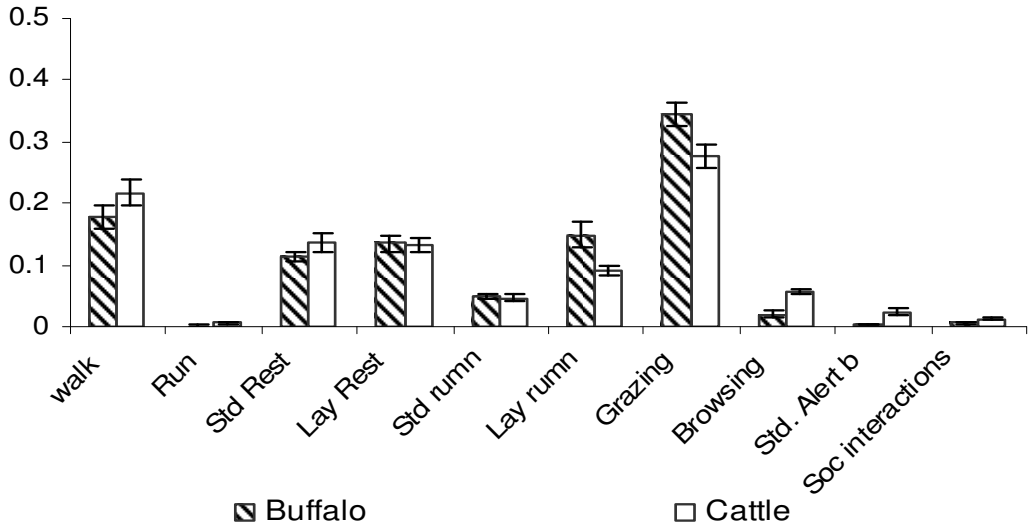


Figure 32: Proportion of time spent in various activities by cattle and buffalos during monsoon.

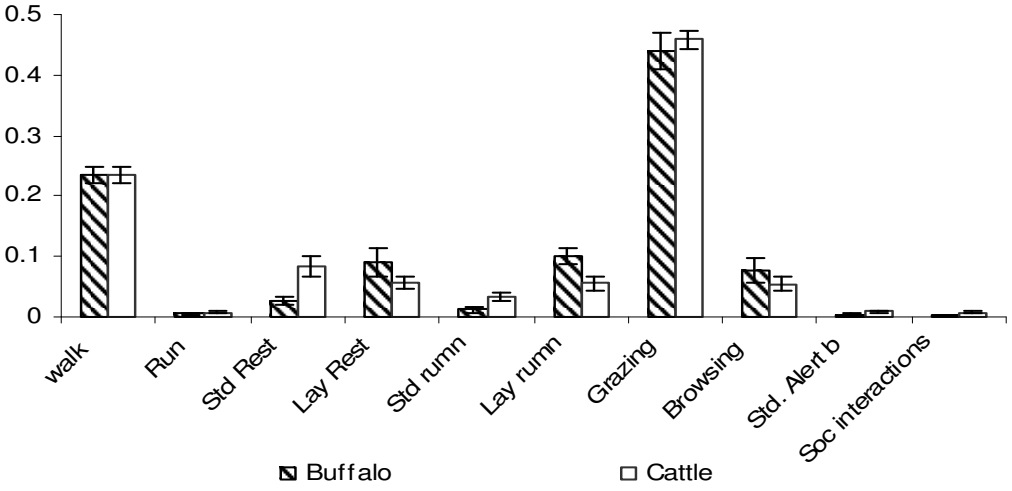
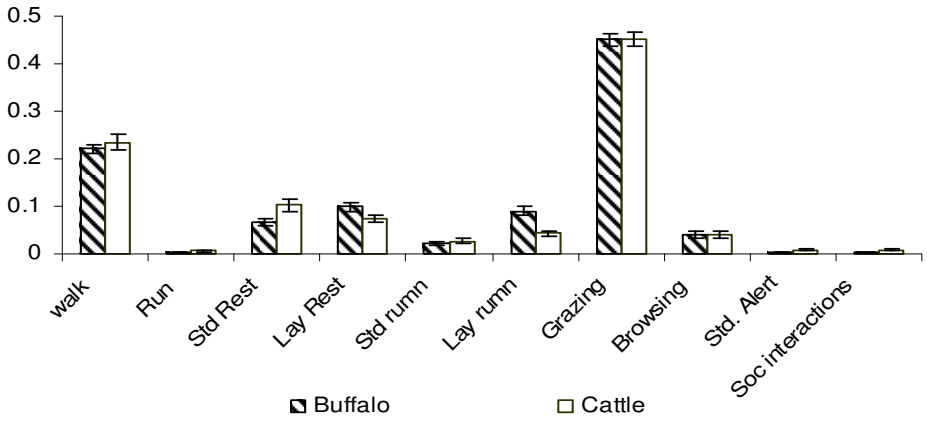


Figure 33: Proportion of time spent in various activities by cattle and buffalos during winter.



Temporal Activity Pattern of Chital and Livestock

Temporal activity of livestock and Chital and livestock were analyzed and compared to determine the temporal overlap between these sympatric herbivores.

Figure 34: Temporal Activity Pattern of Livestock.

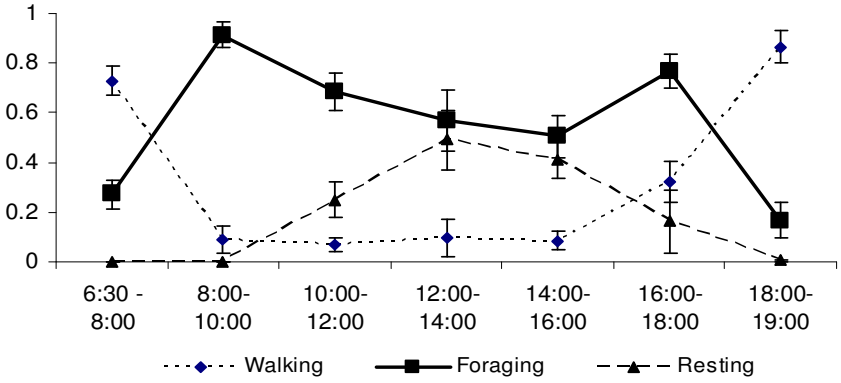
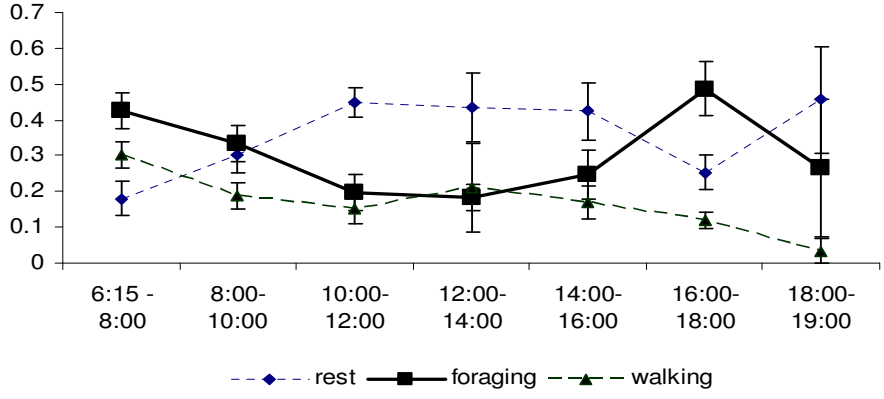


Figure-35: Temporal Activity Pattern of Chital.



For chital population, two distinct foraging peaks were observed, one in morning and second in late afternoon for both these group of animals. The morning peak of chital was occurred earlier than to livestock, as livestock start foraging later compared to chital. The period of second foraging peak is prolonged for chital as chital were observed foraging till late evening while livestock return earlier to their respective corrals in the Ness. (**Figure 34, 35**)

Habitat Use by Chital and Livestock

Differential resource selection is one of the principle factors, which permit species to coexist. It is generally assumed that animals will select a habitat that will be best able to satisfy its requirements and thus high quality resources will be selected more than low quality resources. But since availability is not uniform, use may change accordingly.

Habitat Availability

The total foraging area of livestock of 4 Maldhari nesses was 42.09 km^2 and of chital was 2.23 km^2. The Anogeissus mixed habitat is the dominant vegetation type in the area, followed by Acacia *Ziziphus* thorny scrub and woodland.

Chital

Chital was found in three broad habitat categories in the study area, i.e. *Acacia-Ziziphus* scrubland, *Anogeissus* mixed dry deciduous forest and Riverine forest. Chital were rarely found in *Boswelia-Lanea- Terminalia* habitat. Overall *Acacia Ziziphus* scrubland habitat was predominantly used by chital for foraging however the most preferred habitat were *Anogeissus* mixed and Riverine habitat types, while *Acacia Ziziphus* was least preferred habitat.

Seasonal variation in differential habitat use for foraging was observed. The riverine habitat was least used for foraging by chital during monsoon and winter but highly preferred as it is rich in the food resource availability and diversity. However this habitat was crucial during the leanest period of the year as this habitat was found to be highly used for various activities including foraging, most preferred habitat for foraging

was Anogeissus mixed habitat. The Anogeissus mixed habitat was found rich in and browse during this lean period also.

During monsoon and winter *Anogeissus* mixed habitat contributed significantly (21 ± 6%; 25 ± 9% respectively) to foraging while during summer foraging was more restricted to *Acacia Ziziphus* and Riverine **(Figure 36-38)**. It seems likely that *Anogeissus* mixed habitat was most preferred (Figure 38B) but least used as it is intensively used by livestock (42 ± 5.7 %,) during summer, and therefore chital tended to avoid it. Besides that *Anogeissus* mixed habitat is largely composed of dry deciduous trees providing no shade in extreme hot summer days. Though it was the least preferred habitat during summer chital was found spending more time in *Acacia Ziziphus* for grazing i.e. foraging on ground cover (74.5 ± 5.3 %), mostly feed on fallen pods of *Acacia sps.* and sparsely distributed herbs barely covering the ground.

During winter *Anogeissus* mixed habitat was most preferred and used habitat for foraging (**Figure 38 & 38A**). During winter, as fresh browse was still available in early winter months in all habitat types, proportionate browsing contributed more than the grazing i.e. foraging on ground cover.

During monsoon browsing i.e. foraging on nutritionally rich tender shoots of shrub and tree species, contributed more to the foraging activity than foraging off the ground cover in *Acacia Ziziphus* scrubland hence this habitat was highly used for the foraging. It could be the reason that *Acacia Ziziphus* is not the preferred one as prolonged water logging during monsoon does not allow grasses and herbs to grow. During monsoon grazing was mostly restricted to *Anogeissus* mixed habitat.

Overall, grazing i.e. foraging on ground cover i.e. grass, forbs, leaves, fruits and browsing contributed almost equally to the total foraging through out the study. The results of foraging habitat use is strongly supported by food habit study (Table-5), as major food items were browse than graze in the total seasonal diet of chital.

Figure 36 A: Comparative foraging activity of chital during monsoon

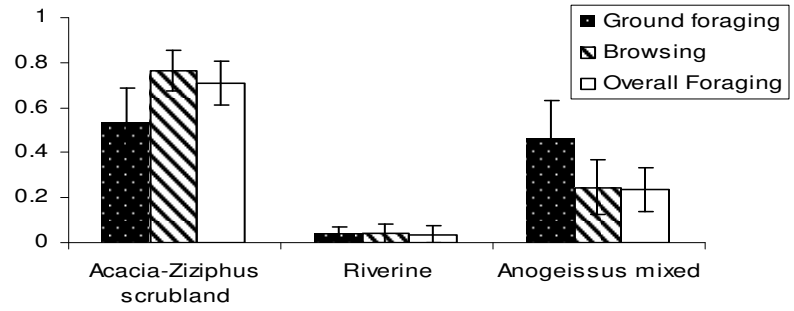


Figure 36 B: Habitat preference for foraging by chital during monsoon.

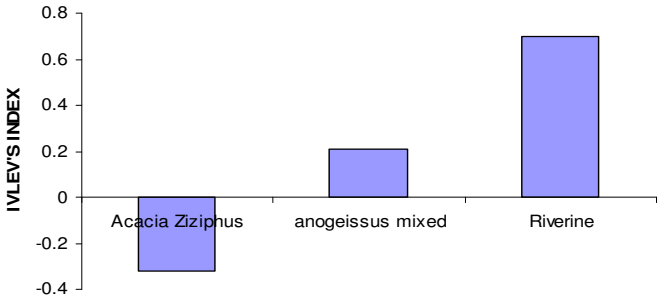


Figure 37 A: Comparative foraging activity of chital during summer

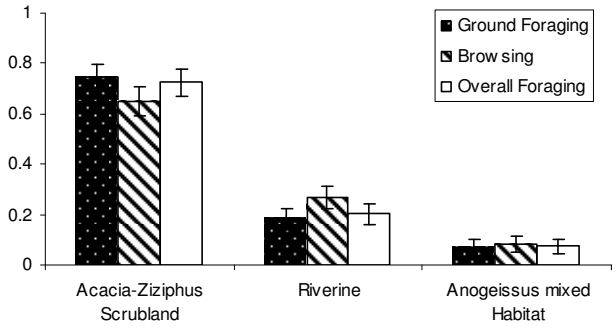


Figure 37 B: Habitat preference for foraging by chital during summer.

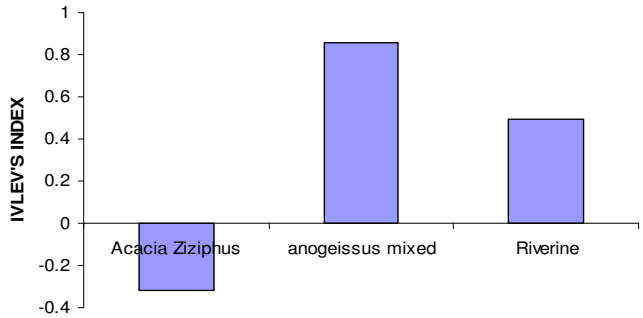


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Figure 38 A: Comparative foraging activity of chital during winter

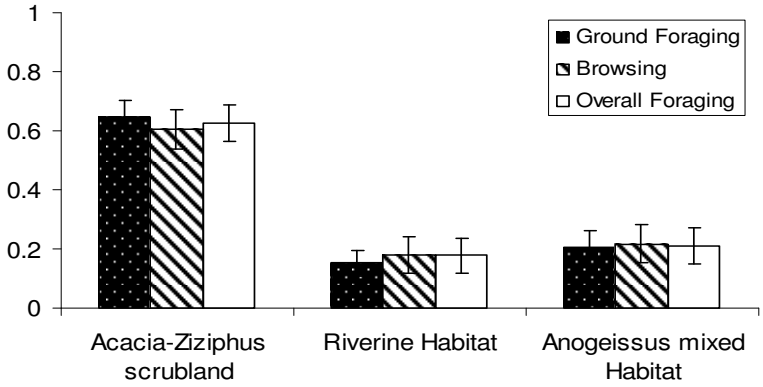


Figure 38 B: Habitat preference for foraging by chital during winter.

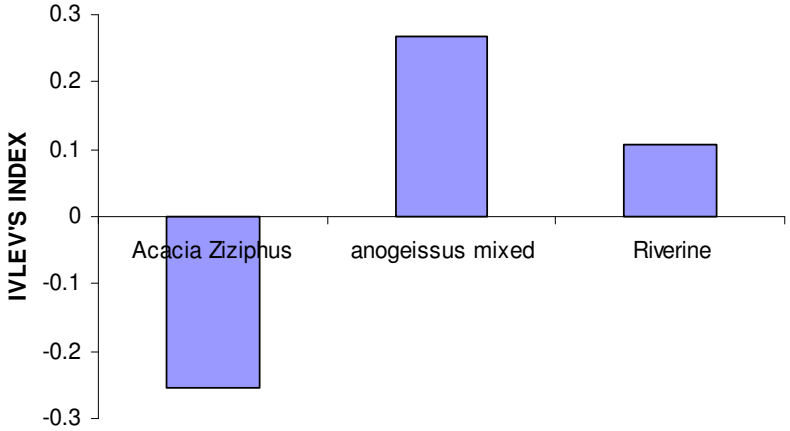
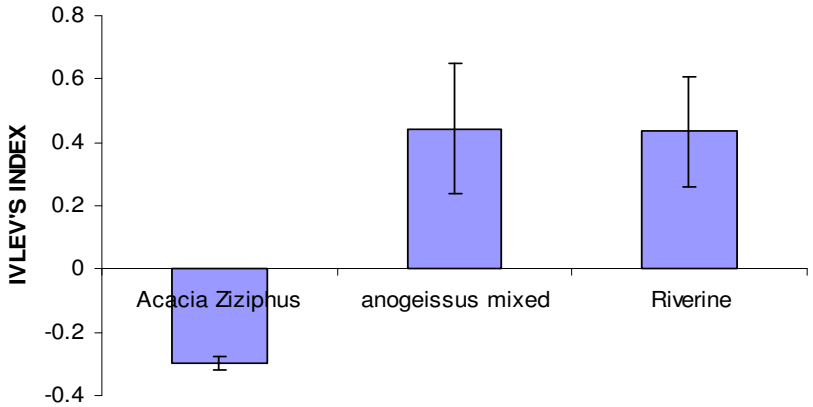


Figure 38 C: Habitat preference for foraging by chital in various habitat types.



Livestock

Livestock was found using four broad habitat types in intensive study area during the entire study; namely, *Acacia Ziziphus* scrubland, *Anogeissus* mixed woodland and *Boswelia- Lanea- Terminalia* vegetation types for various daily activities. Habitat use by livestock was observed for winter, summer and monsoon.

Buffalo

The results revealed that *Anogeissus* mixed dry deciduous forest were predominantly used during all three seasons while during summer habitat use for foraging was more or less diffused across all four habitat types (**Figure 39-41**). Buffalos were found to browse more in *Acacia Ziziphus* scrubland and Riverine habitats and graze more in Anogeissus mixed woodlands and *Boswelia Lanea Terminalia* habitats during winter (**Figure 39**).

During monsoon months livestock was observed to roam in larger area as water availability was more widespread and hence livestock spend more time in steeper forage rich i.e. *Boswelia Lanea Terminalia* and *Anogeissus* mixed habitats though these habitats were not preferred relatively **(Figure 40**). While during winter and summer foraging was found more or less diffused across the habitats. The use of *Boswelia Lanea Terminalia* is restricted during summer and overall it is not a preferred habitat **(Figure 41)** due to its arid nature with no drinking water, though it is being used relatively more as forage availability was still comparatively higher. The riverine habitat was least used for foraging by buffalos but this habitat was used primarily for shelter during hot afternoon hours. Though these habitats are linear strips along water course and are extremely limited in size, it is highly preferred habitat as these stretches provide good variety of food items. Livestock congregate in larger herds at water pools in riverine habitats spending time on resting and ruminating. The probability of encountering large carnivores is higher in dense riverine patches hence herd keepers don't allow their livestock to forage in this habitat for longer duration.

Figure 39 A: Comparative foraging activity of Buffalo during winter

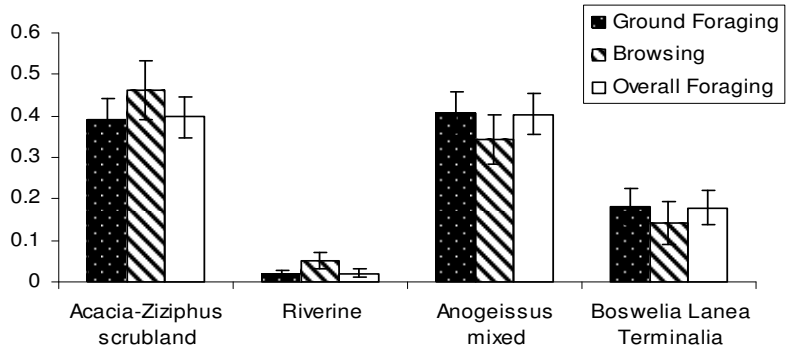


Figure 39 B: Habitat preferences for foraging by buffalo during winter

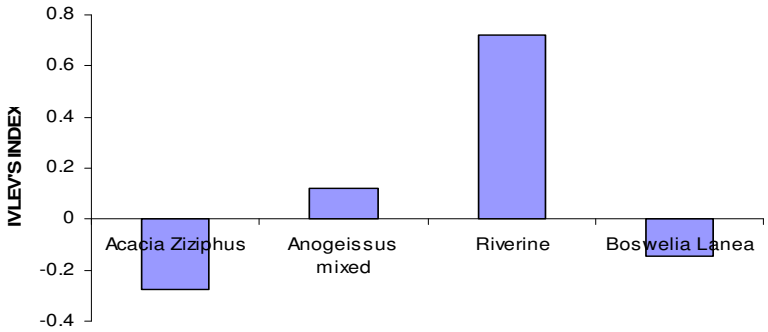


Figure 40 A: Comparative foraging activity of Buffalo during monsoon.

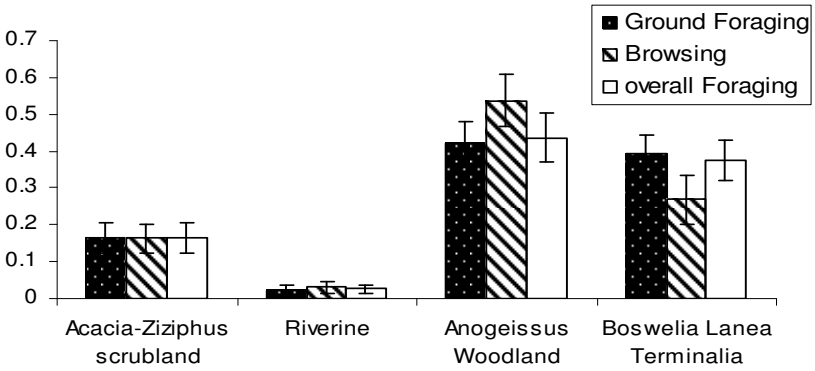


Figure 40 B: Habitat preferences for foraging by buffalo during monsoon.

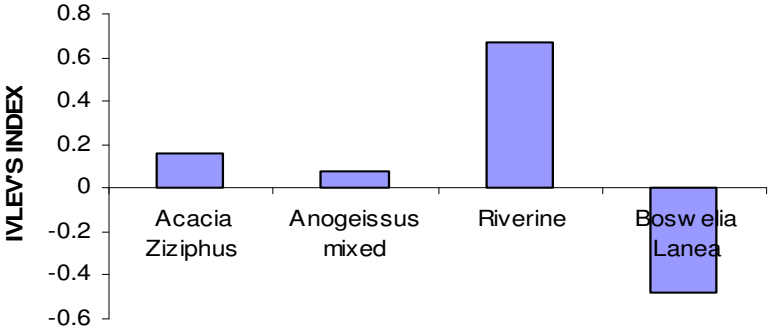


Figure 41 A: Comparative foraging activity of Buffalo during summer.

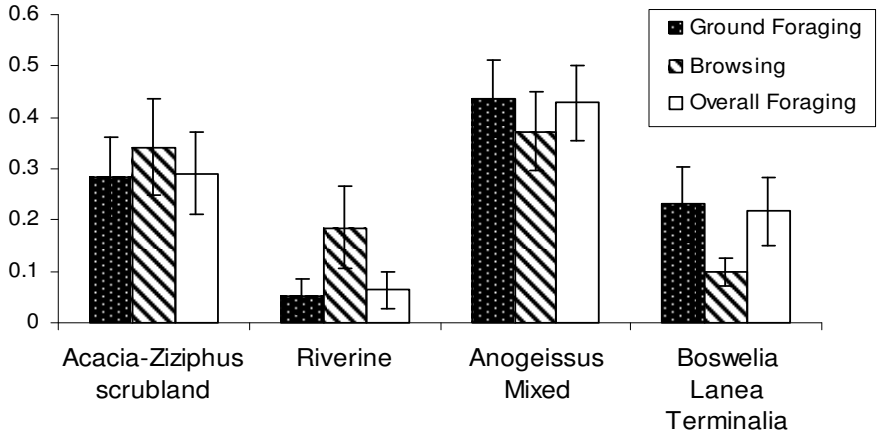


Figure 41 B: habitat preferences for foraging by buffalo during summer.

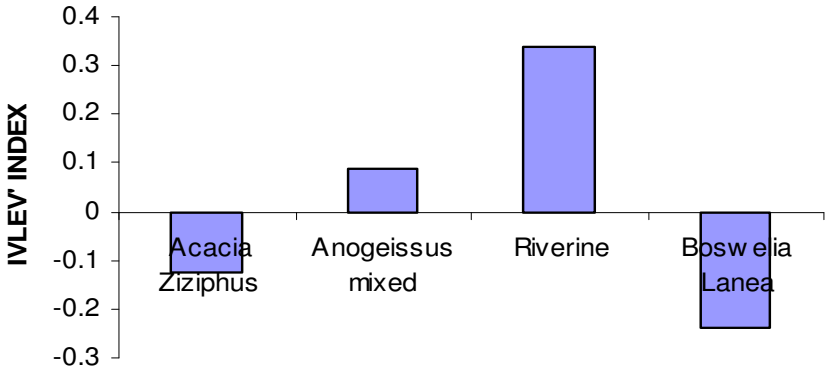
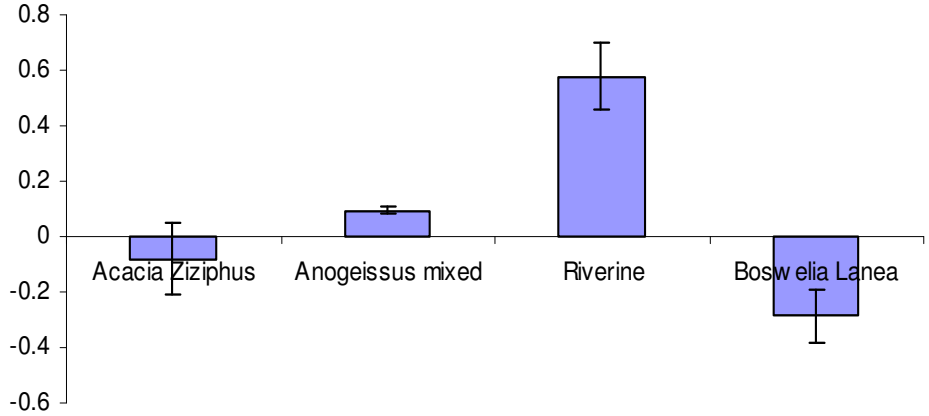


Figure 41 C: habitat preferences for foraging by buffalo in various habitat types.



Cattle

The results of habitat use for foraging is given in Figure 42A, 43A and 44A and the comparison of habitat use with that of habitat preference during that particular season are given in Figure 42B, 43B and 44B.

The use of different habitat for foraging is almost similar to that of buffalos during different seasons. The major difference observed between cattle and buffalos is the contribution by foraging on ground cover and foraging on fruits and leaves directly from trees and shrubs to total foraging. Cattle spend equal time on 'grazing' (foraging on ground cover) and 'browsing' (browse available on shrubs and tree), during monsoon and winter. While in summer cattle spent afternoon hours foraging in riverine habitats where browse availability is higher than other habitat (**Figure 42**).

Though cattle more preferred *Anogeissus* mixed habitat than Riverine as seasonal diet of cattle reflects more graze items than browse which is relatively more available in *Anogeissus* mixed habitat.

The poor resource condition during summer causes increased 'browsing' in *Acacia Ziziphus* scrubland and Riverine habitat. Whereas 'grazing' used to increase in *Anogeissus* mixed and *Boswelia- Lanea- Terminalia* habitats (**Figure 44**).

Comparison among these three herbivore species revealed that chital was observed spending more time in *Acacia Ziziphus* scrubland for foraging though it was not a preferred habitat, than cattle and buffalo during monsoon **(Figure 36, 39, 43)**.

During winter foraging was relatively diffused across the habitats for chital where habitat preference was relatively generalized, whereas in cattle and buffalo foraging activity across the habitat was relatively diffused during summer. However cattle preferred Anogeissus mixed habitat and buffalo preferred Riverine during summer (**Figure 38, 39, 42**).

The riverine habitat was relatively more used by cattle for foraging during winter afternoon hours compare to buffalos, which spent more time in resting during afternoon hours (**Figure 39 and 42**).

Figure 42 A: Comparative foraging activity of cattle during winter

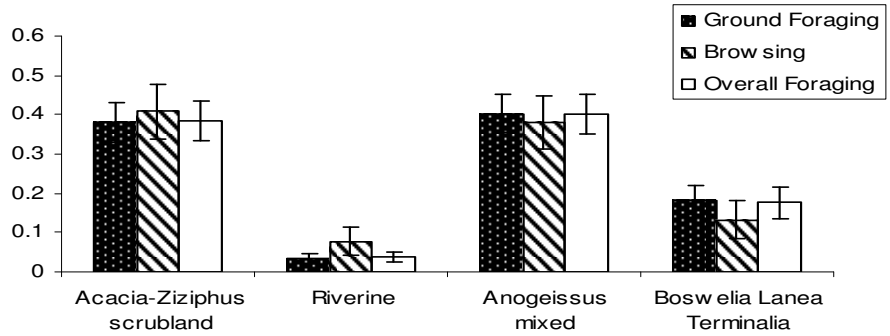


Figure-42 B: Habitat preference for foraging by cattle during winter

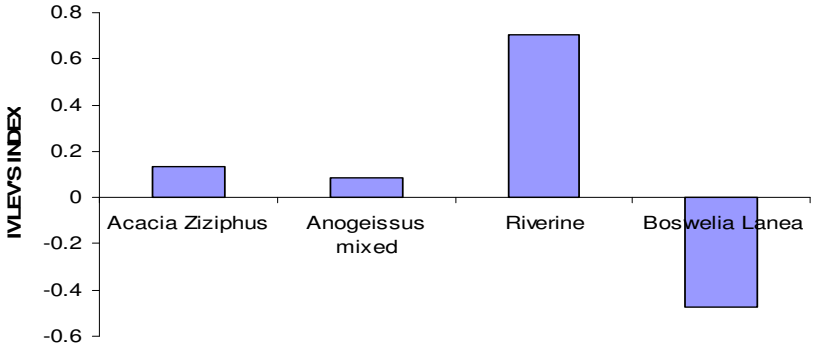


Figure 43 A: Comparative foraging activity of cattle during monsoon

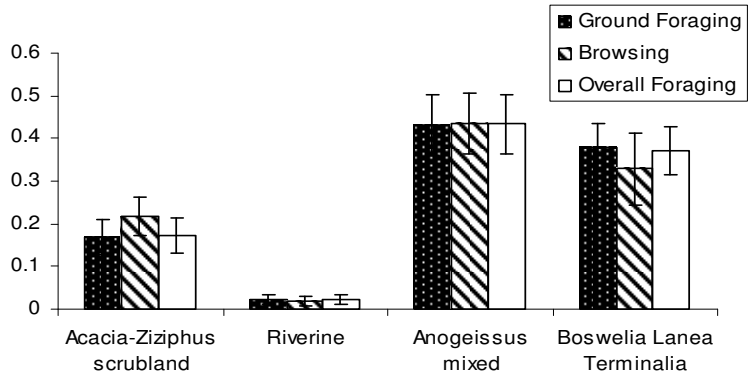


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Figure 43 B: Habitat preference for foraging by cattle during monsoon

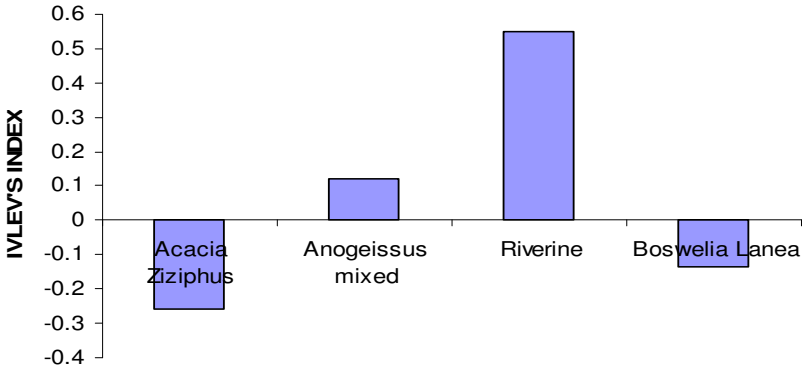


Figure 44 A: Comparative foraging activity of cattle during summer.

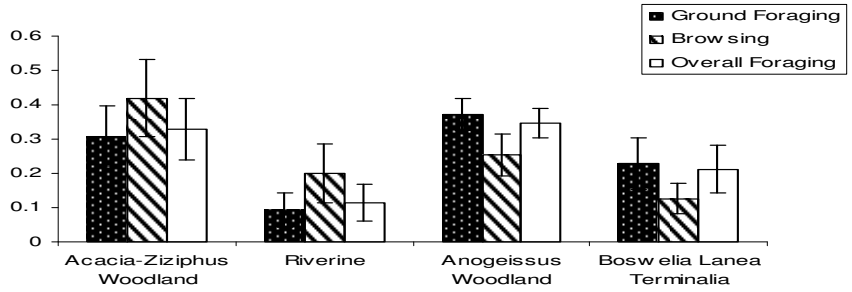


Figure 44 B: habitat preference for foraging by cattle during summer

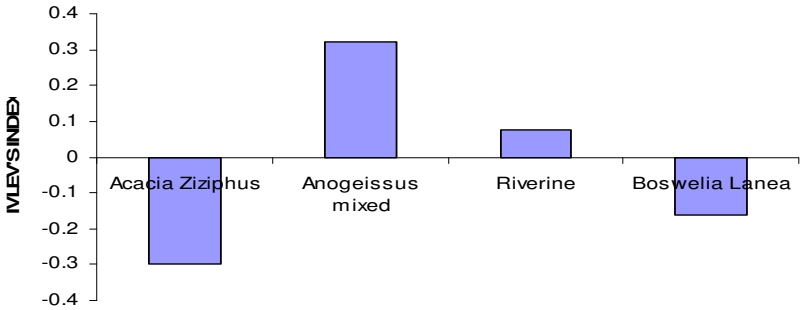
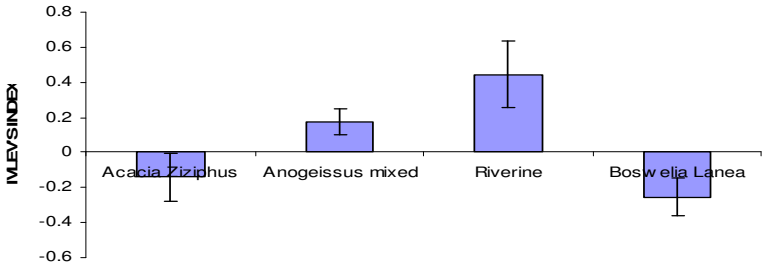


Figure 44 C: habitat preferences for foraging by cattle in various habitat types



Chital and both species of livestock had a high preference for the limited productive riverine habitat for foraging. The second preferred habitat was *Anogeissus* mixed woodland by chital and livestock. However, chital were not observed to use the steeper slope *Boswelia—Lannea* habitats which though not rating as a preferred habitat were used by livestock. Thus, livestock and chital both keyed in on similar habitats to obtain their food.

Habitat- wise Seasonal Diet Composition of chital and livestock

A comparative account of food habits of chital, livestock and buffalos is given below. Food habits are compared for three habitat types during different seasons. The summarized results are shown in **Table 5** and discussed below.

Table 5: Comparative account of food habit study of chital, cattle and buffalo in Gir (East)

Season	Habitat	Habitat use						No. Individuals			No. of food sps			no. bites		
		chital (SE)		cattle (SE)		buffalo (SE)		chital	cattle	buffalo	chital	cattle	buffalo	chital	cattle	buffalo
Summer 06	*Acacia Ziziphus*	0.72	0..05	0.32	0.08	0.31	0.08	11	13	11	10	23	16	1829	1520	1741
	Anogeissus mixed	0.07	0.02	0.29	0.05	0.41	0.05	9	14	8	14	13	19	1694	1843	1513
	Riverine	0.20	0.04	0.48	0.12	0.07	0.02	9	11	27	13	19	23	1297	1520	1480
Winter 06	*Acacia Ziziphus*	0.74	0.04	0.37	0.09	0.27	0.07	22	7	7	16	19	22	2147	1254	1412
	Anogeissus mixed	0.06	0.03	0.36	0.07	0.45	0.06	14	7	9	7	21	22	609	1972	2567
	Riverine	0.20	0.05	0.05	0.02	0.07	0.03	24	8	13	25	27	36	983	1589	2088
Monsoon 05	*Acacia Ziziphus*	0.71	0.10	0.33	0.09	0.16	0.04	21	12	18	14	21	26	2096	2191	3153
	Anogeissus mixed	0.23	0.01	0.43	0.07	0.44	0.06	16	15	14	16	14	22	1828	1640	1545
	Riverine	0.08	0.05	0.02	0.01	0.03	0.01	26	16	20	18	25	40	1922	1848	2452
Summer 05	*Acacia Ziziphus*	0.61	0.10	0.33	0.09	0.29	0.08	14	11	12	15	15	13	1802	1270	1580
	Anogeissus mixed	0.11	0.04	0.35	0.04	0.42	0.07	7	6	8	16	7	4	2354	1301	1764
	Riverine	0.28	0.11	0.11	0.05	0.06	0.03	15	13	16	17	11	14	2310	1160	1110
Winter 05	*Acacia Ziziphus*	0.63	0.06	0.38	0.05	0.40	0.05	17	10	20	6	3	17	831	994	2556
	Anogeissus mixed	0.21	0.06	0.40	0.05	0.41	0.05	16	18	19	15	9	16	719	2278	2602
	Riverine	0.17	0.06	0.38	0.01	0.02	0.01	24	12	20	23	22	8	919	1688	772

Monsoon 04

Acacia- Ziziphus Habitat

In *Acacia- Ziziphus* scrubland chital (n=23) was observed feeding (total bites 2248) on 38 different food items. *Paspalidium spp*. was the most frequent food item in the diet of chital followed by *Apluda mutica* and *Echinochloa colonum*.

Amongst livestock 3 cattle and 9 buffalos were observed for their bite counts. A total of 3534 bites were recorded of cattle and 2594 bites of buffalos. Cattle were found feeding on 21 food items and buffalos on 7 food items. In *Acacia Ziziphus* scrubland, *Themeda cymbaria* contributed largely to the dietary composition of cattle followed by *Heteropogon contorious* whereas, *Apluda mutica* and *Themeda cymbaria* constituted the major bulk of the buffalo diet.

Here, all three herbivores were found to be feeding on grasses but the major food items are different for them.

Anogeissus Mixed Habitat

In *Anogeissus* mixed dry deciduous forest 9 chital individuals were found feeding on 28 species of plants. A total of 1527 bites were recorded during this season. In this habitat type, *Apluda mutica* contributes predominantly to the total diet of chital during this season followed by *Aristida spp*.

Among livestock, 4 cattle and 5 buffalos were observed for their bite count. A total of 843 and 1858 bites were recorded of cattle and buffalos respectively. The cattle were observed feeding on 14 different food items whereas buffalos were feeding on 13 food items. *Aristida spp* and *Apluda mutica* were the most frequent food items of cattle and buffalos respectively.

A little diet overlap was observed between these two groups of ungulates as *Aristida spp* and *Apluda mutica* were common frequent food items in chital as well as livestock diet.

Winter 05

Acacia Ziziphus scrubland

In this habitat 17 different chital individuals were observed directly for their bite counts. A total of 17 different plant species were recorded in a total of 831 bites recorded in *Acacia- Ziziphus*scrubland. Among all consumed plant species and their parts, *Ziziphusmoritiana* fruits were highest in number followed by *Ziziphusmoritiana* leaves and *Acacia nilotica* leaves.

A total of 2556 and 994 bites counted of 17 different buffalo and10 different cattle individuals. In this habitat buffalos found feeding on 17 different species of food plant species where as cattle fed upon 6 food plant species. Among all food items *Heteropogon contorious* contributed predominantly to the total dietary composition of buffalos which is followed by *Aristida spp,* while in cattle diet *Aristida spp* contributed predominantly compared to the other items which was followed by *Heteropogon contorious*.

It was observed that chital fed upon browse items while livestock consumed more grasses in this habitat.

Anogeissus mixed woodland

In Anogeissus mixed habitat a total of 719 bites were counted of 21 different chital individuals. Chital were found to be feeding on 15 different fodder species. Among all observed food species selected by chital *Ziziphus moritiana* fruits were again on top of the list followed by Acacia catechu leaves.

In this habitat 2602 and 2278 bites were counted from 19 buffalos and 18 cattle. This habitat provides 16 different food plants to buffalos and 9 to cattle, of which again *Heteropogon contorious* is the most frequent food items followed by *Eremopogon foveolatus* locally known as 'Shaniyar' in the diet of both the domestic ungulates.

Riverine Habitat

This habitat offered maximum number of food species to chital diet i.e. 23 different plant species. A total of 31chital individuals were observed for their bite counts. 919 bites of 23 different plant species were noted. The most frequent food items in this habitat was *Ziziphusmoritiana* leaves, *Ficus racemosa* fruits and *Aristida spp.*

20 different buffalos and 12 cattle were observed in this habitat and a total of 772 and 1688 bites were counted respectively. The diet of buffalo in this habitat consists of 8 different species while cattle were found feeding on 22 species of food plants, among all *Aristida spp* is the most frequent fodder species of both, which is followed by *Heteropogon contorius* in buffalo diet and *Apluda mutica* in cattle diet.

In this habitat type livestock largely fed upon *Aristida spp* which is comparatively more abundant than other grass species. But chital relied on fresh *Ziziphus moritiana* leaves and *Ficus racemosa* fruits. The difference in food species consumption between these two groups of ungulates could have been resulted due to absence of grass species in available riverine patches for focal group of chital, as prominent and frequent use of same patches by livestock.

Summer 05

Acacia Ziziphus Scrubland

Summer is resource poor period in intensive study area. During the bite count observations of 14 different chital individuals a total of 15 plant species were found to be selected by them in 1802 total observed bites. *Aristida sps* was most frequent food item among all food items, followed by *Acacia nilotica* leaves and *Acacia leucoplia* leaves.

During summer 05, 21 buffalos and 11 cattle were observed for their food habits in this habitat. A total of 1580 and bites were counted of buffalos and cattle respectively. Overall 13 and 15 plant species were found in the dietary composition of buffalo and cattle respectively. The major contribution to the total dietary composition was made by the leaves of *Wrightia tinctoria* followed by *Aristida spp* and the leaves of *Ziziphusmoritiana* in cattle diet while *Apluda mutica, Aristida spp* and *Eremopogon foveolatus* contributed to the buffalo diet.

Here, *Aristida spp* was most frequent food item in Chital diet, whereas livestock consumed more browse item. Though little diet overlap was observed between chital and cattle as both used *Aristida spp* as a major food item in this habitat type.

***Anogeissus* mixed**

In *Anogeissus* mixed habitat 2354 bites were counted of 17 different individuals. Overall 16 different food items were observed fed upon by chital. Here, *Apluda mutica* locally known as 'Foflu' an abundant gramanoid of intensive study area was most frequent among others followed by *Aristida sps* and *Eremopogon foveolatus*.

In this habitat a total of 1764 and 1301 bites were counted (N= 8 buffalo, N=6 cattle). Buffalos were found to be fed upon 4 plant species while cattle were seen feeding upon 7 food plant species. Among all *Apluda* mutica in buffalo diet and *Eremopogon foveolatus* cattle diet are the most frequently observed food items followed by *Aristida spp* and *Eremopogon foveolatus* in buffalo diet and *Aristida spp* and *Apluda mutica* in cattle diet.

The maximum overlap was observed during summer as it is the leanest period for food resource availability. The *Anogeissus* mixed habitat, which was comparatively more fodder rich than other habitat types. Though major dietary overlap between chital and livestock there was no resource limitation observed for chital foraging.

Riverine Habitat

A total of 2310 bites counted of 15 different chital individuals during direct observation. This habitat contributed 17 different food items to chital diet. This habitat supports many fruit bearing trees which were reflected in selected food items of chital. Most frequent food item was fruits of 'Karapta' a small tree restricted to ravine patches only followed by *Syzygium heyneanum* fruits locally known 'Jambu' and *Ficus glomarata* fruits.

A total of 1110 and 1160 bites were counted of 16 different buffalos and 13 different cattle. The food items of buffalos and cattle contain 16 and 11 plant species respectively. In this habitat *Tamarinds indica* a tree common on river bank contributes largely to the dietary composition of cattle which is followed by the leaves of *Ziziphus moritiana* and *Syzygium heyneanum* whereas the leaves of *Ziziphus moritiana* is the major food item in buffalo diet followed by *Capparis sepiaria.*

Both the group of ungulates i.e. chital and livestock used browse items more in their diet here in this habitat. Though both relied on browse, chital fed upon fruits while livestock used leaves of same species.

Monsoon 05

***Acacia Ziziphus* scrubland**

During this season a total of 2096 bites were counted of 21 chital individuals. The food items include 14 different plant species and their parts. Among all food items *Acacia nilotica* leaves, flowers of *Xeromphis uliginosa* locally known as 'Gengdi' and *Paspalidium sps* were most frequent.

In Acacia *Ziziphus* scrubland, a total of 3153 and 2191 bites were counted from direct observation of 18 different buffalos and 12 different cattle individuals. Buffalos were found to be feeding on 26 different food plants and cattle on 21 food plants. Among all *Apluda mutica* was the major dietary component of buffalo diet followed by *Eremopogon foveolatus* and *Leucas cephalotes* locally known as 'Kubdo', whereas *Eremopogon foevolatus* contributed largely to cattle diet which was followed by *Leucas cephalotes* and *Helecteres isora*

There is no major dietary overlap was found between chital and livestock in this habitat. Chital diet was largely constituted by fresh browse whereas livestock diet was composed of grass and forbs species. Livestock were more generalized then chital in diet selection.

***Anogeissus* mixed**

A total of 1828 bites were recorded during direct observations of 16 chital individuals in this habitat. They were found to be feeding on 16 different food items. *Paspalidium sps* was the most occurred food item followed by *Aristida sps* and *Apluda mutica.*

A total of 1545 and 1640 bites were counted for 14 different buffalos and 15 different cattle. Overall buffalos were seen feeding on 22 species of plants whereas cattle were seen feeding on 14 different food plants. *Apluda mutica* was the major food item in the dietary composition of buffalo in this habitat during this season followed by *Aristida spp* and *Eremopogon foveolatus.* In cattle diet *Eremopogon foveolatus* contributed predominantly followed by *Apluda mutica* and *Leucas cephalotes.*

In this habitat a little diet overlap was observed between chital and livestock. *Apluda mutica* was the common and frequent food item in their diet composition. A little potential for competition for foraging between chital and livestock in *Anogeissus* mixed habitat type was observed.

Riverine Habitat

In riverine habitat a total of 26 different chital individuals were observed feeding on 18 different food items from 1922 recorded bites. During this food habit observation session an orchid species *Eulophia spp* was largely consumed which is not commonly found in Gir. Other frequent food items are *Wrightia tinctoria* leaves and *Anogeissus latifolia* leaves.

20 different buffalos and 16 individual cattle were observed and a total of 2452 and 1848 bites were counted of buffalo and cattle respectively. This habitat provided maximum number of plant species i.e. 40 to the diet of buffalo and 24 to the diet of cattle. Among all, *Helecteres isora* locally known as 'Antedi' contributed predominantly to the total diet of buffalo followed by *Eremopogon foveolatus* and *Leucas cephalotes,* while here in cattle diet *Leucas cephalotes* was followed by *Apluda mutica*.

Buffalos and cattle were found to be more generalized as their diets were more diverse then chital. No major dietary overlap was observed in this habitat during in monsoon.

Winter 06

***Acacia Ziziphus* scrubland**

A total of 2147 bites were counted of 22 individual chital in *Acacia Ziziphus* scrubland during this season. The food items include 16 plant species of which *Acacia nilotica* leaves, *Ziziphus moritiana* leaves and *Paspalidium* sps are most frequent species in chital diet.

7 buffalos and 7 cattle were observed and a total of 1412 and 1254 bites were counted. Here, 22 and 19 different food plants were found fed upon by buffalos and cattle. The major contribution to the dietary composition of buffalo and cattle were made by *Cymbopogon jwarancusa, Eragrostis poaeoides* and *Aristida spp*, followed by *Apluda mutica* and *Paspalidium spp* respectively.

During winter, in *Acacia Ziziphus* scrubland, chital were observed feeding on fresh browse of *A. nilotica* and *Z. moritiana* where as livestock were observed more grazing then browsing.

***Anogeissus* mixed**

In Anogeissus mixed woodland habitat a total of 609 bites were counted from 14 individual chital. In this habitat 7 species of food plants were found to be fed upon by chital. Among these food items *Erogrostis sps*., *Aristida* sps and leaves of *Acacia catechu* were most frequent food items of chital diet.

A total of 2567and 1972 bites were counted from 9 and 27different buffalos and cattle. Overall 22 and 21 different plant species were found in the diet of buffalos and cattle. Among all, *Aristida spp.* predominantly contributed to the diet composition of buffalo followed by *Eremopogon foveolatus* and *Apluda mutica* while, Apluda mutica is the major food plant species of cattle diet followed by *Leucas cephalotes* and *Cymbopogon jwarancusa*.

Chital diet was composed of short and sparse grass *Erogrostis sps* and *Aristida sps* off the ground and sparse leaves of *A. catechu* as a browse. Whereas livestock fed on relatively tall and dense grasses only like *Apluda mutica, Eremopogon foveolatus and Cymbopogon jwarancusa*.

Riverine Habitat

In this habitat 983 bites from 24 chital individuals were counted. Riverine habitat harbored maximum number of food items of chital. A total of 25 plant species and their parts were found in chital diet. Among all *Achyranthus aspera* was contributing largely followed by the fruits of *Ziziphus moritiana* and an herb *Barleria prionitis.*

13 and 8 individual buffalos and cattle were observed and a total of 2088 and 1589 bites were counted. Buffalos were found feeding on 36 food plant species while; cattle were found feeding on 28 food plants. Among all, *Helecteres isora* was the major food item in buffalo diet followed by *Leucas cephalotes* and *Barleria prionitis* whereas, *Aristida spp* contributed predominantly to the cattle diet followed by *Dicanthium annulatum* locally known as 'Jinjvo' and *Cymbopogon jwarancusa*. Here, chital were found to be feeding on forbs while cattle were by and large grazer feeding on grass species like *Aristida spp* and *Cymbopogon jwarancusa*.Whereas, buffalos mostly fed upon browse species *Helecteres isora*.

Summer 06

***Acacia Ziziphus* scrubland**

In Acacia *Ziziphus* habitat a total of 11 different individuals were observed for an overall 1836 bites. During food habit observation of chital, 11 different food items were recorded, out of which fruits of *Acacia leucoplea, Acacia catechu* and *Acacia nilotica* predominantly contributed to the chital diet in this habitat during summer 06.

A total of 1741and 1520 bites were counted in this habitat from 11 and 13 different individual buffalos and cattle. Buffalos were found feeding on 16 different food plant species whereas cattle were seen feeding on 13 different food plants. The major food item of buffalo and cattle diet was the leaves of *Ziziphus moritiana* followed by *Apluda mutica* and *Aristida spp.* in buffalo diet and *Achyranthus aspera* and *Capparis sepiaria in* cattle diet.

The major food items of chital were pods of *Acacia sps.* Whereas cattle and buffalo diets were relatively more generalized and composed of grasses and forbs along with browses.

***Anogeissus* mixed Habitat**

A total 0f 1694 bites were counted of 9 chital individuals. The diet composition of chital for this habitat in summer includes 14 different food item species. The leaves of Anogeissus latifolia predominantly contributes the diet composition followed by *Acacia nilotica* leaves and *Aristida spp*.

A total of 1513 and 1843 bites were counted from 8 and 14 different individual buffalos and cattle. Overall 8 species of plants were found contributing to the diet of buffalos and 13 species to the cattle diet, in this habitat. *Aristida sps* was the major contributor to the total diet of buffalo followed by *Apluda mutica* and *Eremopogon foveolatus* while in cattle diet *Apluda mutica* was the major food item followed by *Aristida sps* and *Anogeissus latifololia*

Here, chital were observed predominantly feeding on dry leaves of *Anogeissus latifolia* and *Acacia nilotica* whereas livestock were largely dependent on grasses.

Relatively this habitat is resource rich and caters the diverse food choices of these two groups of ungulates.

Riverine Habitat

9 different Chital individuals were observed feeding for a total of 1297 bites of 13 different food items. In this habitat 13 different food items were contributed in chital diet. Among all food items *Barleria prionitis* was the most frequent food items followed by shrubs- *Flacourtia indica* and *Capparis sepiaria.*

In this habitat a total of 1480 and 1520 bites were counted of 27 individual buffalos and 11 different cattle. The diet of buffalos consist 23 food plant species whereas cattle diet consists 19 food plant species. Among all, leaves of *Anogeissus latifolia* contributed largely to the diet of buffalos followed by *Ziziphus moritiana* leaves and *Capparis sepiaria.* In this habitat, *Tamarinds indica* contributed largely to the cattle diet followed by the leaves of *Anogeissus latifolia*

Here, chital diet is composed of sparsely grown *Barleria prionitis* and shrubs *Flacourtia indica* and *Capparis sepiaria* whereas, livestock diet constituted by major contribution of browse items.

Detailed Seasonal Food Habits of Chital and livestock

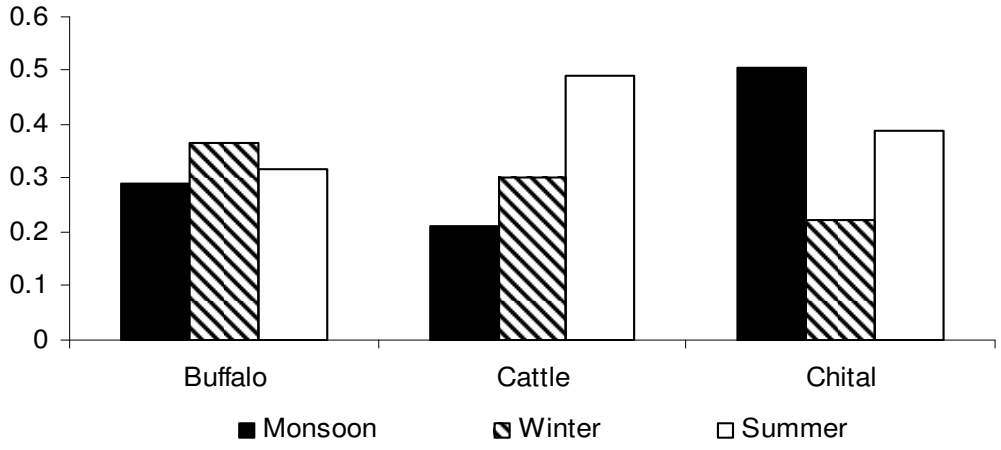
Chital in intensive study area of Eastern Gir used three different habitat types i.e. *Acacia Ziziphus* scrubland, *Anogeissus* mixed woodland and riverine patches (Moist mixed forest along rivers) and were rarely observed in *Boswelia Lanea Terminalia* habitat. The proportionate habitat use for foraging of each habitat calculated and used as correction factor to obtained the weighted contribution of each food item in the dietary composition. The detailed results are given in the **Tables 5, 6 and 7.**

Niche Breadth index

The Niche breadth of all three herbivore species computed for three different seasons. The results of Niche Breadth are given in the **Figure 45**. The diet niche breadth of buffalo was almost constant through out the year, whereas seasonal fluctuations in diet

niche breadth were observed in chital and cattle. The comparison between chital and cattle diet niche revealed that cattle were relatively more generalized feeder during summer while chital were more generalized during monsoon. During winter the niche breadths of these three large herbivores almost were almost matching. It could be the reason that during winter habitat use for foraging is diffused across the habitat and the availability of palatable plant items is higher during the same time.

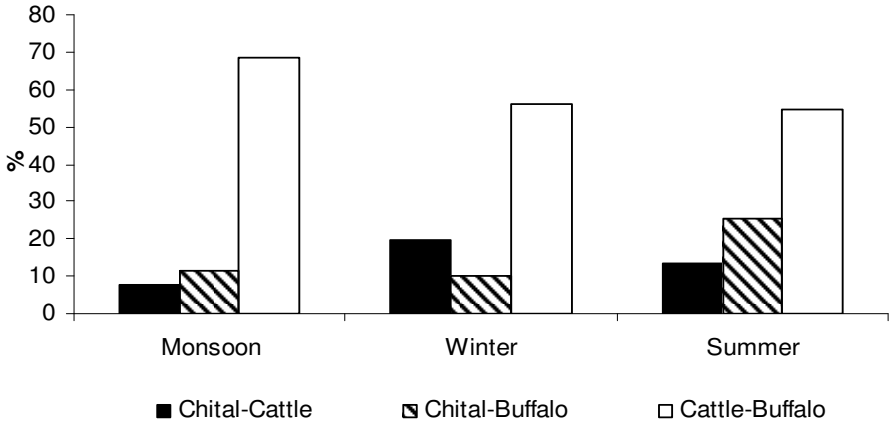
Figure 45: Seasonal Diet Niche Breadths of Chital Cattle and Buffalo.



Niche overlap

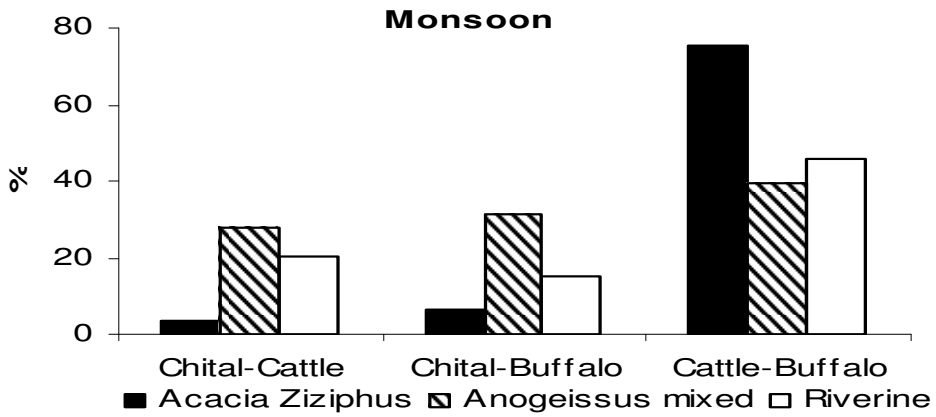
However, the niche overlap simply does not relate to the resource competition. The higher overlap indices may simply mean that resource is highly used by both species (Holt 1987) and on the basis of such indices the potential of competition for particular resource can be visualized. Here, we evaluated the food resource overlap between sympatric wild and domestic ungulates to understand whether potential for food resource competition prevail and if it is so then to evaluate seasonal diet niche overlap pattern and habitat wise diet niche overlap.

Figure 46: Seasonal diet overlaps among chital cattle and buffalo



Overall, major dietary overlap was observed between cattle and buffalo, mostly more than 50 across the seasons. However there is no major dietary overlap observed between chital and livestock, the overlap was maximum between chital and buffalo in summer (25.48 %) and chital and cattle in winter (19.41 %) **(Figure 46).** For better understanding of their diet overlap and subsequent forage competition, the diet overlap was also computed for different habitat types in different seasons (**Figure 47-49**). The diet overlap computed for all three possible combinations i.e. chital-cattle, chital- buffalo and cattle-buffalo. The overlap between cattle and buffalo diet was computed just to understand the amplitude of resource use overlap pattern between sympatric species. The comparison of the overlap between cattle- buffalo with chital-cattle and chital-buffalo helps better interpretation of diet overlap.

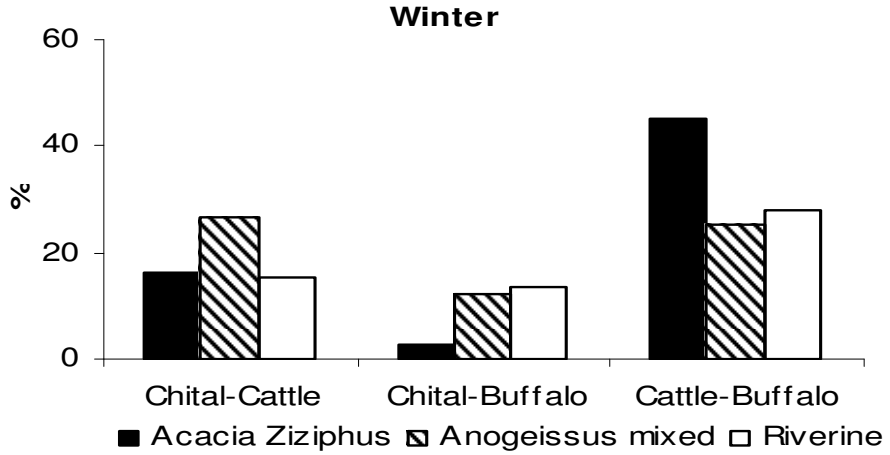
Figure 47: Habitat wise Diet niche overlaps among chital cattle and buffalo during monsoon.



During monsoon, the diet overlaps between chital and cattle as well as chital and buffalo was relatively high in *Anogeissus* mixed habitat. Though the overlap was not observed more than

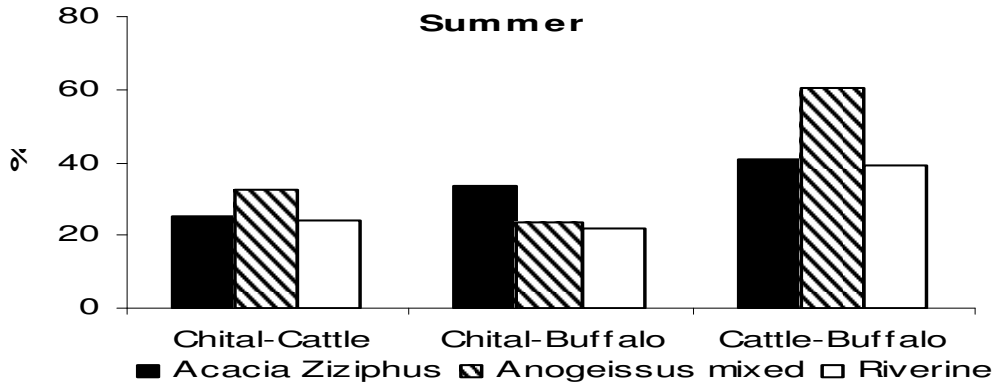
30 % in either combinations i.e. chital-cattle or chital- buffalo whereas it was more than 40 % in all available habitat between cattle and buffalo. The potential for marginal foraging competition is in the Anogeissus mixed habitat for chital-cattle and chital – buffalo combinations.

Figure 48: Habitat wise Diet niche overlaps among chital cattle and buffalo during winter.



During winter the food resources are abundant and diverse, little overlap was observed between chital and livestock. The only diets overlap which is not more than 30 % was observed between chital and cattle in Anogeissus mixed habitat. The rest habitats as well as diet overlap between chital and buffalo were very low comparatively.

Figure 49: Habitat wise Diet niche overlaps among chital cattle and buffalo during summer.



During summer which is believed to be much potent period for resource competition between sympatric herbivore shows little higher diet overlap between chital and cattle as well as chital and buffalo in the intensive study area. In spite, relative resource poorness the potential for forage competition remains between chital and cattle in *Anogeissus* mixed habitat and between chital and buffalo in Acacia *Ziziphus* habitat only.

Chital

Food habits of chital are shown in **Table 6.** The dietary composition of chital largely constituted by browse species like *Acacia nilotica*, *Ziziphus moritiana*, *A. catechu*, *A. leucophloea* and grass species like *Apluda mutica* and *Aristida sps.* During monsoon chital diet is relatively more diverse as miscellaneous food items contributed significantly. The food habit result indicates that chital is more browser than grazer in the Intensive study area.

Table 6: Food Habits of Chital During Different Seasons

Season	Food item (Species)	Acacia *Ziziphus* A	Anogeissus mixed B	Riverine C	% bite in diet A+B+C	dry wt/ bite	dry wt in 100 bites	% dry wt. Contribution to actual diet
Summer 06	*Acacia nilotica (fruit)*	10.80	0.00	0.00	10.80	2.52	27.20	33.69
	Acacia luecophloea (fruit)	17.53	0.00	0.00	17.53	0.86	15.12	18.72
	Ziziphusmoritiana	9.65	0.91	1.56	12.12	0.86	10.42	12.91
	Acacia catechu (fruit)	13.06	0.44	0.00	13.50	0.70	9.47	11.73
	Capparis saparia	0.00	0.53	2.97	3.50	0.79	2.77	3.42
	Acacia luecophloea (leaves)	7.87	0.00	0.00	7.87	0.28	2.23	2.76
	Wrightia tinctoria	0.00	0.62	1.68	2.30	0.47	1.07	1.32
	Flacourtia indica	0.00	0.00	3.63	3.63	0.24	0.89	1.10
	Acacia nilotica (leaves)	5.66	1.42	0.00	7.08	0.12	0.86	1.07
	Barleria priontis	0.00	0.00	4.92	4.92	0.15	0.76	0.94
	Anogeissus latifolia	0.00	1.45	0.00	1.45	0.52	0.76	0.94
	Aristida spp	0.00	0.66	0.00	0.66	0.02	0.01	0.01
	others< 5%				14.65	0.63	9.20	11.39
Winter 06	*Acacia nilotica (leaves)*	27.70	0.00	1.04	28.74	0.72	20.65	52.55
	Apluda mutica	4.18	0.59	0.00	4.77	0.66	3.13	7.97
	Paspalidium spp. (Retz.)	7.25	0.00	0.00	7.25	0.33	2.39	6.09
	Achyranthus aspera	4.35	0.00	2.74	7.10	0.33	2.34	5.96
	Anogeissus latifolia	0.00	0.86	1.44	2.30	0.52	1.19	3.04
	Acacia catechu (leaves)	4.18	0.99	0.00	5.17	0.19	0.98	2.51
	Ziziphusmoritiana (fruit)	0.00	0.39	2.07	2.47	0.33	0.81	2.07
	Erogrostis spp	0.00	1.62	0.00	1.62	0.33	0.54	1.36
	Securingea leucopyrus	0.00	0.00	1.08	1.08	0.33	0.36	0.90
	Aristida spp	0.00	1.06	0.00	1.06	0.33	0.35	0.89
	Barleria priontis	0.00	0.00	1.77	1.77	0.15	0.27	0.70
	*Kutelo**	0.00	0.00	1.14	1.14	0.09	0.10	0.26
	Ziziphusmoritiana (leaves)	0.00	0.00	1.61	1.61	0.04	0.06	0.16
	Wrightia tinctoria	0.00	0.35	1.12	1.46	0.04	0.05	0.14
	others< 5%				19.34	0.31	6.06	15.42
Monsoon 05	*Acacia nilotica (leaves)*	14.64	0.00	0.00	14.64	0.08	1.17	14.75
	Unid. Grass spp	11.56	0.00	0.00	11.56	0.09	1.01	12.75
	Xeromphis ugiginosa	14.23	0.00	0.00	14.23	0.05	0.76	9.54
	Aristida spp	0.00	6.62	0.00	6.62	0.11	0.72	9.07
	Securingea leucopyrus	4.73	0.00	0.71	5.44	0.13	0.71	8.93
	Paspalidium spp.	11.73	7.56	0.00	19.29	0.03	0.63	7.97
	Apluda mutica	0.00	3.24	0.00	3.24	0.12	0.40	5.04
	Eulophea spp	0.00	0.00	1.50	1.50	0.10	0.14	1.80
	Anogeissus latifolia	0.00	0.00	0.87	0.87	0.16	0.14	1.75
	Wrightia tinctoria	0.00	0.00	0.92	0.92	0.12	0.11	1.43
	Triumfetta rotundifolia	0.00	1.99	0.00	1.99	0.05	0.10	1.22
	Unid. Grass spp	0.00	0.00	0.62	0.62	0.10	0.06	0.74
	Barleria priontis	0.00	0.00	0.60	0.60	0.10	0.06	0.73
	others< 5%				20.32	0.09	1.93	24.29
Summer 05	Karapta*	0.00	0.00	12.20	12.20	1.46	17.77	32.60
	Aristida spp	15.02	3.14	0.00	18.16	0.45	8.21	15.06
	Acacia luecoplea (leaves)	9.48	0.00	0.00	9.48	0.40	3.79	6.96
	Ficus racemosa	0.00	0.00	2.05	2.05	1.58	3.25	5.96
	Syzygium heyneanum	0.00	0.00	5.66	5.66	0.55	3.11	5.71
	Apluda mutica	5.16	3.93	0.00	9.09	0.34	3.09	5.67

	Food item (species)	Acacia Ziziphus A	Anogeissus Mixed B	Riverine C	% bite in diet A+B+C	dry wt/ bite	dry wt in 100 bites	% dry wt. Contribution to actual diet
Summer 05	*Eremopogon foveolatus*	3.00	1.70	0.00	4.70	0.38	1.81	3.31
	Ziziphusmoritiana (leaves)	8.34	1.19	0.00	9.53	0.16	1.56	2.87
	Acacia nilotica (leaves)	9.75	0.00	0.00	9.75	0.06	0.59	1.07
	Capparis saparia	0.00	0.00	2.23	2.23	0.11	0.25	0.46
	others< 5%				20.14	0.55	11.08	20.33
Winter 05	*Acacia nilotica (fruit)*	11.59	0.00	0.00	11.59	2.30	26.59	39.43
	Ziziphusmoritiana (fruit)	16.55	8.14	0.00	24.69	0.74	18.15	26.91
	Acacia luecoplea (fruit)	8.13	0.00	1.20	9.32	0.79	7.37	10.92
	Ziziphusmoritiana (leaves)	16.40	3.86	4.36	24.63	0.15	3.69	5.48
	Acacia catechu (fruit)	0.00	4.07	0.00	4.07	0.41	1.67	2.47
	Ficus benghalensis	0.00	0.00	2.39	2.39	0.35	0.83	1.22
	Aristida spp	0.00	2.81	2.12	4.93	0.16	0.76	1.13
	Paspalidium spp	3.08	0.00	0.00	3.08	0.16	0.48	0.71
	Cymbopogon jwarancusa	0.00	0.00	1.14	1.14	0.16	0.18	0.27
	Anogeissus latifolia	0.00	0.00	1.20	1.20	0.12	0.14	0.21
	others< 5%				14.27	0.53	7.58	11.24

Cattle

Food habits of cattle are shown in **Table 7**. The seasonal diet of cattle across the habitat types are generally composed of grass species like *Heteropogon contorious*, *Eremopogon foveolatus* and *Apluda mutica.* The major dietary contribution was made by grass species, though browse contribution to the diet was significant compare to buffalos. Food habit of cattle was relatively more generalized during monsoon.

Table 7: Food Habits of cattle during Different Seasons

Season	Food item (species)	Acacia *Ziziphus*	Anogeissus mixed	Riverine	% Bite in diet	Dry wt/ bite	Dry wt in 100 bites	% dry wt. Contribution to actual diet
Winter 05	*Heteropogon contorius*	0.00	27.17	0.00	27.17	1.91	51.89	47.83
	Eremopogon foveolatus	0.00	3.39	0.00	3.39	3.18	10.76	9.92
	Ziziphusmoritiana (leaves)	10.18	0.00	0.00	10.18	0.97	9.83	9.06
	Ziziphusmoritiana (fruit)	10.09	0.00	0.22	10.31	0.79	8.15	7.51
	Themeda cymbaria	0.00	4.17	0.00	4.17	1.16	4.83	4.45
	Acacia luecoplea (fruit)	5.00	0.00	0.00	5.00	0.96	4.80	4.42
	Acacia nilotica (leaves)	7.13	0.00	0.00	7.13	0.34	2.39	2.20
	Aristida spp	0.00	2.52	1.03	3.56	0.60	2.13	1.97
	Apluda mutica	0.00	0.00	0.56	0.56	1.69	0.95	0.87
	Heteropogon triticeous	0.00	0.00	0.40	0.40	1.28	0.52	0.47
	Ziziphusoenoplia	0.00	0.00	0.22	0.22	0.93	0.21	0.19

	Food item	Acacia *Ziziphus*	Anogeissus mixed	Riverine	% Bite in diet	Dry wt/ bite	Dry wt in 100 bites	% dry wt. Contribution to actual diet
Winter 05	*Leucas cephalotes*	0.00	0.00	0.40	0.40	0.48	0.19	0.17
	others < 5%				9.96	1.19	11.84	10.91
Summer 05	*Eremopogon foveolatus*	0.00	12.41	0.00	12.41	2.32	28.79	26.41
	Aristida spp	4.97	7.16	0.00	12.14	1.35	16.32	14.97
	Apluda mutica	0.00	6.52	0.00	6.52	2.37	15.43	14.15
	Saro*	0.00	5.83	0.00	5.83	1.94	11.31	10.38
	Wrightia tinctoria	6.03	0.00	0.96	6.99	1.26	8.81	8.08
	Bauhmia racemosa	3.14	0.00	0.00	3.14	1.58	4.95	4.54
	Ziziphusmoritiana (leaves)	3.32	0.00	2.01	5.33	0.91	4.83	4.43
	Anogeissus latifolia	2.09	0.00	0.00	2.09	1.41	2.94	2.70
	Tamarindus indica	0.00	0.00	3.53	3.53	0.74	2.60	2.38
	Terminalia crenulata	0.00	0.00	0.59	0.59	1.28	0.76	0.70
	Syzygium heyneanum	0.00	0.00	1.02	1.02	0.64	0.65	0.60
	Barleria prionitis	0.00	0.00	0.65	0.65	0.54	0.35	0.32
	Holptelia iniegrifolia	0.00	0.00	0.96	0.96	0.31	0.29	0.27
	others < 5%				8.59	1.28	10.98	10.07
Monsoon 05	*Eremopogon foveolatus*	11.25	15.64	0.12	27.01	0.90	24.31	51.74
	Apluda mutica	2.79	14.45	0.50	17.74	0.50	8.80	18.74
	Leucas cephalotes	3.64	2.96	0.56	7.17	0.46	3.33	7.09
	Saro*	2.63	0.00	0.00	2.63	0.71	1.87	3.99
	Helectere isora	3.00	0.00	0.00	3.00	0.49	1.47	3.12
	Boswelia serrata	0.00	2.83	0.00	2.83	0.49	1.38	2.93
	Heteropogon contorius	2.23	0.00	0.00	2.23	0.24	0.53	1.14
	Aristida spp	2.96	0.00	0.13	3.09	0.16	0.49	1.04
	Pupalia lappcea	0.00	2.59	0.15	2.74	0.18	0.48	1.02
	Triumfetta rotundifolia	0.00	0.00	0.12	0.12	0.25	0.03	0.06
	others < 5%				9.81	0.44	4.29	9.13
Winter 06	*Apluda mutica*	6.21	12.84	0.00	19.05	0.61	11.66	29.29
	Aristida spp	16.39	4.90	0.50	21.79	0.43	9.35	23.47
	Eremopogon foveolatus	0.00	3.05	0.00	3.05	1.20	3.66	9.19
	Cymbopogon jwarancusa	0.00	4.95	0.47	5.42	0.52	2.83	7.09
	Leucas cephalotes	3.22	5.35	0.44	9.02	0.22	2.01	5.05
	Paspalidium spp.	4.07	0.00		4.07	0.43	1.74	4.37
	Dicanthium annulatum	0.00	0.00	0.48	0.48	0.54	0.26	0.64
	Iseilema anthephroides	0.00	0.00	0.42	0.42	0.53	0.22	0.55
	Helecteres isora	0.00	0.00	0.40	0.40	0.53	0.21	0.54
	Ischaemum pilosum	0.00	0.00	0.46	0.46	0.40	0.18	0.46
	Barleria prionitis	0.00	0.00	0.31	0.31	0.39	0.12	0.31
	others < 5%				14.62	0.52	7.58	19.04
Summer 06	*Ziziphusmoritiana*	10.49	0.00	4.51	15.01	1.26	18.84	17.22
	Apluda mutica	0.00	13.11	0.00	13.11	1.33	17.43	15.92
	Anogeisus latifolia	0.00	3.74	5.60	9.34	0.93	8.65	7.90
	Aristida spp	0.00	7.72	0.00	7.72	0.98	7.55	6.90
	Achyranthus aspera	6.56	0.00	0.00	6.56	0.97	6.37	5.82
	Nadi*	0.00	0.00	5.56	5.56	1.10	6.12	5.60
	Tamarindus indica	0.00	0.00	8.58	8.58	0.71	6.06	5.54

Summer 06	*Food item*	Acacia *Ziziphus*	Anogeissus mixed	Riverine	% Bite in diet	Dry wt/ bite	Dry wt in 100 bites	% dry wt. Contribution to actual diet
	Eremopogon foveolatus	2.01	0.00	0.00	2.01	1.93	3.88	3.54
	Ziziphusoenoplia	0.00	0.00	3.85	3.85	0.97	3.74	3.41
	Wrightia tinctoria	2.31	0.00	0.00	2.31	0.74	1.71	1.56
	Rangari*	0.00	0.00	2.83	2.83	0.58	1.63	1.49
	Capparis saparia	3.10	0.00	3.18	6.28	0.16	1.02	0.94
	others < 5%				27.23	0.97	26.44	24.16

Buffalo

Food habits of buffalo are shown in **Table 8**. The buffalo diet was largely composed of grass species like *Apluda mutica*, *Heteropogon contorious* and *Eremopogon foveolatus.* The major contribution was made by 3-4 food items only and rest food items supplemented the diet. During monsoon buffalo diet was more diverse like chital and buffalo. Buffalos are by and large grazer as their diet chiefly comprises grass species.

Table 8: Food Habits of Buffalo during Different Seasons

Season	Food item (species)	Acacia *Ziziphus* A	Anogeissus mixed B	Riverine C	% bite in diet A+B+C	dry wt/ bite	dry wt in 100 bites	% dry wt. Contribution to actual diet
Winter 05	*Heteropogon contorius*	21.02	0.00	0.00	21.02	2.94	61.69	42.78
	Aegle marmelos	0.00	23.83	0.00	23.83	0.98	23.23	16.11
	Dichrostachys cinerea (fruit)	0.00	3.25	0.34	3.59	3.68	13.18	9.14
	Saro*	0.00	4.86	0.00	4.86	2.12	10.29	7.13
	Aristida spp	11.31	0.00	0.00	11.31	0.81	9.16	6.35
	Ziziphusmoritiana	1.66	4.30	1.11	7.07	0.86	6.08	4.22
	Paspalidium spp.	0.00	0.00	0.54	0.54	0.03	0.01	0.01
	others <5%				10.42	1.97	20.57	14.26
Summer 05	*Apluda mutica*	1.99	24.24	1.22	27.44	2.77	76.01	47.97
	Aristida spp	6.62	11.69	0.00	18.31	1.58	28.93	18.26
	Eremopogon foveolatus	0.00	6.82	0.00	6.82	2.83	19.26	12.15
	Acacia nilotica	3.09	0.00	0.00	3.09	1.45	4.48	2.83
	Ziziphusmoritiana	4.39	0.00	0.00	4.39	0.92	4.04	2.55
	Anogeissus latifolia	2.00	0.00	0.00	2.00	1.44	2.88	1.81
	Acacia catechu (leaves)	2.21	0.00	0.00	2.21	1.08	2.37	1.50
	Ziziphus oenoplia	3.79	0.00	0.00	3.79	0.62	2.35	1.48
	Wrightia tinctoria	2.08	0.00	0.55	2.63	0.65	1.71	1.08

	Food name (Species)	Acacia *Ziziphus* A	Anogeissus mixed B	Riverine C	% bite in diet A+B+C	dry wt/ bite	dry wt in 100 bites	% dry wt. Contribution to actual diet
Summer 05	*Terminalia crenulata*	0.00	0.00	0.87	0.87	1.93	1.67	1.05
	Capparis saparia	0.00	0.00	0.90	0.90	1.60	1.44	0.91
	Heteropogon triticeous	0.00	0.00	0.43	0.43	2.02	0.88	0.55
	Cymbopogon martinii	0.00	0.00	0.42	0.42	1.60	0.67	0.42
	Bauhmia racemosa	0.00	0.00	0.33	0.33	1.60	0.53	0.33
	others <5%				7.04	1.60	11.27	7.11
Monsoon 05	*Apluda mutica*	4.18	21.33	0.28	25.80	0.79	20.41	38.55
	Eremopogon foveolatus	3.99	5.62	0.41	10.02	1.59	15.91	30.05
	Aristida spp	1.46	6.44	0.15	8.05	0.27	2.18	4.12
	Saro*	1.34	0.00	0.00	1.34	1.61	2.16	4.09
	Leucas cephalotes	1.97	0.00	0.30	2.27	0.76	1.72	3.25
	Pupalia lappcea	0.96	0.00	0.00	0.96	0.33	0.32	0.60
	Helectere isora	0.00	0.00	0.33	0.33	0.91	0.30	0.57
	Bauhmia racemosa	0.00	0.00	0.13	0.13	0.93	0.12	0.23
	others <5%				12.77	0.77	9.81	18.53
Winter 06	*Eremopogon foveolatus*	0.00	10.78	0.00	10.78	3.49	37.58	31.07
	Aristida spp	4.15	11.32	0.00	15.46	1.38	21.28	17.59
	Apluda mutica	0.00	7.90	0.00	7.90	1.39	10.99	9.09
	Cymbopogon jwarancusa	4.32	3.17	0.00	7.49	1.10	8.21	6.79
	Surwali*	0.00	3.17	0.00	3.17	1.73	5.47	4.52
	Erogrostis Spp	4.28	0.00	0.00	4.28	1.27	5.44	4.50
	Doliu*	3.38	0.00	0.00	3.38	1.27	4.29	3.55
	Helectere isora	0.00	0.00	1.42	1.42	1.27	1.80	1.49
	Achyranthus aspera	3.67	0.00	0.00	3.67	0.33	1.19	0.99
	Barleria prionitis	0.00	0.00	0.67	0.67	1.27	0.85	0.70
	Ischaemum pilosum	0.00	0.00	0.64	0.64	1.27	0.81	0.67
	Dicanthium annulatum	0.00	0.00	0.63	0.63	1.27	0.79	0.66
	Iseilema anthephroides	2.25	0.00	0.00	2.25	0.33	0.73	0.60
	Jambudiyu*	0.00	0.00	0.55	0.55	1.27	0.70	0.58
	Leucas cephalotes	0.00	0.00	0.70	0.70	0.52	0.37	0.30
	Wrightia tinctoria	0.00	0.00	0.54	0.54	0.59	0.32	0.26
	others <5%				15.85	1.27	20.12	16.64
Summer 06	*Apluda mutica*	7.23	9.57	1.24	18.04	1.59	28.74	23.32
	Eremopogon foveolatus	0.00	9.32	0.00	9.32	2.12	19.78	16.05
	Aristida spp	3.61	10.82	0.00	14.43	1.23	17.73	14.39
	Ziziphusmoritiana (leaves)	8.61	0.00	1.56	10.17	1.58	16.09	13.05
	Cymbopogon jwarancusa	0.00	5.80	0.00	5.80	1.42	8.21	6.66
	Cymbopogon martini	0.00	2.08	0.00	2.08	2.72	5.66	4.59

Summer 06

Food name (Species)	Acacia *Ziziphus* A	Anogeissus mixed B	Riverine C	% bite in diet A+B+C	dry wt/ bite	dry wt in 100 bites	% dry wt. Contribution to actual diet
Themeda cymbaria	0.00	2.83	0.00	2.83	1.59	4.50	3.65
Tamarindus indica	2.64	0.00	0.46	3.11	1.33	4.13	3.35
Malvelo*	1.75	0.00	0.00	1.75	1.36	2.38	1.93
Anogeissus latifolia	0.00	0.00	1.80	1.80	1.25	2.26	1.84
Rangari*	0.00	0.00	1.43	1.43	0.94	1.34	1.09
Capparis saparia	3.16	0.00	1.56	4.72	0.18	0.86	0.70
Terminalia crenulata	0.00	0.00	0.36	0.36	1.36	0.49	0.40
Nadi*	0.00	0.00	0.44	0.44	0.87	0.38	0.31
others <5%				7.86	1.36	10.70	8.68

Though chital and livestock had similar habitat preferences for foraging, however, their diet overlap was minimal (see diet niche overlap) suggesting that the potential for direct competition between chital and livestock was small. The maximum potential for competition exists in winters when both livestock and chital build up their body reserves to face the resource lean summer. In times of extreme drought both livestock and chital may show plasticity in their diet to meet the limited supply and there is a possibility of a greater diet overlap resulting in competition under such situations.

Ungulate and Chital Density Estimates

The results of ungulate density estimates of Gir PA as a whole and for each different ecological zone are given in the **Table 9**. Simultaneously chital density was also computed for the same areas as shown in the **Table 9A**. The result indicates a density trend in the Gir PA reflecting the ecological conditions changing from west to eastward. The annual rainfall pattern changes from Gir west to Gir east i.e. Gir west receives higher rain fall than Gir east hence, habitats in Gir west are more productive than the National Park and Gir east which in turn reflected by ungulate density. There is no direct effect of livestock presence on Ungulate density was observed as Gir west holds a number of Maldhari settlements whereas National Park is devoid of any human interference. Ungulate population is directly responding to the prevailing ecological conditions then livestock grazing.

Table 9: Wild Ungulate Density (per km^2) Estimates of Gir PA

	Density	SE	Effort	N	DCV
Gir PA	51.86	7.614	223.27	79	14.68
Gir west	62.01	14.10	67.28	24	22.70
Gir central	55.68	11.49	74.82	26	20.64
Gir east	35.92	9.23	84.28	29	25.64

Table 9A: Chital Density (per km^2) Estimates of Gir PA

	Density	SE	Effort	N	DCV
Gir PA	46.17	7.3	223.27	79	15.98
Gir west	49.48	11.7	67.28	24	23.97
Gir central	44.47	13.38	74.82	26	30.09
Gir east	30.30	9.65	84.28	30	31.87

Monitoring of Ness

INTRODUCTION:

The most important human component of the Gir ecosystem has been the population of resident Maldharis. Maldharis are mixed pastoral communities who have been an integral part of Gir forest for centuries. They live in small pastoral settlements called Nesses scattered all over the Gir forest. There are 54 nesses with approximately 3900 human population and a cattle population of around 15000 (Pati 2000). In addition there are 14 settlement villages and 97 peripheral revenue villages around Gir. Maldharis are used to a nomadic lifestyle and live on a primarily vegetarian diet, thereby posing little direct threat to wild animals. Sale of dairy products has always been the mainstay of their economy. Their domestic livestock comprise mainly of buffaloes and cattle and occasionally of camels and horses.

Predation on domestic livestock by carnivores was formerly considered to be an aberrant form of behaviour (Finn 1929). Guggisberg (1975), however, stated that predation on domestic livestock by large carnivores is an ancient conflict. Predation on domestic livestock by Asiatic lion (*Panthera leo persica*) in Gir forest has been reported by many authors. Joslin (1973) reported that an analysis of 480 lion scats revealed that 75-83% of the lion's diet was comprised of livestock. Sinha (1987) reported that about 48-52% of the lion's diet was comprised of domestic livestock while Chellam (1993) found that about 25% of the lion's diet to be domestic livestock. Srivastav (1997) pointed out the easy availability of livestock and restricted mobility of the livestock as the two main reasons for lions making livestock kills. Dharaiya *et al.*. (2005) studied the seasonal changes in the food habits of the Asiatic lion and leopard (*Panthera pardus fusca*) in the Gir protected area from 332 lion scats and 366 leopard scats and observed domestic livestock to be the most preferred prey for lions during monsoon whereas the leopard prefer chital throughout the year followed by langurs in winter and summer and livestock in monsoon. The study showed that the infiltration of domestic livestock in the sanctuary during monsoon affects the food habits of both the large cats. Depredation of livestock by large or small carnivores has been well documented globally by many authors (Bauer and de Iongh 2005, Kolowski and Holekamp 2005, Madhusudan 2003, Morsbach 1987,

Creekmore 1992, Hoogesteijn *et al.* 1992, Oli 1991, Dwivedi 1982, Krukk 1980, Rabinowitz 1986, Mishra 1997).

Herein we estimate the contribution of domestic livestock to the endangered lion's diet and evaluate the impact of this predation on the economy of the local community—the Maldharis.

Methodology:

Among 54 nesses in the Gir forest, six nesses were selected within the Intensive Study Area of Sanctuary (East). Monitoring of these nesses was carried out for the period of April 2005 to July 2006. The methods adopted for the monitoring were as follows:

1. Estimating availability and demographic structure:

For this purpose, a total head count of the livestock staying in the nesses was carried out during evening when all livestock were back at the ness as well as through interviews of Maldharis. Data regarding demographic structures of the livestock belonging to each Maldhari was recorded. All the cattle and buffaloes were classified into young calf, juvenile, sub-adult and adult for both the sexes. Both adult female cattle and buffalo were classed into a) milk yielding, b) temporarily dry but in reproductive age groups and c) non-productive, to understand the economic value of the livestock for the Maldhari. Mortality (both natural and predation) patterns of the livestock were also recorded.

Density of the livestock was calculated on the basis of average foraging area calculated after generating a buffer consisting of the foraging radius around each study ness. As there is seasonal migration of Maldharis from outside villages during monsoon, livestock population and demographic structure were estimated seasonally.

2. Estimating predation, livestock mortality and carnivore scavenging:

Study Nesses were monitored on a weekly to monthly basis for collecting data on livestock deaths. In each Ness one to two Maldharis were provided data performas and appropriate incentives to record all deaths of livestock. Data from each livestock death were gathered on various parameters such as species, age-sex and productivity classes,

estimated weight of the individual, name of the owner and approximate monetary value of the individual. Livestock that died due to natural causes were dumped outside the Nesses. Data were recorded if these carcasses were scavenged, by which species (Lion/Leopard/Hyaena etc.), and what portion of the dead livestock were consumed. For all predation events, the time, location, number and species of the carnivore were recorded along with a brief description of the event. The monetary value of the livestock was assigned on the basis of the livestock species, gender, age group and productivity class (**Table: 10**).

A one way Analysis of Variance was performed on number of the livestock predated by lions with seasons as the main effects to detect seasonal variation in lion predation pressure.

Table: 10 Monetary Values (Rs) for various age-sex-productivity categories of livestock used for analysis

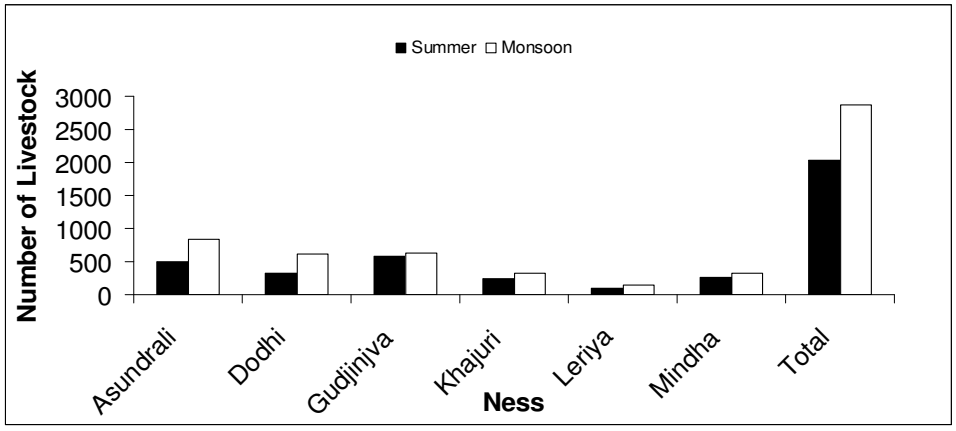
Age group	**Approximate Average Market Value (Rs) used for computing Financial Losses**	
	Buffalo	**Cattle**
Young male	300	200
Young female	500	250
Juvenile male	500	250
Juvenile female	1,000	500
Sub-adult male	1,000	500
Sub-adult female	3,000	1,500
Milk yielding adult female	10,000	5,000
Pregnant (litter productive)adult female	6,000	3,000
Non-productive adult female	2,000	500
Adult reproductive male	5,000	2,000
Non reproductive adult male (old bullocks\bulls)	1,000	500

Results:

Buffaloes are the dominant livestock of the nesses (77.7%) followed by cattle and other livestock including camel and horse. The observed seasonal differences between the number of livestock reflects immigration of Maldharis from outside Gir during monsoon in nesses like Dodhi, Asundrali and Gudjinjva while for the other nesses it is only the stock purchase and recruitment of new individuals (**Figure: 50**).

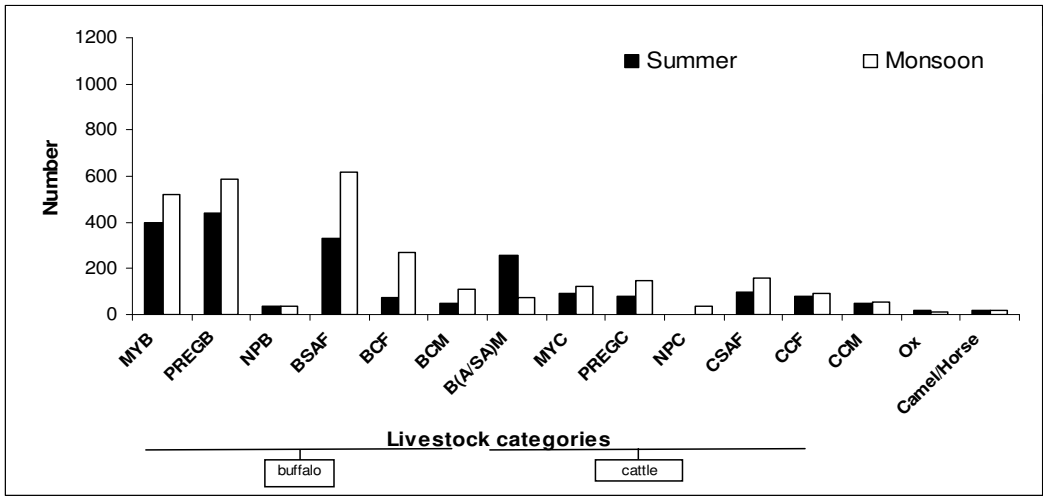
The area coverage by foraging livestock from the six study nesses was 68 sq km (Range 62-74 sq km). The density of the livestock was estimated to be 30/sq km (range 27/sq km to 33/sq km) during summer and 42/sq km (range 39/sq km to 46/sq km) during monsoon within the study area.

Figure 50: Seasonal trend of livestock population in each ness during summer and monsoon



Maximum number of livestock was found to be composed of buffalo followed by cattle (**Figure: 51**).

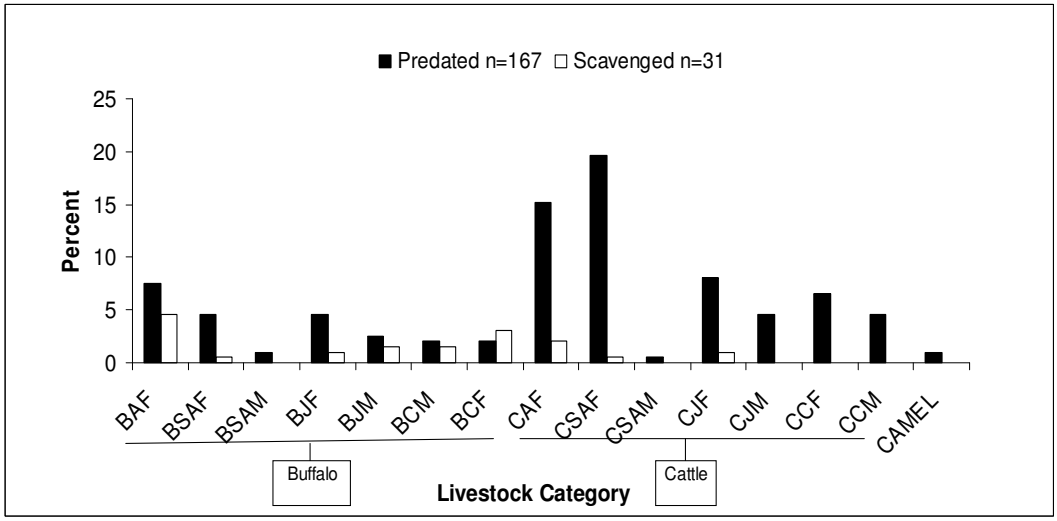
Figure 51: Seasonal population structure of livestock within the intensive study area encompassing 6 ness sites in Gir (East) [2005-2006]



MYB- milk yielding buffalo, PREGB- pregnant buffalo, NPB- non productive buffalo, BSAF- buffalo sub adult female, BCF- buffalo calf female, BCM- buffalo calf male, B(A/SA)M- buffalo adult or sub adult male, MYC- milk yielding cow, PREGC- pregnant cow, NPC- non productive cow, CSAF- cow sub adult female, CCF- cow calf female, CCM- cow calf male.

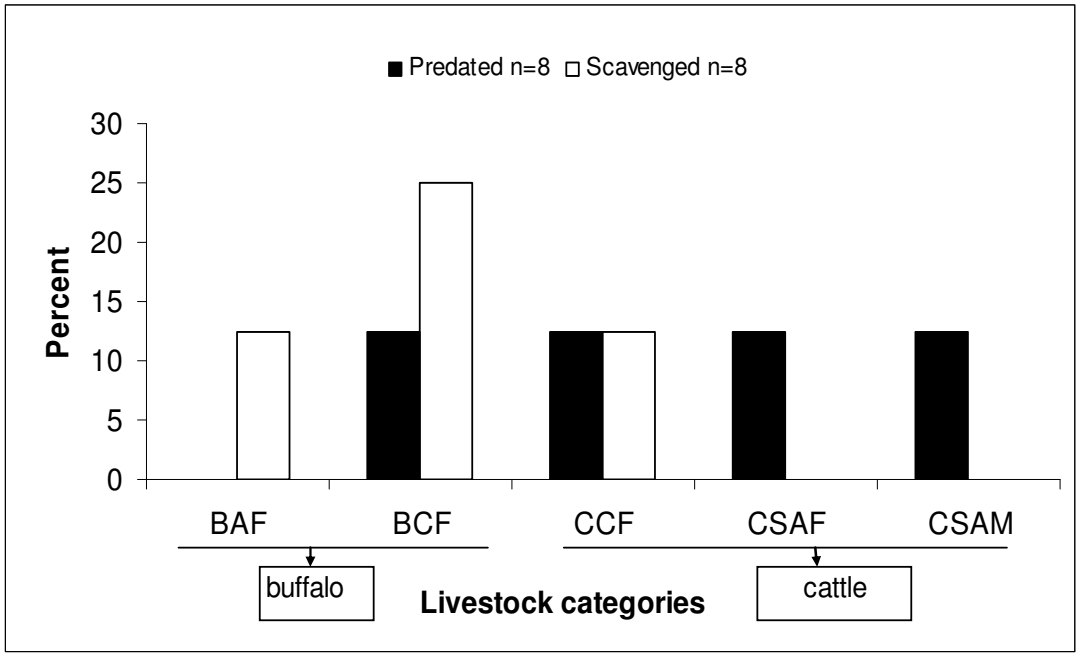
It was evident from the study that of a total of 167 predation events recorded, lions were observed to predate predominantly on sub-adult cows (19.6%) followed by adult cows (15%) (**Figure: 52**). More scavenging events were recorded on adult female buffaloes reflecting a higher carcass availability of this livestock category in the study area.

Figure 52: Percent of the livestock killed and scavenged by lions



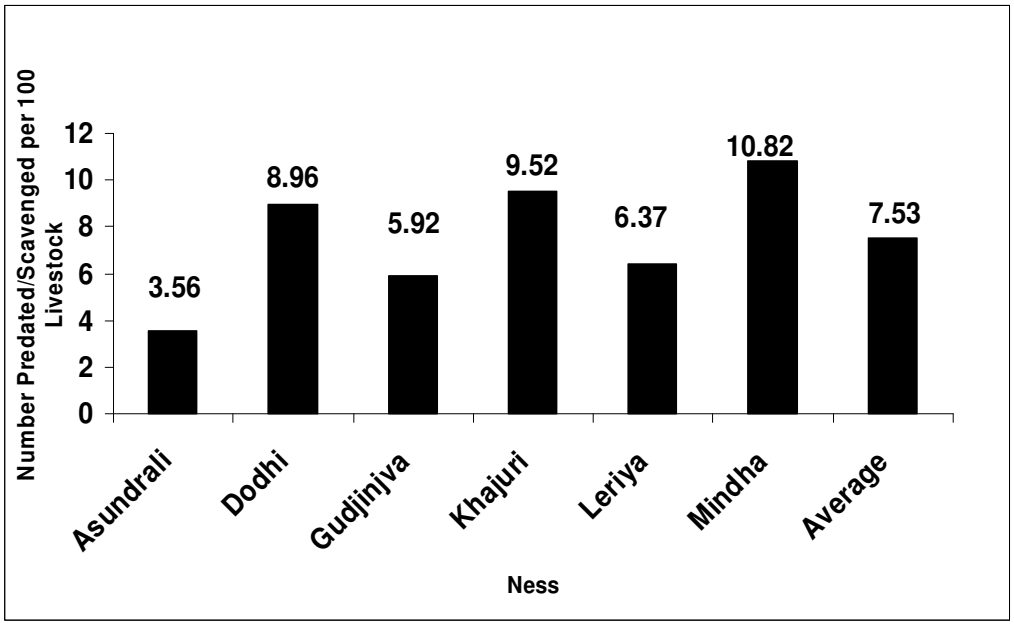
On the other hand leopards were observed to predate on livestock within the range of their own weights. Predation by leopards was similar on buffalo female calf, female cattle calf, sub-adult male cattle and sub-adult female cattle (12.5%). Adult buffaloes were not observed to be killed by leopard while scavenging of the carcass of adult buffalo by leopard was high (**Figure 53**).

Figure 53: Livestock killed and scavenged by leopards.



There seems to be no relation between the total population of livestock in a ness and use by large carnivores. The location of ness likely plays a more significant role in its livestock vulnerability to predation. Even though Asundrali had the maximum livestock population, livestock of Mindha Ness and Dodhi Ness were more heavily utilized by large carnivores. (**Figure: 54**).

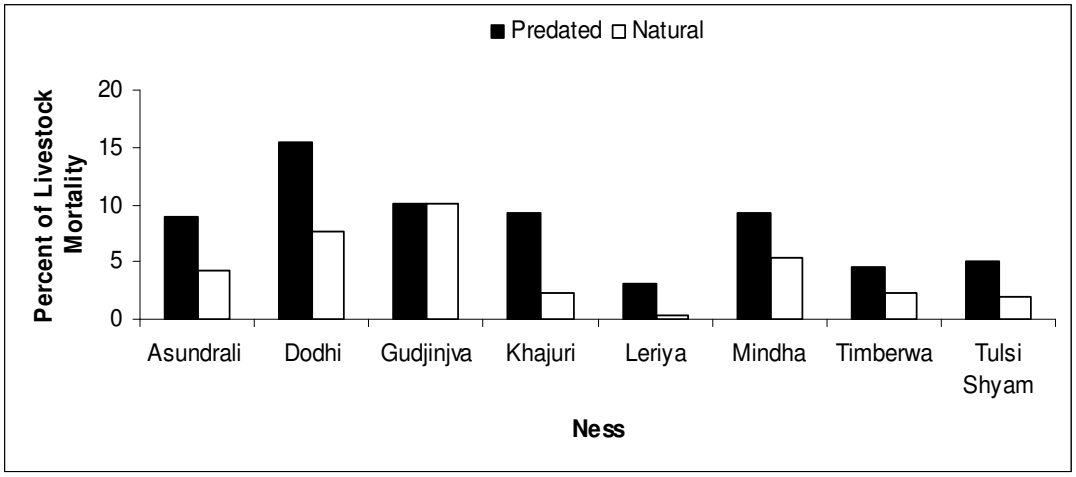
Figure 54: Contribution of livestock to large carnivores (Lions/Leopards) from various study Nesses



Lions were found to utilize the livestock from Dodhi, Mindha and Khajuri Nesses more than their availability while under utilizing the livestock in the Nesses like Asundrali and Gudjinjva. In Leriya the livestock were found to be utilized in accordance to their availability by lions (chi square value=21.45, df=5, p value=0.0006).

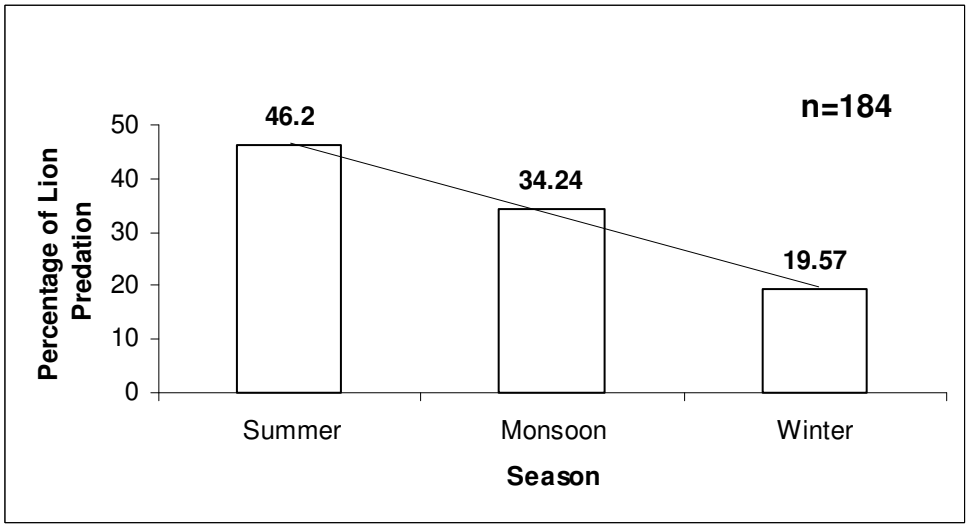
Apart from the predation by the carnivores, natural death of the livestock due to some disease or other causes plays an equally important role in regulating livestock numbers in the Nesses. Dodhi ness had the highest percentage of predation compared to other nesses while Gudjinjva had equal percentage of livestock mortality caused by predation and other causes. Leriya had highest percentage of livestock killed compared to natural deaths (**Figure: 55**).

Figure 55: Mortality of Livestock in the Study Nesses (2005-2006)



Lion predation on livestock also shows a seasonal pattern [ANOVA, DF 2, 15, F=3.9, p=0.04] (**Figure: 56**). The predation on livestock is highest in summer followed by monsoon and winter. This reflects the infiltration of livestock inside the park during the middle to late summer thereby increasing their availability to lions. The Maldharis who came from the outside leave the forest after Deepavali thereby decreasing the number of livestock vulnerable to predation by lion.

Figure 56: Seasonal variations in the livestock predation pattern by lion

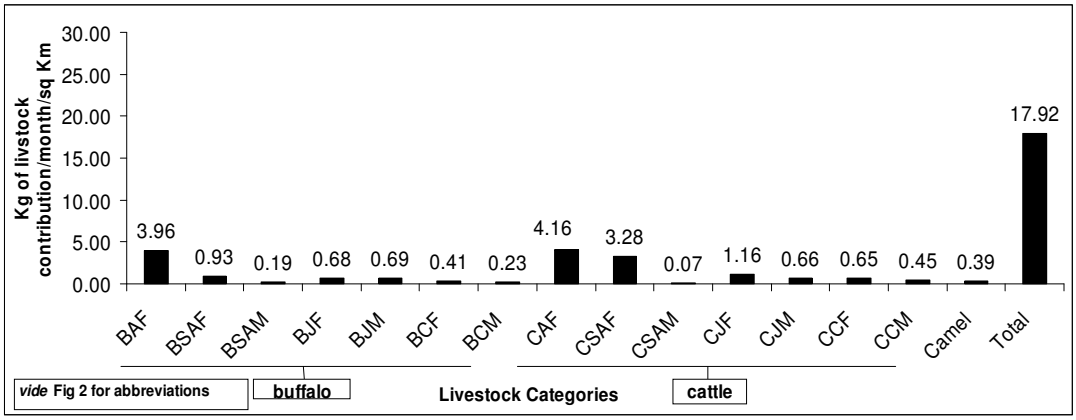


Another reason for high livestock predation during summer may also be the poor condition of the livestock in summer. As most of the non-productive livestock were left behind in the herd Maldharis were likely less vigilant to avoid predation.

Moreover, lion density likely declined during monsoon in Gir forest as several lions moves out in the peripheral areas due to increase in cover in agricultural fields and insect harassment in the forest. This accounts for less predation during monsoon even though the livestock numbers are highest in monsoon.

Livestock contributes a large amount of biomass to the lion's diet. Livestock were estimated to contribute 19,500 Kg of biomass to the lion's diet for the period of 16 months. This translates into approximately 1219 Kg per month in an area of 68 Sq Km. (**Figure: 57**).

Figure 57: Contribution of livestock to lion's diet in terms of biomass.

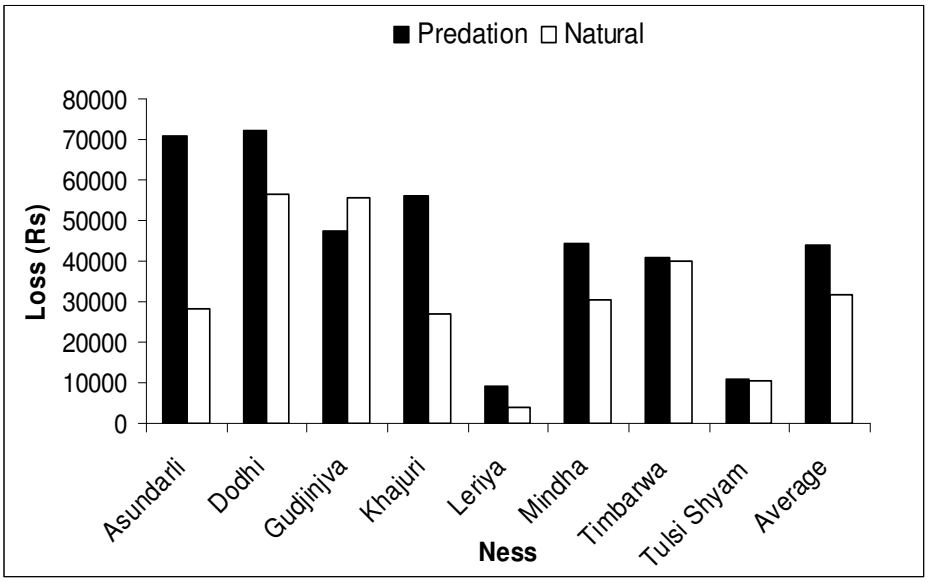


As per as the density estimation of lions encompassing the study area, the total number of lions using the study area was estimated to be 11. With the requirement of 2,672 Kg of food per lion per year (Joslin, 1973), total requirement of the lion population would be 39,184 kg of food biomass for the study period of 16 months. Of this approximately 50% was composed of livestock out of which 83% was from livestock predation.

Maldharis incur a substantial amount of financial loss from the depredation of livestock. All the nesses except Gudjinjva faced more financial loss due to predation rather than from natural death of livestock. Dodhi ness incurred the maximum loss from the natural death as well as predation of livestock by lions. In this analysis the

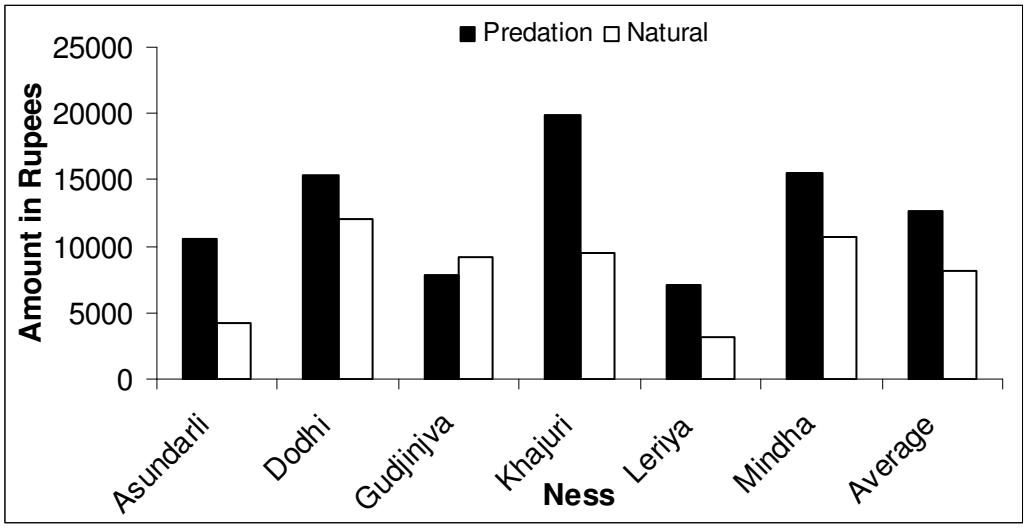
livestock of Tulsi Shyam Temple Trust and the revenue village of Timbarwa were also included. (**Figure: 58**).

Figure 58: Comparative Financial Loss due to livestock mortality by Lion/Leopard predation and other natural causes in the study nesses



In order to get the actual scenario of loss faced by each ness against the stock of their livestock, financial loss per hundred livestock was calculated. The average financial loss per hundred livestock was calculated to be Rs 20,830 (Rs 12,688 from predation and Rs 8,142 from Natural deaths) with Khajuri ness having the highest loss and Leriya having the lowest. (**Figure: 59**)

Figure 59: Monetary losses due to mortality of livestock by predation and other causes within the study nesses



Since predation on livestock is at least partially additive and non compensatory form of mortality to natural causes it significantly adds on to the financial loss incurred by Maldharis. The forest department has a compensation scheme for predated livestock which has recently been revised (M.L. Sharma *pers comm.*) to reflect market values of livestock. A mechanism of streamlining the procedural paperwork for quick authentication and payment of compensation would greatly alleviate the financial burden on the Maldhari as well as help in fostering their continued tolerance to carnivore predation.

In the case of lions, livestock forms an important component of their diet through predation and scavenging. Removal of this food source is likely to have a significant effect on lion density, pride size and structure and demography.

FUTURE WORK PLAN

As mentioned in the introduction the full array of the project objectives could not be addressed due to

A) Delays in obtaining radio collaring permits and subsequent delays in conducting the field collaring exercise
B) Technology failure of HABIT Research collars for satellite uplink and GPS robustness.

Majority of remaining project objectives are dependent on VHF, satellite, and GPS collars. These are; the study of peripheral lion population (ranging pattern, habitat use, demography and predation ecology), and the study of lion dispersal from within and outside the PA. A minimum timeframe of 4 years is required to address this objective. With 2-3 Satellite/GPS/VHF collars deployed in Savarkundla-Palitana, Girnar, and coastal population, and a minimum of 5-6 sub adult males and 4-5 sub-adult females to be collared for addressing the dispersal objective. MoEF has granted approval for 20 lions of which 3 males have been radio-collared. The already collared lions would need to be monitored for data on ranging, social organization, land tenure, and habitat use for a period of 3 years (average battery life of currently deployed radio-collars).

The other objectives that need to be addressed are the long term monitoring of vegetation plots and exclosures for evaluating the trends in vegetation caused due to wild ungulate and livestock grazing.

We are in the process of high resolution mapping of Gir landscape to better understand the factors responsible for animal distribution patterns and land use patterns. This objective requires another 1-2 years to complete. Some progress has been made in identifying and developing genetic markers for population estimation, however, this component requires more time.

To address the above objectives WII requests a four year extension of the research project (April 2007 to March 2011).

Role of the Researchers:

Four researchers of Wildlife Institute of India have worked on this project. Role of the different researchers were:

Ms V. Meena (2002 onwards): She has been engaged with collecting data on the demography and social organization of lions from west and central Gir. Besides, she has been responsible for monitoring radio-collared lions.

Shri Chittaranjan V. Dave (2004 onwards): He has worked on the ungulate livestock interaction in Gir (East) along with the estimation of ungulate density in the entire Gir Protected Area. He has established and monitored the permanent vegetation plots. He was also assigned to collect the ground validation data for satellite mapping.

Shri Kartikeya Singh Chauhan (2004- 2005) and Shri Kausik Banerjee (2005 onwards) have worked on monitoring of the nesses for predation data and livestock counting in Gir (East). They also started reconnaissance survey of the satellite lion population in the Savar Kundla Taluka of Amreli district and Palitana Taluka of Bhavnagar district.
The researchers have been working as a team and often sharing responsibility of each of the tasks as and when required.

LITERATURE CITED

- **Ables, D. and Fuchs (1974).** Conclusions. In: The Axis Deer in Texas: Ernest D. Ables (ed). The Caesar Kleberg Research Program in Wildlife Ecology. 79-83 pp.

- **Ables, D.E. (1974).** Introduction. In: The Axis deer in Texas. Ernest D. Ables (ed) The Caesar Kleberg Research Program in Wildlife Ecology.Altmann.

- **Abrams P. (1980).** Some comments on measuring niche overlap. *Ecology.* **Vol.61** pp 44-49

- **Andersons, D. R. Laake, B., Crain, B. and Burnham, K. (1979)** Guidelines for transect sampling of biological population. *J. Wildl. Manag*. Vol. **43 (1)**: 71-79

- **Badoni V., Jhala, Y.V., Q.Qureshi (2005).** Lion Monitoring System Version 1.0. Software for long term monitoring of lions. Wildlife Institute of India, Dehra Dun.

- **Bauer, H. & Detnogh, H.H., (2005).** Lion (*Panthera leo*) home ranges & livestock conflicts in Waza National Park, Cameroon. *African Journal of Ecology*, 43, 208-214

- **Bertram, B.C.R.** 1975. The social system of lions. *Sci. Am*. 232:54-65.

- **Berwick, S.H. & Jordan, P.A. (1971)**. First report of the Yale-Bombay Natural History Society studies of wild ungulates at the Gir Forest, Gujarat, India *J. Bombay. Nat Hist. Soc.* 68: 412-423.

- **Berwick, S. (1974).** The community of wild ruminants in Gir ecosystem. Ph. D. Dissertation, Yale University, U.S.

- **Berwick, S. (1976).** The Gir Forest: An Endangered Ecosystem. *American Scientist*, 64, 28-40

- **Bhatnagar, (1997).** Ranging and habitat utilization by the Himalayan ibex (*Capra ibex sibirica*) in Pin Valley National Park. Ph. D. thesis. Saurashtra University, Rajkot. India. 114 pp.

- **Buckland, S. T., Anderson, A. R., Burnham, K. P. and Laake, J. L. (1993)** Distance sampling: Estimating abundance of biological populations. Champion and Hall, London. Pp.446.

- **Burnham, K. P., Anderson, D. R. and Laake, J. D. (1980).** Estimation of density from line transect sampling of biological population s. in: *Wild. Monograph.* Vol. **72**: 1-2002

- **Changappa, B. U. (1971)** Behavioural adaptability in ungulates with special reference to Chital. Fors. Coll. 61 pp

- **Chavan, S. A. (1993)** Vegetation and wildlife studies in Gir forest. Ph. D. Thesis submitted to M. S. University of Baroda, Vadodara, Gujarat.

- **Chellam, R. (1993).** Ecology of the Asiatic Lion (*P. leo persica*). Ph.D. Thesis submitted to Saurashtra University, Rajkot. Pp170.

- **Creekmore, C. (1992).** The paradox called cougar. National Wildlife, Dec-Jan, 1992. National Wildlife Federation. Washington DC.

- **Dalvi, M.K.** 1969. Gir lion census 1968. *Indian Forester*. **95**: 741-752.

- **Dharaiya, N., Soni, V.C., Singh, M. & Harel, P.P. (2005).** Seasonal Changes in food habits of the Asiatic Lion & Leopard in the Gir Protected Area. Pages 40-43 in Jhala, Y.V., Chellam, R. & Qureshi, Q., (eds), Wildlife Conservation. Research and Management (2005). A technical Publication of the Wildlife Institute of India, Dehradun. RR-05/001

- **Dwivedi, G.D. (1982).** Study of predation on domestic livestock by tigers: a case study. A Diploma Dissertation. Wildlife Institute of India.

- **Eisenberg, J. and Siendensticker (1976)** Ungulates in Southern Asia: A consideration of biomass estimates for selected habitats. In: *Biol. Conser*. 293-308

- **Fenton, L.L.(1908)**. The Kathiawar lion. *J. Bombay. Nat Hist. Soc.* 19: 4-15.

- **Finn, F. (1929).** Sterndale's Mammalia. Thacker & Co. Bombay, India.

- **Fleischner, T. L. (1994).** Ecological costs of livestock grazing in western North America. In: *Conservation Biology* **Vol.- 8**, 629-644pp

- **Guggisberg, C.A.W. (1975).** Wild cats of the World. David and Charles. London

- **H. H. T. Prins, J. G. Grootenhuis and T. T. Dolan (1992)** pp 51-80. Kluwer Academic Publishers, Boston, MA.

- **Hoogesteijn, R., Hoogesteijn, A. Mondolfi, E. (1992).** Jaguar Predation vs. Conservation: Cattle mortality by felines on three ranches in the Venezuelan llanos in mammals as predators, ed. Dunstone, N. & Garman, M.H., *Symposia of Zoological Society of London.*

- **Hurlbert S. H. (1978)** The measurement of Niche overlap and some relatives. *Ecology.* Vol. **59** pp 67-77.

- **Ivlev, V.S. (1961).** Experimental Ecology of the feeding of fishes. Yale University Press. New Haven, Conn.

- **Jarman, P.T. (1974).** The Social Organization of antelope in relation to their ecology. *Behaviour* **48**:216-269.

- **Jhala, Y.V. (1991)** Habitat and population dynamics of wolves and blackbucks in Velavadar national Park, Gujarat, India. Ph. D. Dissertation, Virginia Polytechnic Institute and state University, U.S.

- **Jhala, Y.V. (1997)** Seasonal effects on the nutritional ecology of blackbuck (*Antelopa cervicapra*). *J. of Applied Ecol.* Vol. **34**: 1348-1358 pp.

- **Jhala, Y. V. (2004).** Monitoring of Gir. A technical consultancy report submitted to the Gujarat Forest Department under the GEF – India eco development Program, Wildlife Institute of India, Dehradun 157 pp

- **Jhala, Y., Mukherjee, S., Shah, N., Chauhan K., Dave, C. and Jhala, Y. S. (2004)** Monitoring Lions. In: Y. V. Jhala (ed), monitoring of Gir. A technical report submitted to the Gujarat Forest Department, under the GEF- India ecodevelopment program, Wildlife Institute of India, Dehradun.

- **Jhala, Yadvendardev, Qureshi, Qamar, Buva, Vimal, Sharma, Lekhnath. (1999).** Population estimation of Asiatic lions. *Journal of Bombay Natural Hist. Society*. **96 (1):** 3-15.

- **Joslin, P. (1973).** The Asiatic Lion: A study of Ecology and Behavior. Ph.D. Thesis submitted to the Dept. of Forestry & Natural Resources, University of Edinburgh.

- **Khan, J. A. and Vohra, U. (1992)** Group size and group structure of chital. In: *Mammalia*: Vol. **56**: 4.

- **Khan, J. A. (1993)** Ungulate habitat relationships in Gir Ecosystem and its management. Implications. India Center of Wildlife and Ornithology. Ph. D. Thesis. Saurashtra University, Rajkot, India.

- **Khan, J. A., (1993)** Ungulate – habitat relationships in Gir ecosystem and its management implication. Ph.D thesis submitted to the Centre for Wildlife and Ornithology, Aligarh. 185p

- **Khan J. A. (1995)** Conservation and Management of Gir Lion Sanctuary and National Park, Gujarat, India. In: *Biological Conservation.* Vol. **73.** 183-188

- **Khan, J. A., Chellam, R., Rodgers, W. A. and Johnsingh, A. J. T. (1996)** Ungulate density and biomass in the tropical dry deciduous forests of Gir, Gujarat, India. In: *Journal of Tropical Ecology.* Vol. **12**: 149-162 pp.

- **Kie, J.G. 1994.** Calhome. Forestry Sciences Lab. Fresno, California.

- **Kinnear, N.B. (1920).** The past and present distribution of the lion in South Eastern Asia. *J. Bombay. Nat Hist. Soc.* **27**:33-39.

- **Kolowski, J.J. & Holekamp, K.E. (2005).** Spatial, temporal & physical Characteristics of livestock depredations by large carnivores along a Kenyan reserve border. *www. sciencedirect.com.*

- **Kothari, A., Pande, P. Singh, S. and Variava, D. (1989)** Management of National Parks and Wildlife Sanctuaries in India. A status Report. Indian Institutes of Public Administration, New Delhi. 298 pp.

- **Krebs, C. J. (1989)** Ecological Methodology. New York: Harper Collins.

- **Krukk, H. (1980).** The effects of large carnivores on livestock & animal husbandry in Marsabit district, Kenya, Integrated project in arid lands (IPAL). Technical Report E-4 (ITE Project 675).

- **Laake, J. L., Buckland, S. T., Anderson, D. R. and Burnham, K. P. (1999)** DISTANCE: User's guide. Colorado Co-operative Fish and Wildlife Research Unit. Colorado State University, Fort Collins. Colorado, USA.

- **Lal, J. B. (1989)** India's Forests: Myth and Reality. Natraj Publishers, Dehradun.

- **Linton L. R., Davies R. W., Wrona, F. J. (1981)** Resource Utilization Indices: an Assessment. *J. Anim. Ecol*. **Vol- 50** pp 283-292.

- **Livatis, J. A., Titus, K. and Andorson E. M. (1996)** Measuring vertebrate use of terrestrial habitats and foods. In: T. A. bookhout (ed) Research and management techniques for wildlife habitats. Fifth ed. Revised. The wildlife Society, Bethesda. Md. Pp254-274.

- **Madhusudan, M.D. (2003).** Uneasy Neighbours. Human Resource - use & Large Mammal Conservation in the tropical Forests of Karnataka. India. Ph.D. Thesis submitted to Manipal Academy of Higher Education. Manipal. Pp 128.

- **Major J. T. and Sherburne J. A. (1987)** Interspecific relationships of coyotes, bobcats and red foxes in Western Maine. *J. Wildl. Manag*. Vol-**51** pp 606-616.

- **McDonald R. A., Webbon C. and Harris S. (2000)** The Diet of Stoats (*Mustella erminea*) and Weasels (*Mustella nivalis)* in Great Britain. In: *J. Zool. Lond.* Vol-**252** pp 363-371.

- **Mishra, C. & Rawat, G. S. (1998)** Livestock Grazing and Biodiversity Conservation: Comments on Saberwal. In: *Conservaion Biology*. Vol-**12**, pp 712-714.

- **Mishra, C. (1997).** Livestock depredation by large carnivores in the Indian trans – Himalaya: Conflict perceptions & conservation prospects. *Environmental Conservation.* **24 (4):** 338-343.

- **Mishra, C. (2001)** High altitude survival: conflicts between pastoralism and wildlife in Trans-Himalayas. Ph. D. thesis. Wagenigen University, The Netherlands. 128 pp.

- **Mohr, C.O. (1947).** Table of equivalent populations of North American small mammals. *American Midland Naturalist.* **37**: 223-249.

- **Moosbach, D. (1987).** Cheetah in Namibia. *Cat News*: **6.** IUCN, Switzerland.

- **Noss, R. F. (1994)** Cows and Conservation Biology. In: *Conservation Biology*. **Vol-8**, pp 613-616.

- **Oli, M.K. (1991)** Ecology and conservation of the snow leopard project, Nepal. M.Phil thesis submitted to University of Edinburgh, UK.

- **Packer, C and A.E. Pussey (1997).** Divided we fall: Cooperation among lions. *Scientific American.* 32-39.

- **Packer, C., Pussey, A.E. (1983).** Adaptations to female lions to infanticide by incoming males. *Am. Nat.* **121 (5)** 716-728.

- **Pati, B.P. (2000).** Impact of livelihood practices of Maldhari Tribe on Wildlife Habitat of Gir Protected Area, *Indian Forester.* October 2000. 1120-1127.

- **Pennycuick C. J. & J. Rudnai (1970).** A method of identifying individual lions *Panthera leo* with an analysis of reliability of the reliability of identification. *J.Zool.London* **160**: 497-508

- **Pianka E. R. (1986)** Ecology and Natural History of Desert Lizards. Princeton University Press, Princeton. NJ.

- **Pocock, R.I. (1936).**Lion in Baluchistan. *J. Bombay. Nat Hist. Soc.* **38**, 381-382.

- **Prins, H. H. T. (1992)** The pastoral road to extinction: competition between wildlife and traditional pastoralism in East Africa. In: Wildlife Conservation by Sustainable Use.

- **Rabinowitz, A.R. (1980).** Jaguar predation on livestock. *Wildlife Society Bulletin.* **14:**170-174.

- **Ram Prasad and Bhatnagar, P. (1988)** Grazing in Forests: An ecological liability. In: State forest Department Research Institute, Jabalpur. Report no.25

- **Reynolds R. T. and Meslow E.C. (1984)** Partitioning Food and Niche characteristic of coexisting *Accipiter* during breeding. *Auk*. **Vol.-101** pp 761-779.

- **Rhiny, T. (1960)** A field technique for assessing physical condition of some ungulates. In: *J. Wild. Manage*. Vol**. 24**: 92-94

- **Rongstad, O. and Tester, J. (1969)** Movements and habitat use of White tailed deer in Minnesota. *J. Wild. Manag*. Vol. **33**: 366-379 pp.
- **Saharia, V. B. (1984)** Human dimension in wildlife management: The Indian experience. In: Mc Neely and K. R. Milter (eds.)National Park Conservation and Development. Smithsonian Institute Press.
- **Schaller, G. B. (1967)** The deer and the tiger. University of Chicago Press. USA
- **Schaller, G. (1972).** The Serengeti lion: Univ. Of Chicago, Chicago
- **Schoener T. W. (1970)** Nonsynchronous spatial overlap of lizards in patchy habitats. *Ecology.* Vol. **51** pp 408-418.
- **Sharma, Diwakar & A.J.T. Johnsingh, (1995)**. Impacts of management practices on lion and ungulate habitats in Gir. Protected Area. Willdife Insitute of India. Dehradun 88p.
- **Shea, S., Flynn, B., Marchink, R. and Lewis, J. (1990)** Social behaviour, movement, ecology and food habits of Sambar Deer on St. Vincent. National Wildlife Refuge, Florida. Bulletin no. 25, Tall Timber Research Station, Tallahassee, Florida
- **Singh, H.S. & Khamboj, R.D. (1996).** Biodiversity conservation plan for Gir (A management Plan for Gir Sanctuary & NP) Vol I & Vol II. Forest Department, Gujarat state.
- **Singh, H.S. (1997).** Population dynamics, group structure and natural dispersal of the Asiatic lion *Panthera leo persica*. *J. Bombay Nat.Hist.Society*. **94:** 65-70.

- **Sinha, S.P. (1987).** Ecology of wildlife with special reference to the lion (*Panthera leo persica*) in Gir wildlife sanctuary, Saurashtra, Gujarat. Ph.D. Thesis. Saurashtra University, Rajkot, India. 291p

- **Smith, (1974)** Food Habits. In: The Axis deer in Texas. Ernest D. Ables (ed) The Caesar Kleberg Research Program in Wildlife Ecology. Pp 1-7

- **Soni, V.C. (2000).** Study on the satellitic population of lion around Gir PA. Final report. India eco-development project.

- **Srivastav, A. (1997).** Livestock Predation by Gir Lions & Ecodevelopment. *Tiger paper*. Vol. **24**: No.2 Apr-Jun 1997, Pp 1-5.

- **Thill R. E. and Martin A.Jr (1986)** Deer and Cattle Diet Overlap on Louisiana pine- Bluestem Range. *J. Wlldl. Mang*. Vol-**50** pp 707-713.

- **Voeten, M. M.(1999)** Living with Wildlife: Coexistence of wildlife and livestock in an East African savanna system. Ph.D. Thesis. Wageningen University, Wageningen, the Netherlands.

- **Wallmo, O. C., Jackson, A., Hailey, T. and Carlisle, R. (1962)** Influence of rain on the count of deer pallet groups. *J. of Wildl. Manage*. Vol. 26: **(1)**. 50-55 pp.

- **Wynter-Blyth, M.A. & Dharamakumarsinhji, K.S. (1950).** The Gir Forest and its lions. *J.Bombat.Nat. Hist.Society*. **49(4):** 456-470.

- **Wynter-Blyth, M.A. (1956).** The lion census of 1955. *J.Bombat.Nat. Hist.Society*. **53(4)**: 527-536.