Food Habits and Prey Abundance of Leopard (*Panthera pardus fusca*) in Gir National Park and Wildlife Sanctuary

M. Sc. Dissertation

Department of Wildlife Sciences
Aligarh Muslim University
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By
Aishwarya Maheshwari

Supervised By
Dr. Jamal A. Khan

Department of Wildlife Sciences
Aligarh Muslim University
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2006

DEPARTMENT OF WILDLIFE SCIENCES
CONSERVATION MONITORING CENTRE
ALIGARH MUSLIM UNIVERSITY, ALIGARH-202 002
Phones:91-571-2701052 (O), 2700920:Ext. 1700,01,02, Telefax:2701205, e-mail:wsi@sancharnet.in

Certificate

This is to certify that the fieldwork for M.Sc. Dissertation entitled, "Food habits and prey abundance of Leopard (*Panthera pardus fusca*) in Gir Wildlife Sanctuary and National Park" has been carried out by Mr. Aishwarya Maheshwari under my supervision from January 2006 to May 2006. This dissertation is a part of M.Sc. curriculum, which is submitted for the partial fulfillment of Master's Degree in wildlife Science of the Aligarh Muslim University.

The dissertation embodies the original work done by the candidate.

Dr Jamal A. Khan

Dedicated to
Radio collared Leopards

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Chapter 1

1.1 Introduction

Leopard (*Panthera pardus)* is the most widely distributed of all the wild cats in the world (Nowell and Jackson 1996). Fossil evidence, some as old as 1.5 to 2.0 million years (Hemmer 1976, Brain 1981) suggests leopards were once more widely distributed than today. The geographical distribution of leopard extends throughout Africa, central Asia, south-east Asia and north Amur valley in Russia. Leopard is found through the Indian sub-continent with the exception of deserts, the sundarbans mangroves, and densely settled areas (Khan 1986, Jhonsingh *et al.* 1991). It is the most common of the big cats, Myres (1976) recommended that it remain in Appendix 1 of CITES because of its extensive hunting had depressed populations in several parts of Africa. In India it figures in the Schedule I of the Indian Wildlife Protection Act, 1972 (Anonymous). Leopard is placed under Least Concern category of 2002 IUCN Red List of threatened animals.

It has an elongate body and limbs of moderate length. The paws are broad, rounded and the ears are short, The tail is longer than comparison with body or that of Tiger (*Panthera tigris*), assisting its movements. It has a coat of pale yellow to deep gold, pattern with black rosettes. The throat, chest, belly and insides of the limbs are white.

The backs of the ears are black with a white central spot but there are various aberrant coat patterns. One of the most striking is melanism, the leopard being totally black. It is caused by a recessive gene. The skull is relatively elongate but flat on the upper surface. Average adult weights for male 50-70 kg and female ranges 29-54 kg (Nowell and Jackson 1996). Over most of their range, leopards have no particular breeding season. Females are sexually receptive at 3 – 7 week intervals and the period of receptivity lasts for a few days. Sexual maturity is probably achieved at about 2.5 years. Leopard in Africa and India mate at any time of the year, the gestation period is an average of 96 days (90-112) with 2-3 cubs being borned. The young weights 400-700 gm at the time of birth and open their eyes after 7-9 days (Ewer 1973, Hemmer 1976).

1.2 Objectives

The present study was undertaken to investigate the following three objectives:

- Prey Abundance.
- Food and Feeding Habits.
- Kill Monitering.

- **Prey Abundance**

The Line Transect method (Emberhardt 1968, Burnham *et al*. 1980, Buckland *et al.* 1993) was used to estimate the density of wild prey species of leopard (*Panthera pardus fusca*). This method has been effectively used to determine the ungulate densities in the same dry deciduous forest of Gir (khan 1987).

- **Food and Feeding Habits**

Scat analysis reveal information on the feeding habits of wild cats which may not be possible when using other techniques such as locating and identifying the kills (Grobler and Wilson 1972, Smith 1978, Meche *et al.*1990). Scat analysis provides useful information on the feeding ecology of mammals (Riney 1957, Putman 1984).

- **Kill Monitering**

In case of carnivores kills provide useful information pertaining to the hunting strategies, mode of feeding and also competition with other carnivores. Kill also speaks about the prey selection e.g. selectivity for prey species, selectivity for prey size, selectivity for age, sex classes and selectivity towards physically substandard individuals (Karanth and Sunquist 1995).

1.3 Duration of the Study

The present was carried out over a period of four months, from 1st February to 31st May 2006 as an exercise to fulfill the requirements for completion of M.Sc. Curriculum.

1.4 Literature Review

The leopard, up to the 1970's remained unstudied in the wild. Then observations of leopard, often associated with other studies, were reported by Schaller (1972), Eisenberg

and Lockhart (1972) and Muckenhirn and Eisenberg (1973). First intensive study was carried out by Hamilton (1976) on movements using radiotelemetry equipment.

Leopard is less studied than any other big cat like lion and tiger in India. The main focus is on conflict with human at Sanjay Ghandhi National Park, Baria Forest Divison Gujarat and Garhwal Himalayas. Of course the species is more involved in conflict with human than any other large cat but the ecology and of biology should be known and important for long term conservation.

The work on feeding ecology through scat analysis and standardization has been done by Mukherjee *et al.* (1994), Sankar *et al.*(2002) in India and Bothma *et al.*(1994) on Kalahari leopards. Biomass consumption and scat produced in captive leopards and lion was studied by Mukherjee *et al.*(2004). Reproductive biology has been studied by Desai (1973) on captive leopards, Atkinson *et al.* (2002) on side-striped jackals (*Canis adustus*), Reynolds *et al.* (1991) on fox (*Vulpes vulpes*).

Behavioral studies have been conducted on leopard by Chambers and Santipillai (1982) in Sri lanka, work on density estimation from camera trapping and scat counts has been carried out by Khorozyan (2003) in Armenia. Genetic work was conducted for phylogeographic subspecies recognition of 27 subspecies of leopard by Miththapala *et al.* (1995) and same work carried out by Spong *et al.* (2000) on Tanzanian leopard.

Prey abundance for carnivores through transect monitering has been done by Biswas *et al.* (2002), Goyal *et al.* on Tiger, Karanth *et al.*(1995) on leopard, dhol (*Cuon alpinus*) and tiger, Pole *et al.* (2004) on African wild dog (Lycaon pictus), Herfindal *et al.*(2005) on

Eurasian lynx (*Lynx lynx*), Density estimation of ungulates was carried out in the same forest of Gir by *Khan et al.*(1996).

The work on prey selection and kill mointering have been carried out by Karanth *et al.* (2000) on leopard, tiger and dhole, Stander *et al.* (1997) on Namibian leopard, Smith *et al.* (2004) on wolf (*Canis lupus*).

Chapter 2

Study Area

Gir falls in Afro tropical (palaeotropical) realm. As per the Champion and Seth classification, the biome is Dry Deciduous Thorn Forest and Scrublands.

2.1 Location

The Gir Wildlife Sanctuary and National Park spreading in an area of 1412.12 sq.km. in which Gir National Park extending over an area of 258.71 sq.km. is surrounded by the Wildlife Sanctuary extending to an area of 1153.41 sq.km. all around. Major part of Gir is reserve forest. Gir Lion sanctuary lies at 21°20' to 20° 57' N Latitude and 70° 27' to 71° 13' longitude in the Kathiawar peninsula of Gujarat.

2.2 Geology and geomorphology

The Gir forest area is rugged and hilly. The elevation varies from 150.3 to 530.7 m above mean sea level. Hills are of volcanic origin. In this area limestone is in abundance as can be seen form the quarries around the tract. Other rocks are found in the patches like gneiss, quartzite, quartz and feldspar. The area is divided into a number of watersheds, from water streams originate and feed the principle rivers of the tract e.g. Hiran, Datadri, Shinghoda, Machhundri, Ghodavadi, Raval and Shetrunji. Soil varies from place to place. It is generally black with varying proportion of loam. Such soil is found

mainly in valleys and on gentle slopes. The best teak growth is seen on well drained sandy loam soil. The other soils found in the tract are red soils, yellowish-white clay soils, clay and sandy soils.

2.3 Climate

Gir has a wide temperature variation i.e. the maximum temperature goes up to 44°C in the month of May and it falls down to as low as 10°C in the month of December and January. During summer the temperature in the eastern Gir remains slightly higher than in western Gir.

There are three different seasons viz. mansoon, winter and summer. Mansoon extends from June-July to September-October, winter from November to January-February and summer from February-March to May-June. Rain fall in Gir is very irregularly disturbed with maximum 1866 mm in 1994 and minimum as 199 mm in 1987. Rain begins with the onset of the south west mansoon in the month of June and last up to September and a few showers are also received in October and winter rains are unusual.

2.4 Flora

Champion and Seth gave a general description of Gir forest in their revised classification in 1966. These areas fall under the type 5A/Cla i.e. very dry teak forests. From the forestry point of view, it can be classified in to the following sub types:

A. Dry Deciduous Teak Forest

The main species associated with teak (*Tectona grandis*) are khair (*Acacia catechu*), sadad (*Terminalia crenulata*), timbru (*Diospyros melanoxylon*), babul (*Acacia nilotica*), amla (Phyllanthus emblica), ber (Zizyphus mauritina), gorad (Acacia senegal), hermo (*Acacia leucophloea*), khakhar (*Butea monosperma*), garmalo (*Cassia fistula*), lapdu (*Aristida adscensionis*), ratad (*Andropogon cymbaria*) etc.

B. Non Teak Forest

The remaining half of Gir is occupied by this type of forest. The composition of vegetation is more or less same but in eastern Gir dhavdo (*Anogeissus latifolia)* is dominant in the place of teak.

C. Riverine Forest

Riverine forest has a distinct type of vegetation along the rivers and streams. The main species are jambudo (*Syzygium rubicundum*), ravano (*Syzygium cummini*), karanj (*Pongomia pinnata*), vad (*Ficus benghalensis*), kalam (*Mitragyna parvifolia*), amli (*Tamarindus indica*), karamdi (*Carissa conjesta*) etc.

D. Coastal Border Forest

These are the plantations of gandobaval (*Prosopis juliflora*) and saru (*Casuarina equisetifolia*) raised all along the coastal border.

2.5 Fauna

Gir lion sanctuary supports 32 species of mammals, 26 species of reptiles, 300 species of birds and more than 2000 species of insects. Gir is the last home of Asiatic Lion. The important carnivores of the sanctuary include lion (*Panthera leo persica*), leopard (*Panthera pardus fusca*), hyaena (*Hyaena hyaena*), jackal (*Canis aureus*), jungle cat (*Felis chaus*)etc. The important herbivores are chital (*Cervus axis*), sambar (*Cervus unicolor*), nilgai (*Boselaphus tragocamelus*), chousingha (*Tetracerus quadricornis*), hanuman langur (*Presbytis entellus*) etc. Some of the important reptilian fauna are fresh water crocodile (*Crocodylus palustris*), pink ringed tent turtle (*Kachuga tentoria*), starred tortoise (*Geochelone elegans*), Indian monitor (*Varanus bengalensis*), yellow monitor (*Varanus flavescens*), common vine snake (*Ahaetulla nasuta*), common cobra (*Naja naja*), russels viper (*Vipera russelli*), python *(Python morulus*). The avian fauna of Gir forest is also very rich that supports the resident and very few migratory birds. Some of them are peafowl *(Pavo cristatus*), cormorant (*Phalacrocorax niger*), painted stork (*Mycteria leucocephala*), red headed vulture (*Sarcogyps calvus*), common quail (*Coturinx coturinx*), Indian river tern (*Sterna aurantia*), brown fish owl (*Bubo zylonensis*) etc.

Chapter 3

Estimation of Prey Base

3.1 Introduction

It is very necessary and important to collect the data on distribution, density, age and sex composition of prey bases of any predator. Population distribution and behaviour of prey influence the quality of a predator's habitat and the health of predator populations. Therefore, some knowledge about the prey species of any predator is essential before one can understand the ecology of the predator. As far the distribution of prey species is concerned i.e. influenced by the resource gradients, their combination and rate of exploitation. Normally the leopard is an opportunistic feeder and attempts to kill any prey which comes across (Eltringham 1979). The factors which influence the food habits or prey selection are the absolute abundance, relative abundance and relative value of potential prey (Estabrook *et al.* 1976). These three factors are interrelated and the theory of optimal diet predicts that higher abundance of prey species results in greater specialization by increased foraging for the most profitable food item (Pyke *et al.* 1977).

The relative abundance of many smaller mammals such as rodents were difficult to determine because of their habitat preferences and behaviour. Some species like porcupine and black naped hare were seen only at night. This study focus on the food

habits of leopard in relation to the relative density of its prey species including chital, sambar, wild boar, nilgai, chousinga, chinkara, langur and peafowl.

3.2 Methodology

Line transect method (Burnham *et al.* 1980, Anderson 1979) was used to estimate the overall density, relative density, encounter rate and group size. Line transect method is practical, efficient and inexpensive. Four transects were systematic randomly laid varying in length between 3.2km to 4.4km. The total length of all transects was 15.3 km and 14 monitoring were made on each transect at morning (07.00 to 10.00). Two observers carefully scanned the either sides for prey species. Four assumptions were always taken into consideration on transect monitoring:

- Points directly on the line were seen with probability one.
- Points were fixed at the initial sighting position (they do not move before being sighted) and none was counted twice.
- There were no measurement errors.
- All sightings were independent events.

On each sighting on the transect the following parameters were recorded:

- Species and Group Size: The species sighted with the total number of individuals, sex and their status (adult, sub adult and young one) and the distance was pursued for recording one or more animals of the same species with 30m of each other showing signs of coordinated movements were considered as a group.

- Perpendicular distance: The perpendicular distance to the centre of the group or the single animal from the transect line was measured using a range finder (Bushnell 20 – 1000).

The sex was identified on the basis of some characteristic features such as the males of sambar and chital posses antlers but females do not have, similarly male peafowl has colorful feathers. But it was very difficult to categorize the sex of chital and sambar, especially during the fawning period when sub adult males and females appear almost same. Thus such animals were not categorized sex wise to minimize bias in determining the sex ratio.

Distances between starting points of two transects were maintained 0.5km. to 2.5km. to minimize the bias of over counting the prey species on more than one transect.

3.3 Data Analysis

Each transect in summer 2006 had 14 monitoring thus a total of 214.2km walked along transects. The analysis was carried out separately for each species on each transect. The transect data was analysed using the programme DISTANCE (version 5.0 BETA 5, Thomas *et al.* 1993) to estimate species density, mean group size and encounter rate. The minimum Akaike Information Criterion was used to select the model after checking the heaping effect.

Nilgai, hare and chousinga had only 12, 10 and 01 sightings on the transect thus they were not included in the analysis because there should be minimum 40 sightings are necessary for accuracy.

3.4 Results

3.4.1 Density of Wild Prey Species

The estimated overall densities and individuals of all five prey species are in Table. The value of overall density estimated 134.78 animals/km². Chital had the highest density, 61.45 animals/km² where as wild boar had the lowest value of density, 1.62 animals/km². The overall and individual encounter rate, expected and mean group size are also summarized in the table 1.

3.4.2 Group Size and Encounter Rate

The expected value of group size at 95% confidence intervals was estimated 3.7 animals/group. The estimate of mean group size was 3.9 animals/group that varied within 95% confidence intervals from 2.3 to 2.9 animals/group. The encounter rate estimated for overall prey species 2.6 individuals that were varied within 95% confidence intervals form 2.3 to 2.9 individuals. In summer the highest encounter rate was 1.23 individuals of chital population and wild boar had the lowest 0.07 individuals (Table 2).

3.5 Discussion

The prey species play a vital role which limits the population of predator. Thus it is important to collect the data on the status and distribution of prey species and their fluctuations during time intervals. Population size is a wildlife management tool by which the success of a management programme is ultimately judged. Ecologists have emphasized the important role that wild prey species play in ecosystems through their influences on the composition, productivity, nutrient cycle and succession (Crawely 1983) and ultimately on the population of the predator.

Karanth *et al.* (1995) reported from tropical forests of Nagarhole National Park Chital had the highest density (49.1/km²) and supports the highest frequency of occurrence (43.7%) in leopard diet in scats and 83% composed the total kills made by leopard.

Bailey (1973) reported that impala was the most frequent ungulate species and prey in Kruger National Park. Similarly, here chital was the most abundant ungulate and prey species in kill monitoring. Khan *et al.* (1996) reported the densities of chital in 1970 was 3.57/km² and it was surprisingly increased up to 50.8/km² in 1970. Same with sambar density increased 0.24/km² in 1970 to 2.0/km² in1989.

There is a pronounced effect of terrain and habitat structure upon the population, distribution and group size of wild herbivore prey species. Ungulates preferred the habitat types which fulfill their requirements e.g. highest densities of chital were recorded in flat or plain topography harbors *Tectona, Acacia* and *Zizyphus* like woodlands and in the ecotone areas with riverine habitats (khan *et al.* 1996). Similarly Transect4 (T4) was on the hilly terrain and harbors lest density of ungulates especially

of chital, wild boar and nilgai. These habitats types and terrain provide ungulates food, cover and shelter. Ultimately these places are also preferred by predators as far their availability of food, cover and habitat structure are necessary for survival. The differences in densities of chital and sambar in last 35 years are summarized in table 3 with three years data of 1970, 1989 (Khan *et al.* 1996) and 2006 (present study). The transects (n = 4) routes on the map of Gir Protected Area (Map 1) their distances, terrain, habitat types and main plant species are represented and summerised in table 4.

Species	Density			Density of Cluster			ESW		
	D	SE	95% CI	DS	SE	95%CI	ESW	SE	95%CI
Pooled	134.78	12.56	112.22-161.80	36.64	3.04	31.16-43.19	35.44	1.97	31.79-39.52
Chital	61.45	6.4	50.08-75.40	13.28	1.12	11.23-15.70	46.58	2.16	42.57-50.96
Sambar	3.46	0.45	2.14-5.58	1.87	0.42	1.20-2.98	47.26	7.10	34.90-63.99
Langur	24.85	0.52	4.95-7.07	4.21	0.71	3.01-5.88	32.67	4.19	25.30-42.20
Wild boar	1.62	0.40	0.99-2.65	0.41	0.08	0.26-0.63	85.0	0.00	85.0-85.0
Peafowl	12.43	1.50	9.78-15.8	7.24	0.82	5.78-9.08	47.65	2.51	42.93-52.86

Table 1: Density, density of cluster and ESW of five prey species of leopard. D = Density, SE = Standard Error, CI = Confidence Interval, ESW = Effective Stripe Width.

Species	Encounter Rate			Expected Cluster Size			Mean Cluster Size		
	n/L	SE	95% CI	E (S)	SE	95% CI	M (S)	SE	95%CI
Pooled	2.6	0.16	2.3-2.94	3.67	0.16	3.38-3.1	3.9	0.16	2.3-2.94
Chital	1.23	0.08	1.07-1.43	4.63	0.28	4.11-5.21	5.36	0.28	4.83-5.93
Sambar	0.18	0.03	0.12-0.24	1.85	0.17	1.52-2.30	1.84	0.16	1.54-2.20
Langur	0.27	0.03	0.22-0.34	5.90	0.52	4.95-7.03	5.35	0.52	4.68-6.12
Wild boar	0.07	0.01	0.04-0.10	3.93	0.50	2.99-5.16	3.93	0.50	2.99-5.16
Peafowl	0.69	0.06	0.56-0.84	1.71	0.07	1.57-1.86	1.61	0.08	1.44-1.80

Table 2: Encounter rate, Expected and Mean cluster size of five prey species of leopard. n/L = Encounter Rate, SE = Standard Error, CI = Confidence Interval, E (S) = Expected Cluster size, M (S) = Mean Cluster Size.

Species	1970*	1989*	2006
Chital	3.57	50.8	61.45
Sambar	0.24	2.09	3.46

Table 3: Comparison of densities (animals/km²) of chital and sambar in Gir in 1970, 1989 and summer 2006.
*Data source: Khan *et al* (1996).

S.N.	Transect Route	Length (Km)	Distance between s.t. of two transects (Km)	Terrain	Habitat
T1	Bambaphod to Raidi	3.6	0.9, between T1 and T2	Plain and Hilly	TAZ
T2	Akadia to Pillipat	4.1	2.5, between T2 and T3	Plain and stream	TAZ+R
T3	Kanki CP to Bawalwala Chauk	3.2		Plain	TAZ+M
T4	Umrawala shinda to Kapuriya	4.4	0.5 between T3 and T4	Hilly	AZ+M

Table 4: Presentation of transect routes, distance, terrain and habitat.

CP=Check-Post
s.t.=Starting Points
Habitat:
TAZ: *Teak, Acacia* and *Zizyphus*
R: Riverine
M: Mixed.

Main Plant Species:

Tectona grandis, Zizyphus species, Acacia species, Syzygium species, Ficus species, Carissa conjesta, Butea monosperma, Abrus precatorius, Bombax ceiba, Cassia fistula, Manilkara hexandra, Aegle marmelose, Boswellia serrata, Wrightia tinctoria, Phyllanthus emblica, Diospyros melanoxylon etc.

Chapter 4

Scat Analysis

4.1 Introduction

Estimating the consumption of any particular prey type by carnivores depends upon the reliable analysis of diet. The analysis of either stomach contents (Bothma 1965, Fritts *et al.* 1978, Smuts 1979) or scats (Reynolds *et al.* 1991, Mukherjee et al. 1994, Biswas *et al.* 2002, Jethva *et al.* 2003) has become fundamental tool in carnivore research. Of the two, scat analysis has the great advantage that material is easy to collect and does not involve destruction of animals from the study population. Scats provide much more material for studies than any other predator signs, e.g. kill monitoring has not much sound for food and feeding ecology of a predator like leopard because all the kills can not be detected until unless a radio collared is attached with, scavenging is also reported i.e. the preference among the kills can not be thoroughly analysed. Contrast in case of scat analysis the prey species eaten by predator and preference among them can also be studied. Leopard is a solitary, elusive and shy animal and difficult to study its feeding habits in wild. The ability of leopard to feed on a broad spectrum of prey items makes it the most successful predator among big cats.

4.2 Methodology

4.2.1 Collection of Scats

"Scat" is defined as the cluster of individual feces deposited in a single act of defecation (Khorozyan 2003). During summer 2005 under leopard ecology project all the scats were collected. The leopard scats were identified on a basis of field experience and the general criteria described in literature characteristic "segmented" shape with mean diameter 2.7 cm (range 2.0 – 3.0 cm), pointed ends many lobes (Karanth *et al.* 1995, Edgaonkar *et al.* 1998) and the scats create confusion with that of lion sub-adult were not included in the analysis.

4.2.2 Analysis of Scats

The scats were crushed and observed carefully for the presence of indigestible macro elements like claws, feathers etc.12 hairs were collected randomly per scat. This size of hair collection per scat was standardized by analyzing 50 scats and a total of 50 hairs per scat were examined and calculate the mean value. The asymptote was attained at 24 hairs per scat at 100% Confidence Interval (CI) and12 hairs for 95 % CI. The hairs were kept in xylol (xylene and ethyl alcohol) for 24 hours. Slides were prepared with four hairs per slide i.e. three slides for each scat, by mounting hairs in dpx. All the slides were examined under microscope (Olympus) under 40X * 10X magnification. These hairs were compared with known reference slides which were prepared the hairs collected from different kills of wild ungulates and domestic livestock also. Reference

hairs were taken from different parts of the body such as belly, hind and neck portion to minimize the bias of any unknown hair extracted from the scat as there is a considerable difference of different hairs within the body, microscopically.

The hairs were identified on the basis of structural differences like medullary portion, cuticle, cortex and pigmentation in the cells (Koppikar *et al.* 1975). The long hairs such those of buffalo, wild boar etc were cut in to three pieces of proximal, middle and distal and then examined under microscope.

4.3 Data Analysis

A total of 71 scats were analysed of summer 2005 for studying the food habits of leopard. Each prey item was recorded when it was examined under microscope, in case of peafowl the feathers were examined visually at the time of hair extraction and again examined under microscope. The total number of prey species which were examined (i.e. total number of all prey species whenever they were recorded) were cross checked through taking the frequency in percentage at interval of 10 scats.

4.4 Results

4.4.1 Food Habits of Leopard: Analysis of 71 scats shows the diet of leopard in summer-mansoon 2005. There is not a considerable difference in

single prey (35 scats) and two prey (30 scats) and 6 scats shows three prey items (fig).

4.4.2 Diet of Leopard: There is a great diversity found in leopard scat, a total of 12 prey items were recorded in the scats and there percentage occurrence is summarized in the fig.

4.5 Discussion

The diet of a carnivore reflects both the availability of its potential prey items, as well as a suite of morphological, behavioural and physiological adaptations that allow the individual to locate, capture, ingest and digest a variety of prey taxa (Kok *et al.* 2004)

The present study focus on the diet of leopard and it represents the aver all diet spectrum in summer 2005. Sambar has the highest frequency (28.32%) in leopard diet. It is not supported from the available literature by Mukherjee *et al.* i.e. reported chital has the highest frequency (64.7%) in leopard diet followed by sambar (20.2%) langur (15.33%) and other prey species. Here, chital is second highest occurred prey species (23%). The highest frequency of sambar tends to over – represent the larger prey, as they induce the production of a great number of scats (Reynolds *et al.* 1991, Mukherjee *et al.* 2004) and leopard was also reported scavenging on sambar kills made by lion. Chital is of course the one of the best available, abundant and easy to prey. Langur is followed by chital i.e.

13.27% occurrence then civet has 11.5% in leopard scat. Hare is also one of the preferred prey item has 7.96% of frequency of occurrence. Four horned antelope is confined that's why has the lowest frequency as like food dependency is equal on dog and peafowl. Livestock has 4.42% frequency of occurrence include goat (2.65%) and buffalo (1.77%) Mukherjee *et al.* reported 18% occurrence of livestock includes buffalo and cow i.e. absent here in place of goat. Livestock depredation in form of cubs of cow and buffalo and goat, scavenging was also recorded two times on the kills of cow made by lion. Rodents (7.08%) got place after civet in leopard diet and proof the adaptability to survive on such a small prey and feed whatever is available and fluctuate the prey size from largest sambar to smallest rodent in leopard diet.

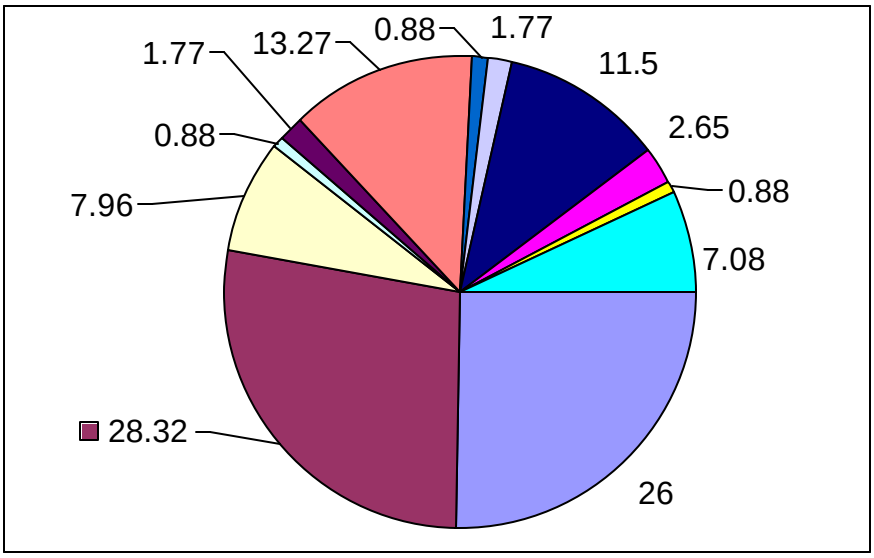


Fig.1: Percentage Occurrence of Prey species of leopard.

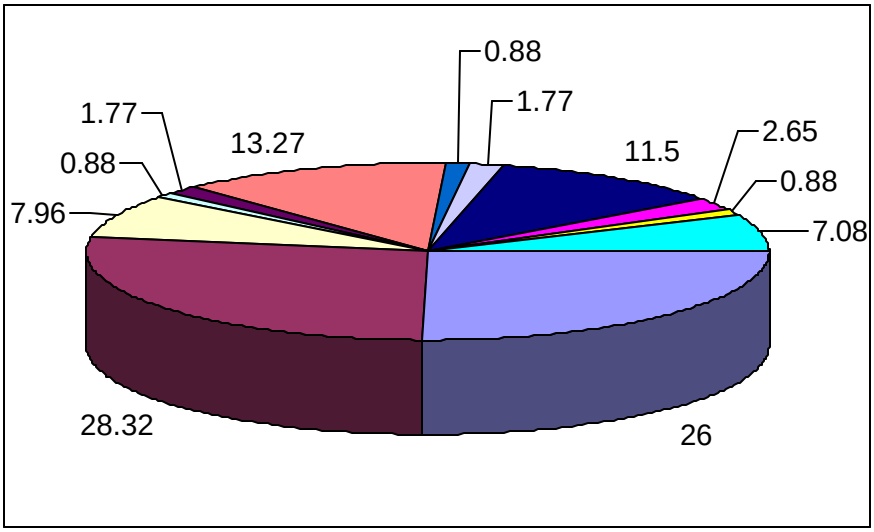
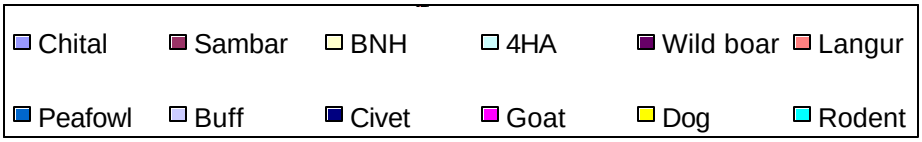


Fig. 2: Percentage occurrence of prey species of Leopard (3D view).



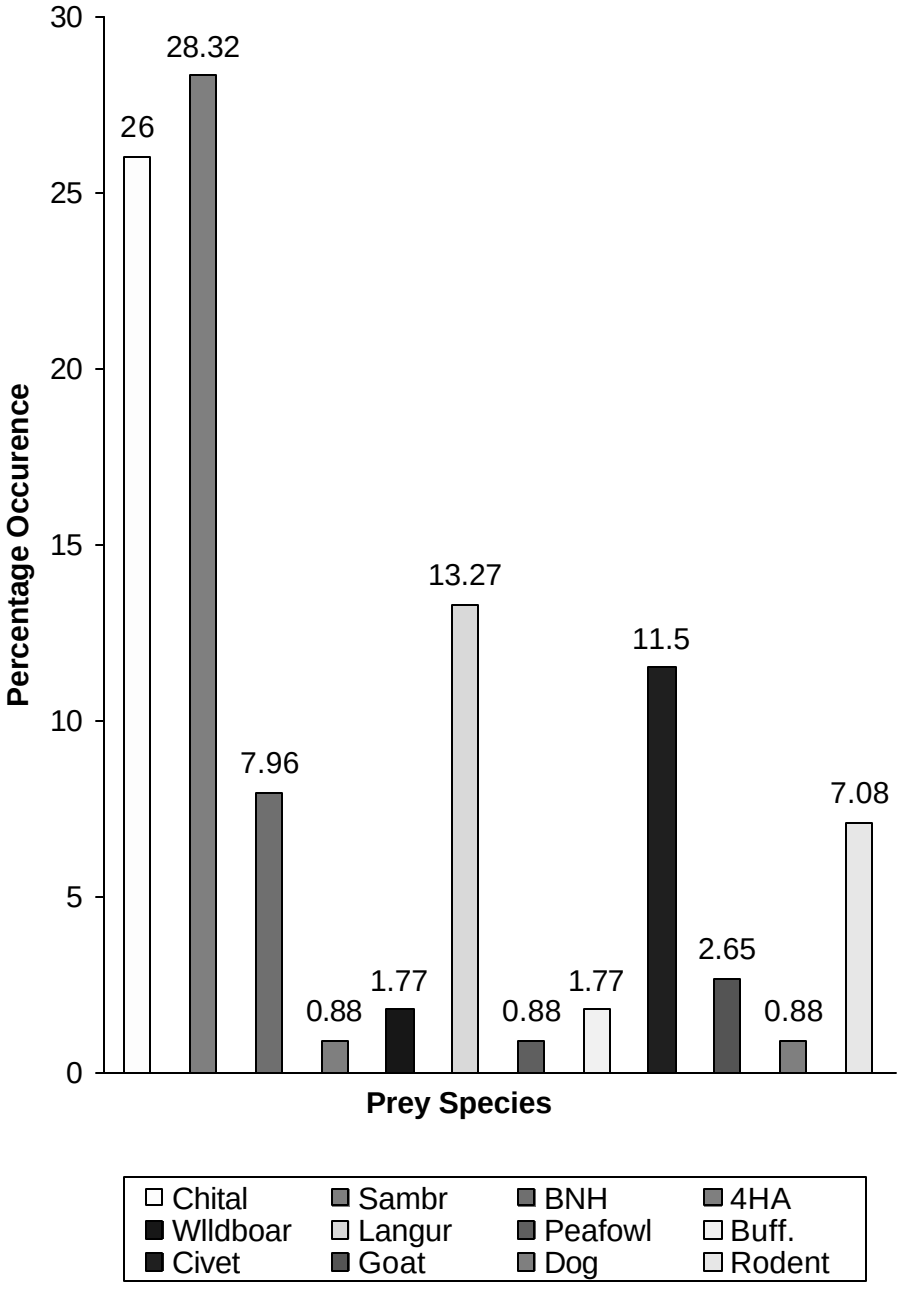


Fig. 3: Percentage occurrence of prey species of leopard.

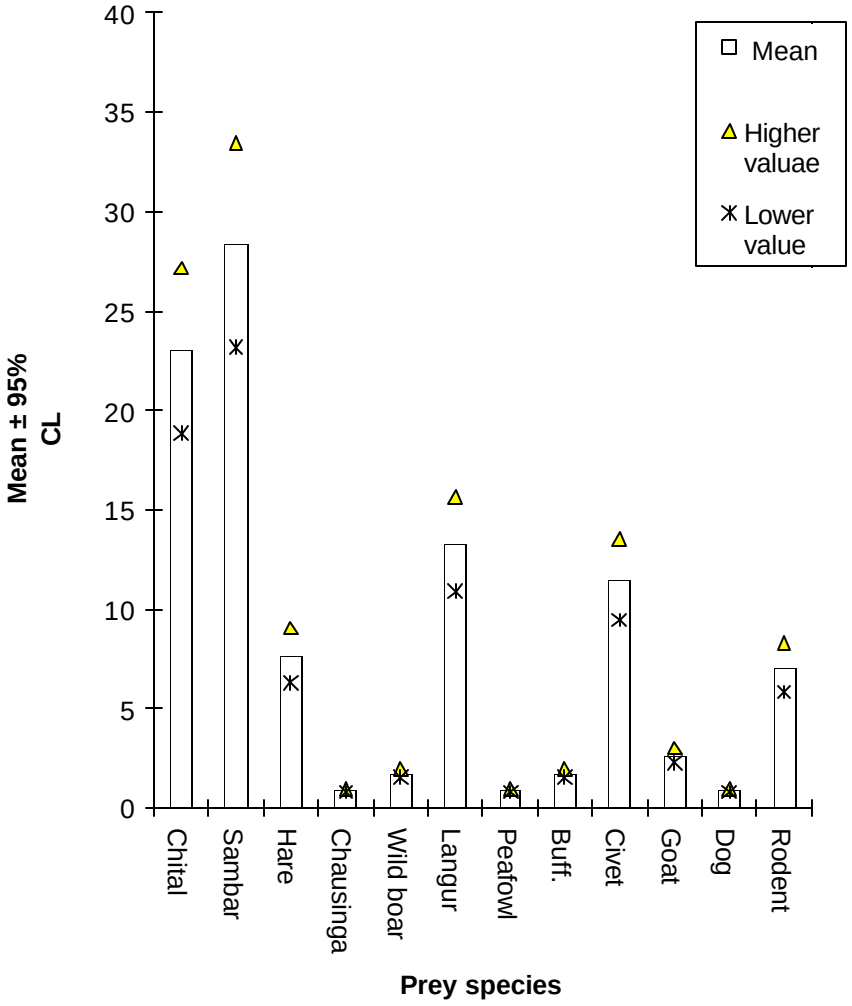


Fig. 4: Mean Values with Confidence limits (CL) of Prey species of leopard.

Photograph 2: Leopard on the Chital Kill

Chapter 5

Kill Monitoring

5.1 Methodology

Very less is known about the hunting strategies or hunting behaviour of leopard because there are very rare encounters to sight a hunting leopard due to its nocturnal habits.

This study is an investigation of the kills made by leopard. The wild species in the prey items of leopard include chital, chousinga, chinkara, sambar, wild boar, civet, rodents, black napped hare, langur and peafowl. The work of kill monitoring of leopard is actually done in the three months February, March and April 2006.

5.2 Kill Searching

Six streams or riverine tracts (Map 2) were selected for kill searching and about 5km track was walked by foot everyday. The main aim is to select these areas for searching is to give preference by ungulates for rich water and food resources and leopard also prefer these areas as far the same food or natural resources are concerned. The tendency to hide or store the kills by leopard under the bushes

and keep them on the branches of the trees, thus the bushes along the streams and tree branches were thoroughly searched.

The kills were located using such cues as decomposition odour, prey alarm calls, predator signs and activities of scavenging animals. When a kill was found then it is classified in the following categories:

A. Fresh Kill: The kill is not consumed completely and chances that leopard would return at the kill. Whenever a fresh kill was encountered, it was monitored in morning and evening hours until the kill was completely consumed.

B. Old kill: The kill is completely consumed and nothing remained in the kill to feed for leopard. The time limitation 5-10 days and this time is recorded on the basis of the condition of the kill, specially if some flesh is attached with some bones then the activity of decomposers, condition of the carcass and the skin attached on the limbs. These cues categorize the kill in the old kills.

C. Very Old Kill: The kill is completely consumed and older than the old kill i.e. more than 10 days. The condition itself defines like no flesh is attached with the kill, the bones are much white and shining to categorize it in the very old kill. Kills which were confused with lion kill (n = 8) are recorded in the field but not included in the analysis.

5.2 Guidelines Developed for Kill Identification

Two large cats exist in Gir sanctuary (leopard and lion) and for the correct identification of the leopard kills I developed some guidelines which were followed to identify the kill and distinguish the kill with lion. These guidelines were developed on the basis of leopard old and fresh kills and lion fresh kills (n = 14) and also the experience in the field on the old kills of the both cats.

A. Sighting of Leopard: It is the simplest way to decide whether the kill is of leopard or not that if leopard is sighted at the kill (n = 2) on the condition that the kill was made by leopard i.e. hunting was seen if not then sure evidences no other predator had made the kill. Such cues as predator signs like pugmark or claws marks if the kill is tried to climbed on the trees were also helpful.

B. Canine Marks: I have recorded the marks of the lower and upper canines on the neck of the prey in some of the fresh kills (n = 4). Throat bite or neck bite is usually done for hunting the prey, thus theses canines marks provide useful information to identify the kill. I have measured these marks.

Space between lower and upper canine = 7.3 – 10.0 cm

Space between two upper canines = 3.4 – 3.8 cm

Space between two lower canines = 2.5 – 2.8 cm

C. Mode of Feeding: On the basis of the fresh kills of leopard and lion I found there is a separate mode of feeding. Leopard opens the kill from the ventral or lateral portion of the abdomen and take off the stomach and intestinal

or inedible portion and starts feeding from the abdominal portion, finish it and reaches to the upper abdomen and chest and at last it feeds on the hind portion. In contrast lion starts feeding from the hind portion first then reaches to the abdomen and chest and neck at last.

D. Condition of the Kill: Condition of the kill also speaks about its predator. In case of fresh kills the signs of dragging and lasts up to a bush where the cover is almost about 100%, the tendency to hide the kill from lion, hyaena, jackal and scavenging birds.

If the kill is climbed on a tree then claws marks on the tree trunk and branches and it applicable for both old and fresh kill. I found in one of the fresh kill that the leopard tried to take the kill on the tree but not succeed and in one of the old kill, the claws marks were visible on the tree and the kill was just lying under the tree.

E. Personal Communication: Information about the kill of leopard and lion is taken from the forest staff and nesses. The aim to take the information about lion kill is minimize the chances of confusing with that of leopard kill in future. The kill is also confirmed with the help of these peoples like in any case of doubt whether the kill is of leopard or lion. A total of six kills were informed from which one kill was fresh and rests were old.

5.3 Collection of Data

At each kill the following parameters were recorded

a) Species, Sex, Reference Place, Time of finding the kill, Date and the probable date when the kill was actually made.

b) GPS Location: Magellan 350. In case of fresh kill the gps is recorded of fighting place, dragging at each point and of course where the kill was found.

c) Bone Marrow: For assessing the health status of the prey animal, the limb is broken and bone marrow is examined visually.

d) Injury and Throat Bite: Any kinds of injury at any place, specially the softer parts or openings of the body were examined. The canine marks on the neck were measured.

e) Habitat, Cover and Vegetation: The type of habitat, the percentage of cover (visually) and the major tree and bush species were also recorded.

f) Distance from Water Point: The distance of the nearest water point or water accumulated areas from the kill is recorded.

g) Nearest Ness: Ness is the Maldhari settlement. Thus I assume ness as the human habitation areas and the distance is recorded from the kill.

h) Jaws Collection: The lower jaw was collected from most of the kills. The age estimation of the killed species is being done on the basis of the lower jaw (Cohen *et al.*1977).

i) Dragging of the kills: Dragging of the fresh kills were measured and recorded at each time whenever they were dragged from place to place to have an idea of dragging done at different kills.

5.4 Results

5.4.1 Analysis of Kill Data

The total numbers of 45 kills were recorded during the study. Among them, 16 kills were fresh and 29 kills were old and very old. The analysis was carried out on the basis of the parameters were recorded and separately for fresh and old kills to estimate the species preyed, percentage killing rate of each species, preference among the species, sex of the species and age group class of the species.

5.4.2 Estimation of Age of Kills: On the basis of total kills (n = 45) they are classified on the basis of different age classes.

i. Birth to 1.5 Years: Fawn or Young one

ii. 1.5 to 3 Years: Sub adult

iii. 3 to 5 Years: Adult

iv. More than 5 Years: Old

It is actually done on the basis of the relative structural differences in the tooth structure at different age classes (Cohen *et al.* 1977) The lower third premolar (P3), first molar (M1), second molar (M2) and third molar (M3) are taken in to

consideration, e.g. the P3 of chital and sambar fawns (birth to 1.5 years) is tri-cusped looks like having three distinct sections, it is replaced by two cusped in older than 1.5 years. In general, as the animal grows the upper surfaces of the teeth become worn away and the chewing ridges become smooth and concave.

5.4.3 Estimation of Kills: The overall kills were found, percentage killing rate of each species, preference among the species, sex of the species and age group class of the species, preferred cover, distance from water points and nesses of the fresh and old kills separately have been summarized in Tabel-5 and 6.

5.4.4 Dragging of the kills: Leopard face a great competition with lion, hyaena, jackal and scavenging avian fauna like crow, kite, eagle and vulture that either they overcome the kill like lion or feed on the leopard kill. Thus it is important to store the kill at suitable places like under the dense bushes of *Carissa conjesta, Syzygium cumini* etc.

In fresh kills the maximum and minimum dragging was recorded 150m and 5m respectively and the average dragging was recorded 41.66m. Maximum dragging was recorded in chital fawn, because it was light in weight i.e. easy to drag. The minimum dragging was recorded in chital adult and sambar fawn. No dragging was seen in one of the fresh kill of adult wild boar.

5.4.5 Kills taken over by Lion: There is a competition between leopard and lion for utilization of natural resources and food is one of the very important and necessary natural resource. As Eaton (1970) described lion is dominant over

leopard and this is also supported by snatching the kills from leopard. The total of 16 fresh kills 6 were overcome by lion and among 29 old kills 3 were taken over by lion i.e. a total of 9 kills taken over by lion.

5.5 Discussion

Chital was found the preferred species in the kills and males are more frequently killed as comparison with females and followed by chital fawns. Not a single adult sambar was being recorded but only a young one was killed in a fruit orchard. Chital population is very large (data from prey abundance on the transects recorded by the student), is the easily available species. Wild boar (n = 3) was also recorded and one of them was injured and old at the time of hunting by leopard. Peafowl is one of the frequent species come across in the kill monitoring. Langur is also one of the prey species in Gir forest and supported by scat analysis but no kill was found in the kill monitoring.

The age-group class also one of the parameter which effect the prey selection. Most of the kills of chital around 3 -5 years old or the adult ones followed by young ones of chital and one sambar, followed by sub adult of chital and 5 kills are of the age more than five years.

Average distance maintained from the nesses is about 1.87 km and the maximum distance is about 4 km i.e. the human habitation areas were avoided at the time of predation support that leopard is a shy cat and avoid disturbances, but the

minimum distance recorded was only 0.2 km on a chital fawn was preyed that may be some of the individuals come near to the settlements areas or it may supports the population of leopard which survives is at the fringes and show the adaptability of this cat.

The availability of water at the time of predation has a very fluctuating role to assume a relationship between point of killing and water point. The average distance calculated about 0.39 km from the water point and the maximum and minimum values are 2 km and 0.003 km respectively.

The tendency to store the kills under the bushes plays an important role i.e. the selection of the maximum cover as 100% found in 12 kills but the cover was nil (0%) was also found in 6 kills and the average cover was recorded 59.56%.

S. No.	Species	Status			
		Male	Female	Fawn	Unidentified
1	Chital	16	9	7	-
2	Sambar	-	-	-	-
3	Wild boar	1	-	-	2
4	Peafowl	7	2	-	-

Table 4: Total number of kills recorded of leopard during study.

S. No.	Species	Status			
		Male	Female	Fawn	Unidentified
1	Chital	6	3	4	-
2	Sambar	-	-	-	1
3	Wild boar	1	-	-	-
4	Peafowl	1	-	-	-

Table 5: Number of fresh kills recording during study.

Parameters	DWP (km)	DN (km)	Cover (%)
Maximum	2	4	100
Minimum	0.003	0.2	0
Average	0.39	1.87	59.56

Table 6: Parameters recorded at each kill

DWP: Distance from water point, DN: Distance from Ness.

Age-Group (Years)	Chital	Sambar
Birth -1.5	7 (21.21%)	1 (3.03%)
1.5 – 3	6 (18.18%)	
3 – 5	14 (42.42%)	
More than 5	5 (15.15%)	

Table 7: Number and percentage of kills in different age-classes recorded

Photograph 1 (A and B):
Fresh kill of female chital made by leopard.

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Chapter 7

Appendices

Appendix 1: List of Mammals at Gir Protected Area.

(* Sighted in the field)

S.No.	English Name	Scientific Name
1	Leopard*	*Panthera pardus fusca*
2	Lion*	*Panthera leo persica*
3	Stripped Hyaena*	*Hyaena hyaena*
4	Common Langur*	*Presbytis entellus*
5	Desert cat	*Felis libyca*
6	Rusty spotted cat	*Felis rubiginosa*
7	Jungle cat	*Felis chaus*
8	Jackal*	*Canis aureus*
9	Indian fox	*Vulpes bengalensis*
10	Indian ratel	*Mellivora capensis*
11	Sambar*	*Cervus unicolor*
12	Spotted deer*	*Cervus axis*
13	Four horned antelope*	*Tetraceros quadricornis*
14	Chinkara*	*Gazelle gazelle*
15	Blue bull*	*Boselaphus tragocamelus*
16	Wild boar*	*Sus scorfa*
17	Small Indian civet*	*Viverricula indica*
18	Common palm civet	*Paradoxurus hermaphroditus*
19	Common mangoose*	*Herpestes edwardsi*
20	Ruddy mangoose*	*Herpestes smithi*
21	Small Indian mangoose	*Herpestes auropunctatus*
22	Pangolin	*Manis carissacaudata*
23	Pale hedgehog	*Paraechinus misfopus*
24	Long eared hedgehog	*Hemiechinus auritus*
25	Musk shrew	*Suncus murinus*
26	Indian hare*	*Lepus nigricollis*
27	Indian porcupine*	*Hystrix indica*
28	Five stripped squirrel*	*Funambulus pennanti*
29	Three stripped squirrel*	*Funambulus palmarum*
30	Indian flying fox*	*Pteropus giganteus*
31	Fulvous fruit bat	*Rousettus leschenaultia*
32	Indian gerbille	*Tetera indica*
33	Indian field mouse	*Mus boodgya*

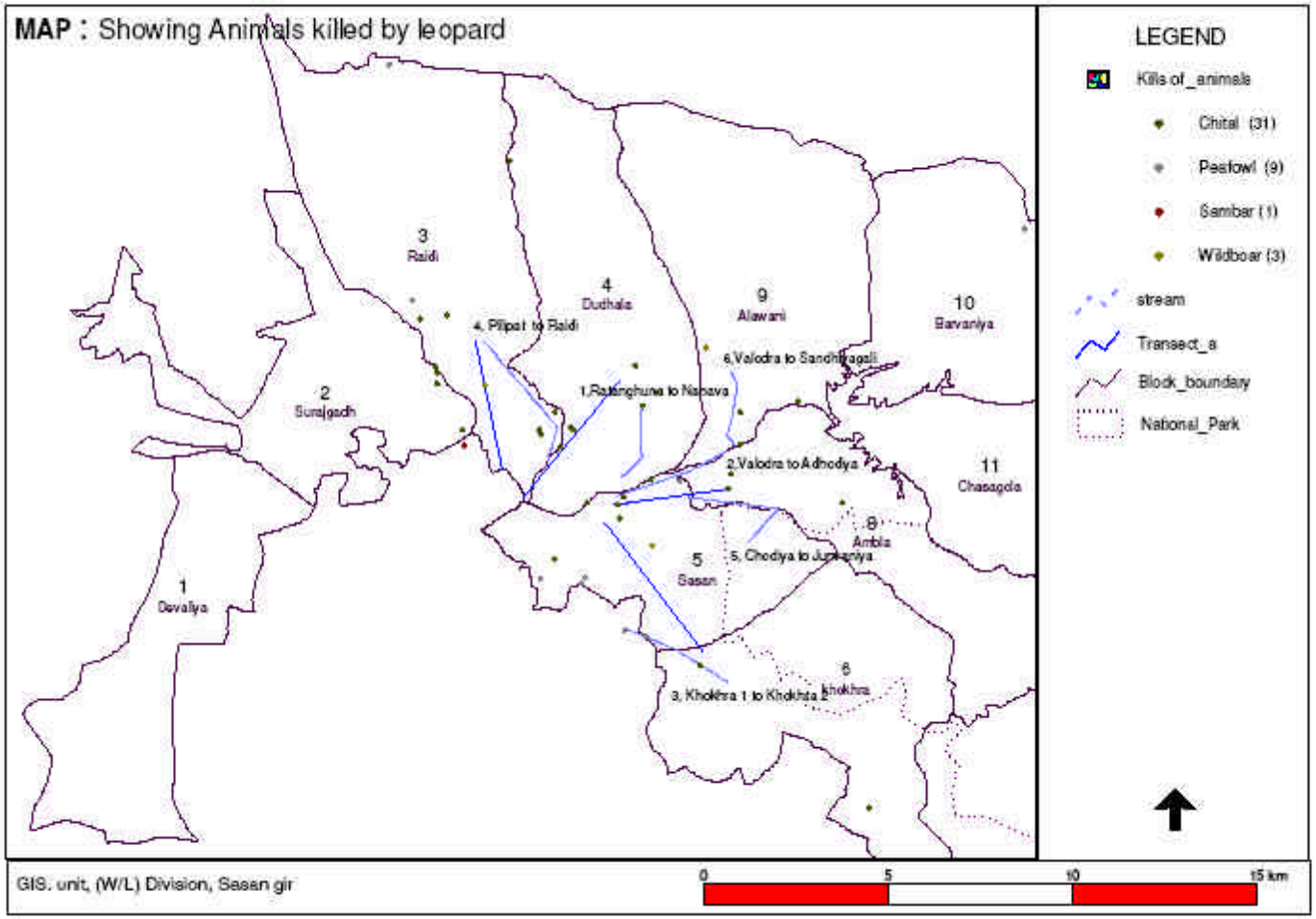
Appendix 2: List of Birds identified at Gir Protected Area

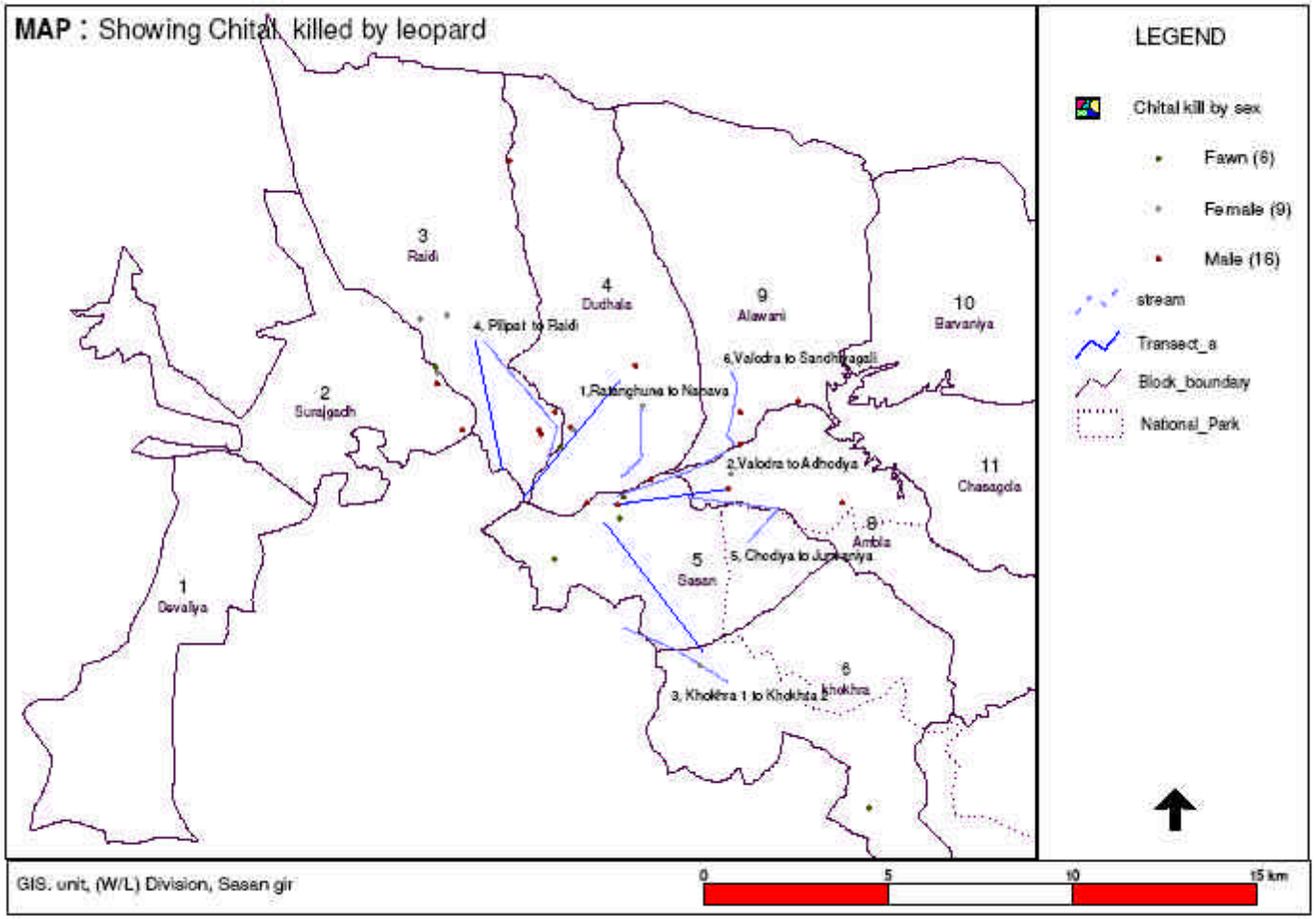
Appendix – 2 : List of Birds Identified in Gir Protected Area

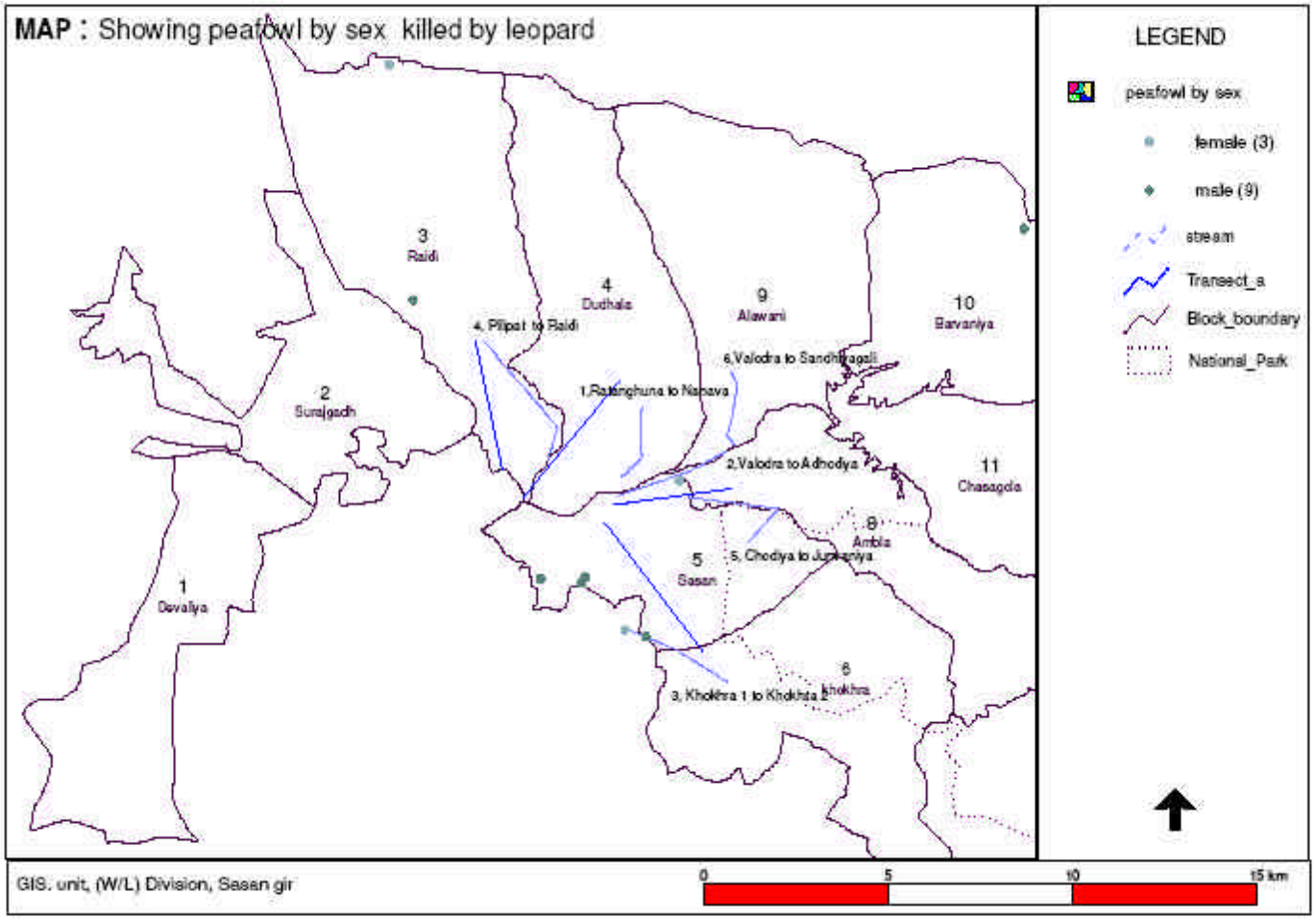
S.No.	Common Name	Scientific Name
1	Little cormorant	*Phalacrocorax niger*
2	Grey heron	*Ardea cinerea*
3	Pond heron	*Ardeola grayii*
4	Cattle egret	*Bubulcus ibis*
5	Large egret	*Ardea alba*
6	Little egret	*Egretta grazetta*
7	Painted stork	*Mycteria leucoecephala*
8	Whitenecked stork	*Ciconia episcopus*
9	White ibis	*Threskiornis aethiopicus*
10	Black ibis	*Pseudibis paplliosa*
11	Black shouldered kite	*Elanus caeruleus*
12	Black kite	*Milvus migrans*
13	Changeable hawk eagle	*Spizaetus cirrhatus*
14	Bonelli's eagle	*Hieraetus fascitus*
15	Tawny eagle	*Aquilla rapax*
16	Crested serpent eagle	*Spilornis cheela*
17	Red headed vulture	*Sarcogyps calvus*
18	White backed vulture	*Gyps bengalensis*
19	Long-billed vulture	*Gyps indicus*
20	Egyptian vulture	*Neophron percnopterus*
21	Indian peafowl	*Pavo cristatus*
22	White breasted water hen	*Amaurornis phoenicurus*
23	Red wattled lapwing	*Vanellus indicus*
24	Yellow wattled lapwing	*Vanellus malabaricus*
25	Common sandpiper	*Tringa tetanus*
26	Indian river tern	*Sterna aurantia*
27	Chestnut bellied sandgrouse	*Pterocles exustus*
28	Painted sandgrouse	*Pterocles indicus*
29	Green pigeon	*Treron phoenicoptera*
30	Blue rock pigeon	*Columba livia*
31	Eurasian collared dove	*Streptopelia decaocta*
32	Spotted dove	*Streptopelia chinensis*
33	Laughing dove	*Streptopelia seneglansis*
34	Roseringed parakeet	*Psittacula krameri*

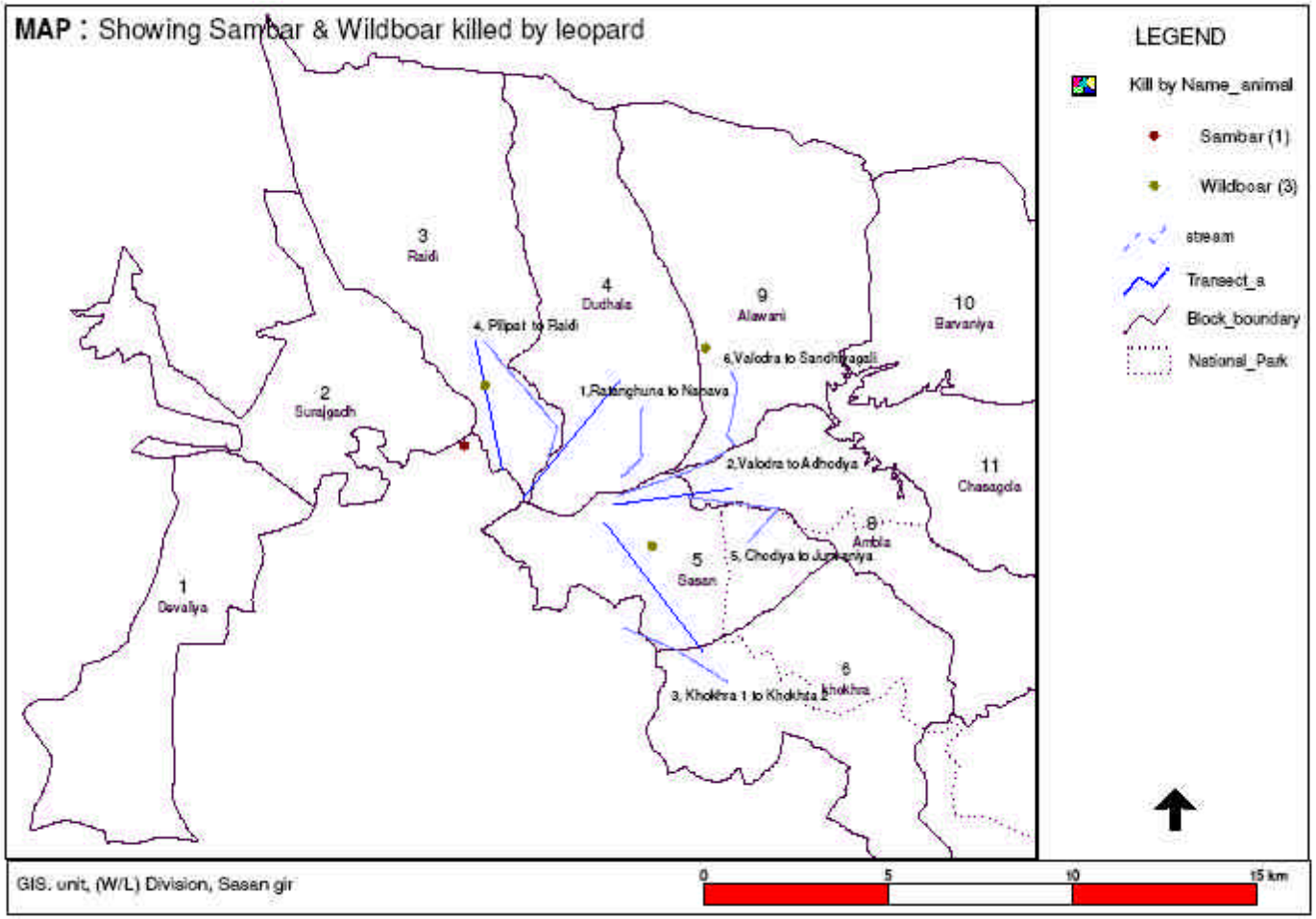
35	Blossomheaded parakeet	*Psittacula cyanocephala*
36	Koel	*Eudynamys scolopaces*
37	Crow pheasant	*Centropus sinensis*
38	Brown fish owl	*Bubo zeylonsis*
39	Spotted owlet	*Athene barma*
40	House swift	*Apus affinis*
41	Common kingfisher	*Alcedo athis*
42	Whitebreasted kingfisher	*Halcyon smyrensis*
43	Green bee eater	*Merops orientalis*
44	Indian roller	*Coracias benghalensis*
45	Hoopoe	*Upapa epops*
46	Crimson breasted barbet	*Magalaima haemacephala*
47	Goldenbacked woodpecker	*Dinopium benghalensis*
48	Pygmy woodpecker	*Picioedes canicapillus*
49	Black drongo	*Dicrurus adsimilis*
50	Brahminy myna	*Sturnus pagodarum*
51	Common myna	*Acridotheres tristis*
52	Bank myna	*Acridotheres ginginianus*
53	Jungla myna	*Acridotheres fuscus*
54	Indian treepie	*Dendroditta vagabunda*
55	House crow	*Corvus splendes*
56	Jungla crow	*Corvus macrorhynchos*
57	Small minivet	*Pericrocotus cinnamoneus*
58	Common iora	*Pericrocotus tiphia*
59	Redvented bulbul	*Pycnonotus cafer*
60	Common babbler	*Turdoides caudatus*
61	Large grey babbler	*Turdoides malcolmi*
62	Jungla babbler	*Turoides straitus*
63	Rufoustailed flycatcher	*Muscicapa ruficauda*
64	Tickell's blue flycatcher	*Muscicapa tickellioe*
65	Papadise flycatcher	*Tersiphone paradisi*
66	Tailor bird	*Orthotomus sutorius*
67	Magpie robin	*Copsychus saularis*
68	Common redstart	*Phoenicurus phoenicurus*

69	Indian robin	*Saxicoloides fulicata*
70	Yellow wagtail	*Motacilla flava*
70	Purple sunbird	*Nectarina asiatica*
72	Oriental white eye	*Zosterops palpebrosus*
73	House sparrow	*Passer domesticus*
74	Indian baya	*Ploceus philippinus*
75	Grey shrike	*Lanius excubitor*


MAP : Showing Animals killed by leopard
LEGEND
Kills of_animals
Chital (31)
Peafowl (9)
Sambar (1)
Wildboar (3)
stream
Transect_a
Block_boundary
National_Park
3
Raidi
4
Dudhala
9
Alawani
10
Barvaniya
2
Surajgadh
11
Chasagola
8
Ambla
5
Sasan
1
Devaliya
6
Khokhra
4. Pipal to Raidi
1.Ratanghuva to Nanava
6.Valodra to Sandhiragali
2.Valodra to Adhodya
5. Chodiya to Jamkandiya
3. Khokhra 1 to Khokhda 2
GIS. unit, (W/L) Division, Sasan gir
0
5
10
15 km


MAP : Showing Chital killed by leopard
LEGEND
Chital kill by sex
Fawn (6)
Female (9)
Male (16)
stream
Transect_a
Block_boundary
National_Park
3
Raidi
4
Dudhala
9
Alawani
10
Barvaniya
2
Surajgadh
11
Chasagola
8
Ambla
5
Sasan
1
Devaliya
6
Khokhra
4. Pipal to Raidi
1.Ratanghuna to Nanava
6.Valodra to Sandhiyagali
2.Valodra to Adhodya
5. Chodiya to Jamkanniya
3. Khokhra 1 to Khokhda 2
GIS. unit, (W/L) Division, Sasan gir
0
5
10
15 km


MAP : Showing peafowl by sex killed by leopard
LEGEND
peafowl by sex
female (3)
male (9)
stream
Transect_s
Block_boundary
National_Park
3
Raidi
4
Dudhala
9
Alawani
10
Barvaniya
2
Surajgadh
11
Chasagola
8
Ambla
5
Sasan
1
Devaliya
6
Khokhra
4, Pipal to Raidi
6,Valodra to Sandhiyagali
1,Ratanghuna to Nanava
2,Valodra to Adhodya
5, Chodiya to Jamkanya
3, Khokhra 1 to Khokhra 2
GIS. unit, (W/L) Division, Sasan gir
0
5
10
15 km


MAP : Showing Sambar & Wildboar killed by leopard
LEGEND
Kill by Name_animal
Sambar (1)
Wildboar (3)
stream
Transect_s
Block_boundary
National_Park
3
Raidi
4
Dudhala
9
Alawani
10
Barvaniya
2
Surajgadh
4, Pipal to Raidi
6,Valodra to Sandhiragali
1,Ratanghuna to Nanava
2,Valodra to Adhodya
11
Chasagola
8
Ambla
5
Sasan
5, Chodiya to Jamkanniya
1
Devaliya
6
Khokhra
3, Khokhra 1 to Khokhda 2
GIS. unit, (W/L) Division, Sasan gir
0
5
10
15 km