ECOLOGY OF THE ASIATIC LION

(*Panthera leo persica*)

Thesis
submitted to the
Saurashtra University

for the degree of
Doctor of Philosophy

in
Experimental Biology

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I have great pleasure in forwarding the thesis of Mr. Ravi Chellam titled "Ecology of the Asiatic lion (*Panthera leo persica*)", for acceptance for the degree of Doctor of Philosophy in Experimental Biology. The thesis embodies original findings and interpretation of facts. This research was carried out by Ravi Chellam under my supervision and has not previously formed the basis for the award of any degree.

Forwarded through:

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Dedicated to late Prof. R.M. Naik,
who made an invaluable contribution
to the cause of conservation in Gujarat.

CONTENTS

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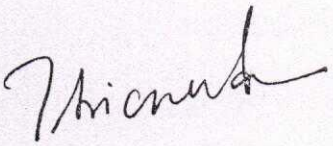
Conducting field research amongst the lions in the Gir forest was a most exhilarating experience for me and I am eternally grateful to the lions and other wildlife for allowing me this privilege.



Ravi Chellam

CHAPTER I

INTRODUCTION

I.1 Introduction:

The sole, free-ranging, wild population of Asiatic lions (*Panthera leo persica*) in the Gir forest, its conspecifics and the habitat have been the focus of ecological research (Hodd 1970; Joslin 1973, 1984; Berwick 1974, 1976; Government of Gujarat 1975; Sinha 1987; Berwick 1990; and Khan, Rodgers, Johnsingh & Mathur 1990) especially when compared with other large carnivore species and their habitats in India. Given this background, another study on the ecology of the Asiatic lions could be regarded as superfluous.

The ecological conditions in India are gradually degrading due to growing anthropogenic pressures. In this context conservation of wildlife and its habitat, for various ecological and economic reasons, assumes paramount importance. To effectively manage wildlife, especially a large carnivore like the Asiatic lion, requires knowledge of its various ecological needs, in particular its food, space and habitat requirements. The available data on the predation ecology, ranging patterns and habitat use of the Asiatic lion was inadequate and this study was launched to fill this gap in our knowledge of the lion's ecology.

India is divided into ten broad biogeographic zones which are sub-divided into 25 biotic provinces (Rodgers & Panwar 1988). The carnivore species assemblage (26 genera with 55 species) reflects this tremendous diversity in habitat availability. A total of 15 species of felids occur in India, of which 4 species belong to the genus *Panthera*,

referred to as the large or roaring cats. Of the remaining eleven, 10 belong to the genus *Felis* or the small cats. The fifteenth species is the clouded leopard (*Neofelis nebulosa*). The cheetah (*Acinonyx jubatus*) became extinct in India only in 1948 (Roberts 1977). Almost all the large cats are facing threats to their long-term survival (Johnsingh 1986). The Asiatic lion in particular is critically endangered due to a variety of reasons (Ravi Chellam & Johnsingh in press). The endangered status of the Asiatic lion is best illustrated by the fact that there is only one free ranging population of less than 300 individuals in the Gir forest and this habitat is surrounded by a growing human population. There has also been an escalation in the lion-human conflicts (Saberwal, Ravi Chellam, Johnsingh & Rodgers 1990; and Saberwal, Gibbs, Ravi Chellam & Johnsingh in prep.) and it is vital that this lion population and its habitat receives the utmost and immediate management care.

I.2 Historical Distribution of the Asiatic Lion:

The earliest lionlike species occurred approximately 1.8 million years ago, as evidenced by Villafranchian deposits of lions in Europe during early Pleistocene (Savage & Russell 1983). The oldest true lions (*Panthera leo spelaea*) evolved about 600,000 years ago and was distributed throughout Europe, across Asia, and into Alaska (Kurten 1968; and Neff 1983). O'Brien, Martenson, Packer, Herbst, de Vos, Joslin, Ott-Joslin, Wildt & Bush (1987), estimated the genetic distance between the African and Asian subspecies of lions using electrophoretic techniques. Their allozyme genetic distance estimates between African and Asian subspecies were low and they stated that the two subspecies shared a common ancestor recently, estimated at between 50,000 and 200,000

years before the present. Due to these low distance values and the failure to detect any subspecific allozyme markers, O'Brien, Martenson *et al.* (1987) state that there is no evidence to suggest that sufficient time has elapsed in the history of these subspecies for specific genetic isolating mechanisms to have developed.

Joslin (1973) has reconstructed the historical distribution of the Asiatic lion based on an exhaustive review of hunting records of the last 200 years (**Fig. I.1**). The Asiatic lion ranged from Syria through Iraq, Iran, Pakistan and most of northern and central India. Reliable records are lacking for their existence in Afghanistan and areas further north. It is extremely doubtful that lions ever occurred in the Arabian peninsula. The Tigris and Euphrates river valleys in Iraq and the adjoining coastal areas of Iran, supported a large lion population. The Asiatic lion attained its most extensive distribution in India, having ranged over the present day states of Rajasthan, Gujarat, Haryana, Punjab, Uttar Pradesh and Madhya Pradesh. They have also been reported at least once from Bihar and Orissa. The river Narmada seems to have been the southern limit of its distribution in India (Joslin 1973). The lion population should have numbered in thousands as reflected in the numbers shot (in Kinnear 1920). Fenton (1909), Kinnear (1920), Pocock (1930) and Joslin (1973) document the decrease in numbers and the distribution of the lions in the then unpartioned India (**Fig. I.2**). All of them are unanimous in identifying uncontrolled shooting of lions, fragmentation and destruction of the lion habitat by human activities (largely conversion into agricultural settlements) as the reasons for this rapid and pronounced decline in the conservation status of the Asiatic lions.

By 1885 the Asiatic lion had become extinct in Syria but was common in Iraq and rare in India. By 1891 it was shot out of the entire Asia Minor region. In India the last lion in central India was shot near Goona in 1873 (Kinnear 1920). Either by 1878 (Nurse 1901) or latest by 1888 (Lydekker 1895) the last lions outside the Gir forest had been shot. For more than the last one hundred years, all the Asiatic lions in India have been restricted to the Gir forest in the Saurashtra peninsula, Gujarat state. The last reports of the Asiatic lions outside India were by Heaney (1944) and Champion-Jones (1945). Both the sightings were in the same area, north of Dizful in Iran and were made in December 1941 and May 1942 respectively.

I.3 Population Trend of the Lions in the Gir Forest:

In tropical forests due to the dense vegetation, difficult terrain and the secretive habits of the animals, making a reliable estimate of the population of wild animals is a very demanding and difficult exercise. The difficulty is compounded when wide ranging large carnivores like the lion, which are largely nocturnal, have to be counted. Using the Bandipur Tiger Reserve as an example, Karanth (1987, 1988) has shown that the currently quoted census figures for the various wildlife reserves in India are unreliable. In assessing the conservation status of endangered species it is of greater importance to be aware of the population trend of the target species rather than deal with exact numbers.

Numerous people have estimated the lion population in Gir using various methods through the last 100 years or more (**Table I.1**). These estimates are unreliable due to the use of inconsistent and scientifically unproven methods. Nevertheless these figures

highlight the drastic reduction in the Gir lion population in the late nineteenth and early twentieth century. Wynter-Blyth & Dharmakumarsinhji (1950) quote numerous estimates from the Junagadh state records for the lion population in Gir, for the period 1880 to 1936. The lion population seems to have been at its lowest (about 12) in 1880. The population persisted at a low level and it was estimated to be fifty in 1920. By 1936, the population had recovered and registered a significant increase to 287 lions. After 1936 the lowest estimate for the population was 177 in 1968 (Dalvi 1969), since then the lion population has been steadily increasing. The 1990 census conducted by the Gujarat Forest Department (GFD) estimates the population to be 284. All the population estimates till 1936, were only of the lions resident in the Junagadh state. Lions were definitely found in the forests extending into the adjacent states of Jetpur, Baroda and Bhavnagar. Hence the numbers in **Table I.1** should be considered as only the minimum estimates for the lion population in the Gir forest as a whole.

The survival of the Asiatic lion in Gir was made possible by the timely protection afforded to it by the then Nawab of Junagadh, beginning from 1900. For long periods, a complete ban on the shooting of lions was enforced and it was relaxed with a very small bag limit as the lion numbers increased. Since 1955, the Government of India has placed a total ban on the killing of lions. The GFD has been sparing no efforts at providing protection to the lions and the Gir habitat.

I.4 Demographic Contraction and its Impact on the Genetic Diversity of the Lion Population:

Drastic reduction in the numbers of isolated mammalian populations, results in inbreeding which leads to an erosion of the genetic diversity of the species thereby

exposing it to increased risk of extinction (Terborgh & Winter 1980). O'Brien, Goldman, Merril, Bush & Wildt (1983) have shown that the cheetah has almost completely lost its genetic diversity. O'Brien, Roelke, Marker, Newman, Winkler, Meltzer, Colly, Evermann, Bush & Wildt (1985) have highlighted the genetic basis for species vulnerability in the cheetah. The population history and the available genetic information of the Asiatic lions closely mirrors that of the cheetah's. Wildt, Bush, Goodrowe, Packer, Pusey, Brown, Joslin & O'Brien (1987) based on their studies of the Asiatic lions in the Sakkarbaug zoo, Junagadh; which holds pure-bred descendants of wild-caught lions from the Gir forest; have established the complete genetic monomorphism of this population. They have also established a direct correlation between genetic variability and two vital physiological traits which govern the reproductive performance of the lions. There was a greater incidence of abnormal sperms (spermatozoa with a tightly coiled flagellum or deranged mid-piece) in the electro-ejaculates of the Asiatic lions, when compared with that of two populations of African lions (*Panthera leo leo*) in the plains of Serengeti National Park and the Ngorongoro Crater. The Asiatic lions also had a much reduced level of circulating testosterone, a critical hormone for spermatogenesis. This is an alarming finding and calls for continuous monitoring and scientific management to safeguard the conservation status of the Asiatic lions. Packer, Pusey, Rowley, Gilbert, Martenson & O'Brien (1991) have shown a decrease in the reproductive performance of a wild population of lions in the Ngorongoro Crater, Tanzania, as a result of decreasing heterozygosity which was caused by a population bottleneck. Thus, loss of genetic variation with its attendant

negative attributes is inevitable in small populations, but attempts should be made to ameliorate these negative impacts by prudent management (Ravi Chellam & Johnsingh in press).

I.5 Differences between African and Asiatic Subspecies of Lions:

The Asiatic lion has a few characteristic morphological and osteological features that have been considered diagnostic for the subspecies and distinguishes it from the African lion (Pocock 1930). The Asiatic lion has a prominent fold of skin that spans the length of the abdomen; the abdominal or belly fold is seldom observed in African lions. The belly fold is clearly visible in both male and female Asiatic lions but it is more prominent in the males (**Plates I.1 & I.2**). The skulls of Asiatic lions collected from the Gir forest, often have a bifurcation of the infraorbital foramen (**Fig. I.3**). This is not an universal occurrence with the lion skulls from Gir but it has never been recorded so far with the skulls of African lions. Male Asiatic lions seldom grow a full and luxuriant mane, especially at the top of the head. Their ears are always clearly visible and not covered by the mane (**Plate I.1**). This is not such a distinct distinguishing character between the Asiatic and African lions. Despite the historical classification of Asiatic and African lions into numerous subspecies, the current opinion is to classify all African lions into a single subspecies *Panthera leo leo* and the Asiatic lions as *Panthera leo persica*.

I.6 Review of Past Research in the Gir:

Naturalists have been writing extensively about the Asiatic lions and the Gir forest for about one hundred years now. Numerous accounts can be found in the British Administrative Records and the Junagadh State Records. Similarly the Journal of the

Bombay Natural History Society has published many articles on the Gir and the lions. Ecological research in the Gir began only in the late 1960s. Joslin's (1973) study focused on the ecology and behaviour of the lions. The major studies were of the habitat, availability of wild and domestic prey, food habits based on faecal analysis, lion predation on domestic stock, the inter-relations between lions and people living in the area, lion population dynamics and general behaviour. Hodd's (1970) research was on the vegetation and the ecological impact of domestic stock on the Gir habitat. Using exclosures he determined the productivity and regenerating capabilities of the vegetation when protected from grazing. Determining the food habits of livestock and wild ungulates during the hot, dry season and to investigate the factors limiting the wild ungulate population of the Gir forest was the focus of Berwick's (1974) study. Rao (1983) and Habibullah (1984) have done work on the phytosociology and productivity of some of the tree species in the Gir. Sinha's (1987) research examined various aspects of the ecology of the Asiatic lion and determination of the food habits of the lions and their movement patterns were his major objectives. Khan (Khan, Rodgers, Johnsingh & Mathur 1990) carried out a collaborative study with my research (February 1987 to May 1989) on the ungulates and their relationship with various habitat factors in Gir. Berwick (1990) reports on the impact of the Maldhari pastoralists on the Gir ecosystem and the socio-economic conditions under which they existed in the 1970s. She also explores the various management options to reduce the inherent conflicts between the maldhari lifestyle and the conservation of the Gir habitat.

I.7 A Brief Description of the Study and Organisation of the Thesis:

The major objectives of my study were to assess the predation ecology, habitat use and the ranging patterns of the lions in the Gir forest. The ultimate and long-term goal of this research effort was to examine the feasibility of a translocation effort in an attempt to establish a free ranging population of lions away from the Gir forest. The ecological data generated would enable the assessment of prospective translocation sites and insights gained about lion behaviour would be invaluable in the planning and implementation of the translocation. A thorough understanding of the prey and space requirements of the lions is essential for their effective conservation and to attempt the establishment of a second free ranging population. Associated information on lion group size and social organisation was also collected. Wild ungulate populations were estimated. Data was collected on the ecology of leopard (*Panthera pardus*) and a record of the sightings of all the carnivores was maintained.

This study was designed to have an extensive scope, to generate base line data for planning the management of the Gir forest and the lions. While such a study has its advantages, it also has severe limitations, in that the ecology and behaviour of individual lions and prides could not be studied in a sustained manner, as it has been done in Serengeti National Park (Schaller 1972; Bertram 1973, 1975a; Hanby & Bygott 1987; and Pusey & Packer 1987). There is a need to follow up this study, with a view to understand the inter-pride dynamics and also the dispersal patterns of the lions, amongst many other aspects of lion ecology.

This thesis is organised into seven chapters. Following this introduction, the study area chapter gives a brief conservation history of the Gir forest and details of the topography, vegetation, the Maldharis and the large mammals. The chapter on prey populations describes the census methods and gives the population estimates for various wild ungulates and the resident livestock population. The age and sex composition of the ungulates is also discussed. Chapter four, which is on the predation ecology of the lions, gives an assessment of the lion's diet based on the analysis of their scats as well as the kill remains of the prey killed and eaten by them. The predation ecology of the lion and the leopard is compared to ascertain, how the prey base is partitioned between these two large carnivores. In the next chapter, the social organisation of the lion is discussed and compared with the reported patterns for the African lions from the savanna of east Africa. The observed social organisation is explained on the basis of the lion's predation ecology in Gir. Chapter six, discusses the results of the radio-tracking studies and estimates the seasonal and annual home ranges for the radio-collared lions. Habitat selection by male and female lions through the various seasons is also discussed. The next chapter discusses the management actions that need to be taken to ensure the conservation of the Asiatic lions. A thesis summary containing the salient features of this study and outlining the major findings is the last chapter.

Field work began in March 1986 and was carried out till May 1990, more or less on a continuous basis. The major periods when I was away from Gir were in mid-December 1987 to January 1988, July to October 1988, January 1990 and April 1990. I was assisted by a team of four field assistants and had a 4-wheel drive jeep for

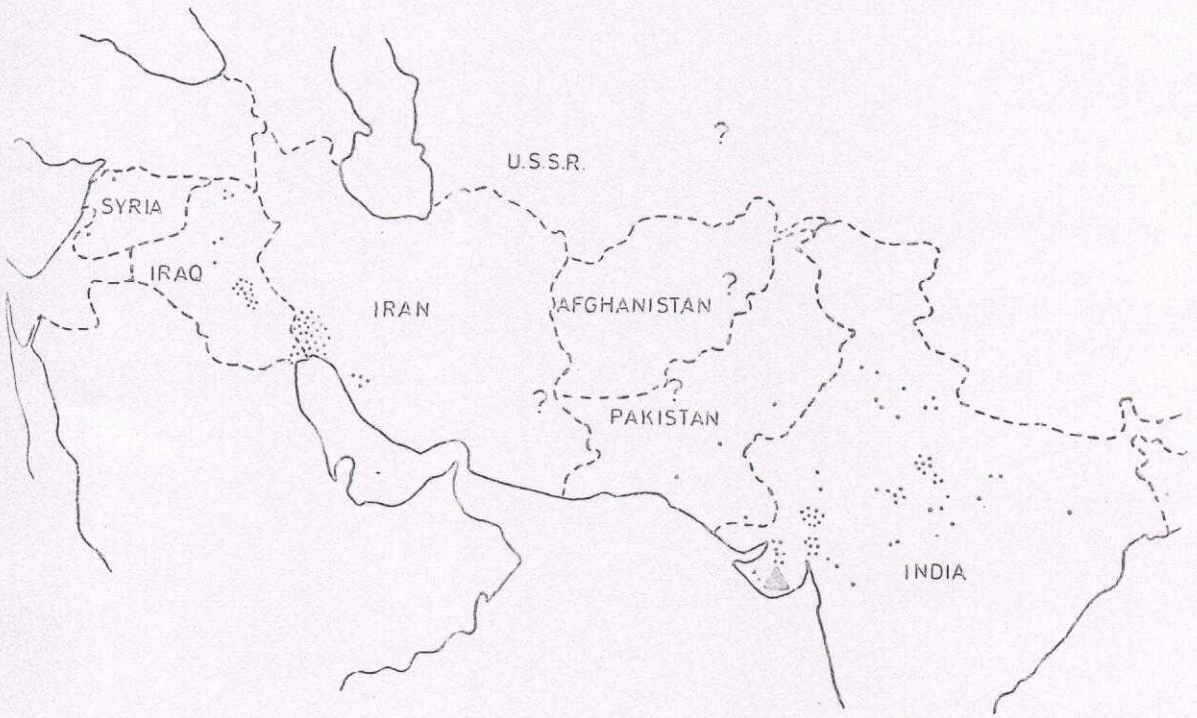
transport. Field work was done both on foot and from the vehicle. A permanent base camp was established at the park headquarters at Sasan (Gir West), while temporary camps were at Chodavadi (National Park) and Bhimchas (Gir East).

Table I.1 Asiatic lion census figures from 1880 to 1990, Gir Forest, India.

Year	Adult		Total	Sub-adult		Total	Cub	Total	Census method used[a]	Source[b]
	Male	Female		Male	Female					
1880								< 12	A	1
1893								31	A	1
1900			11				8	19	A	1
1913								≤ 20	A	1
1920								50	A	1
1936	143	91	234				53	287	B	1
1950			179-187		40 young			219-227	C	2
1955	141	100	241				49	290	C	3
1963	82	134	216				69	285	C	4
1968	60	66	126				51	177	D	4
1974	40	52	92	13	25	38	50	180	D	5
1979	52	68	120	13	14	27	58	205	D	5
1985	66	75	141			50	48	239	D	5
1990	99	122	221				63	284	D	5

a: A = estimate B = pug marks at drinking sites
C = all pug marks D = counts on buffalo baits

b: 1 = in Wynter-Blyth and Dharmakumarsinhji (1950)
2 = Wynter-Blyth and Dharmakumarsinhji (1950)
3 = Wynter-Blyth (1955) 4 = Dalvi (1969) 5 = Gujarat Forest Department



. Confirmed record

? Questionable record

▲ Present location

Figure I.1: Past and present distribution of Asiatic lions, based on records of lions shot or sighted since 1781 (after Joslin 1973).

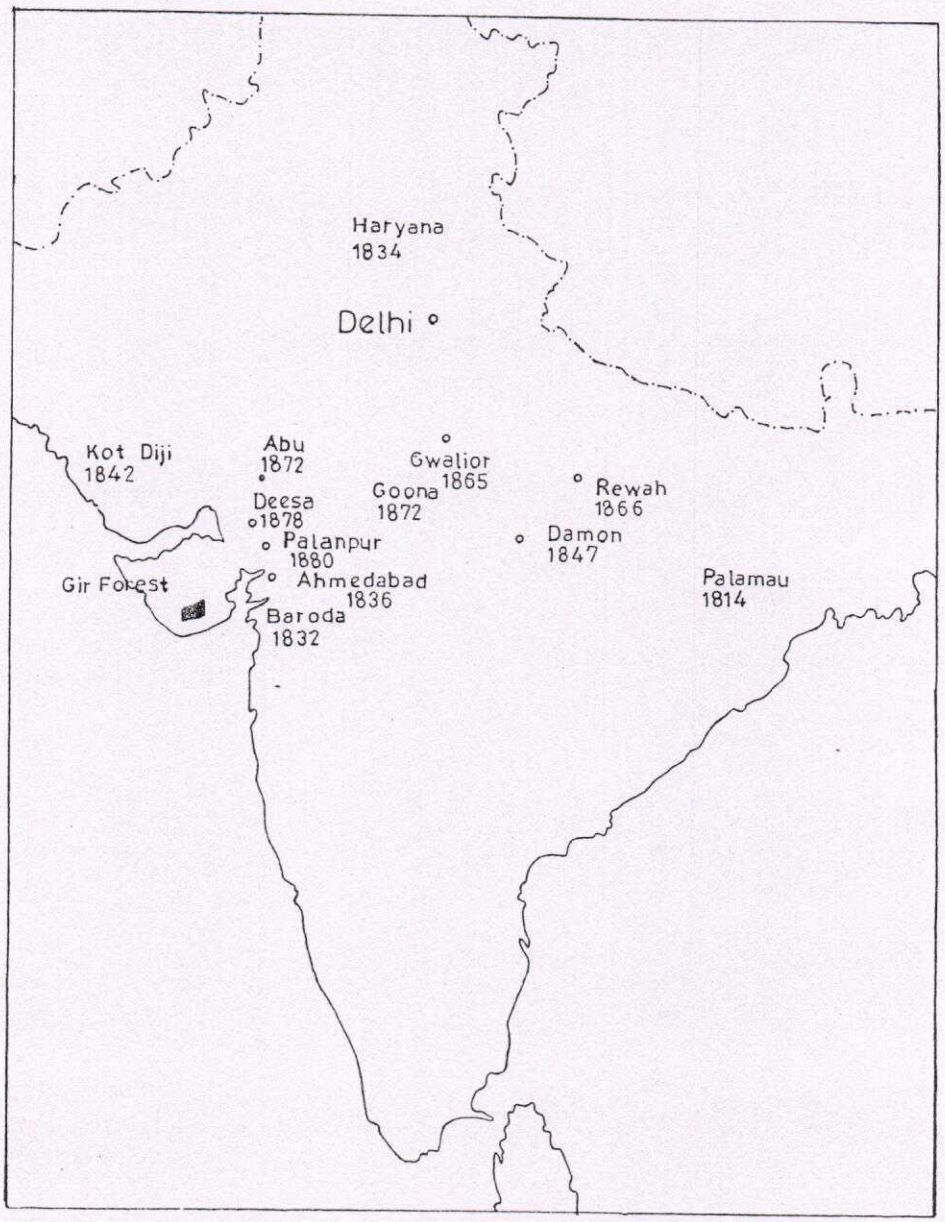


Figure I.2 : Map of undivided India indicating the year when lions were last recorded in different areas in central and northern India (after Pocock 1930).

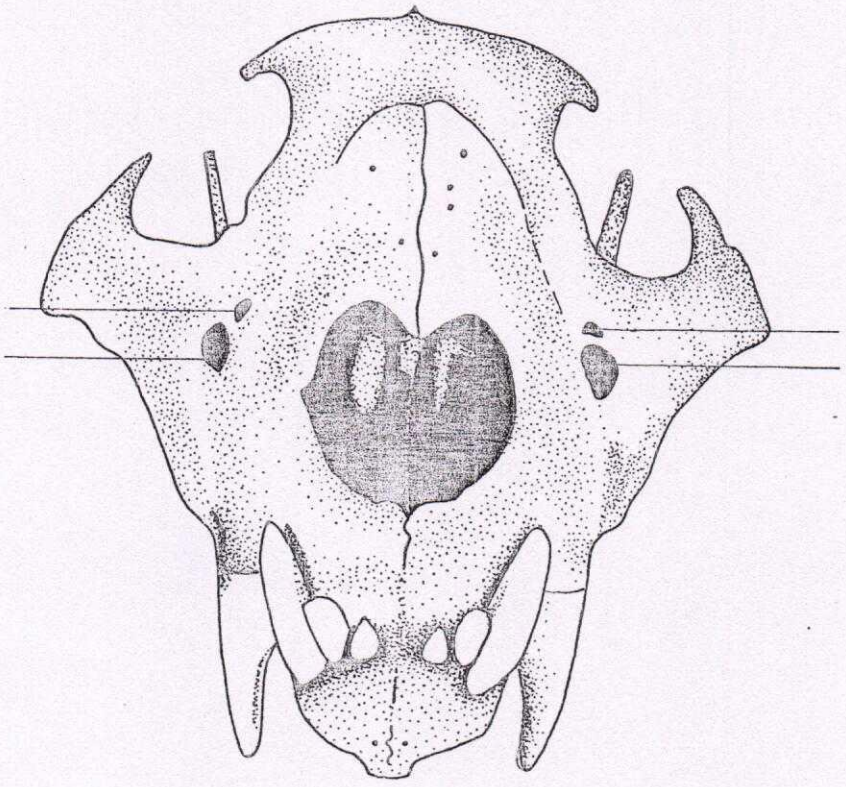


Figure I.3: The paired infraorbital foramen in the skull of a lion from the Gir forest.

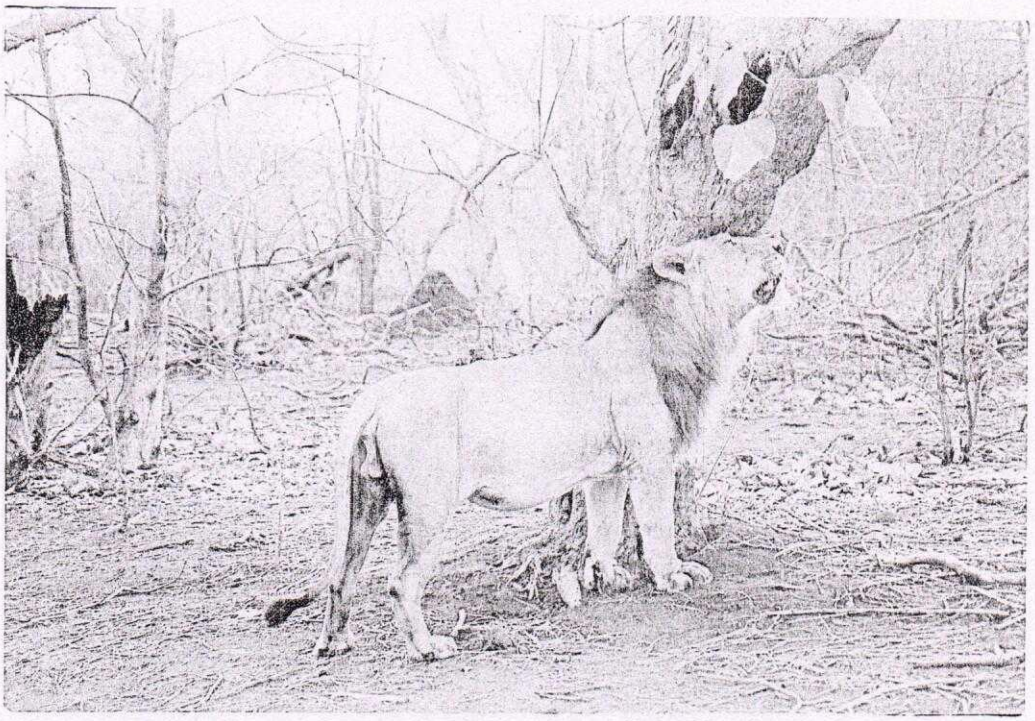


Plate I.1: Adult male Asiatic lion. Note the sparse mane on top of the head and the belly fold.

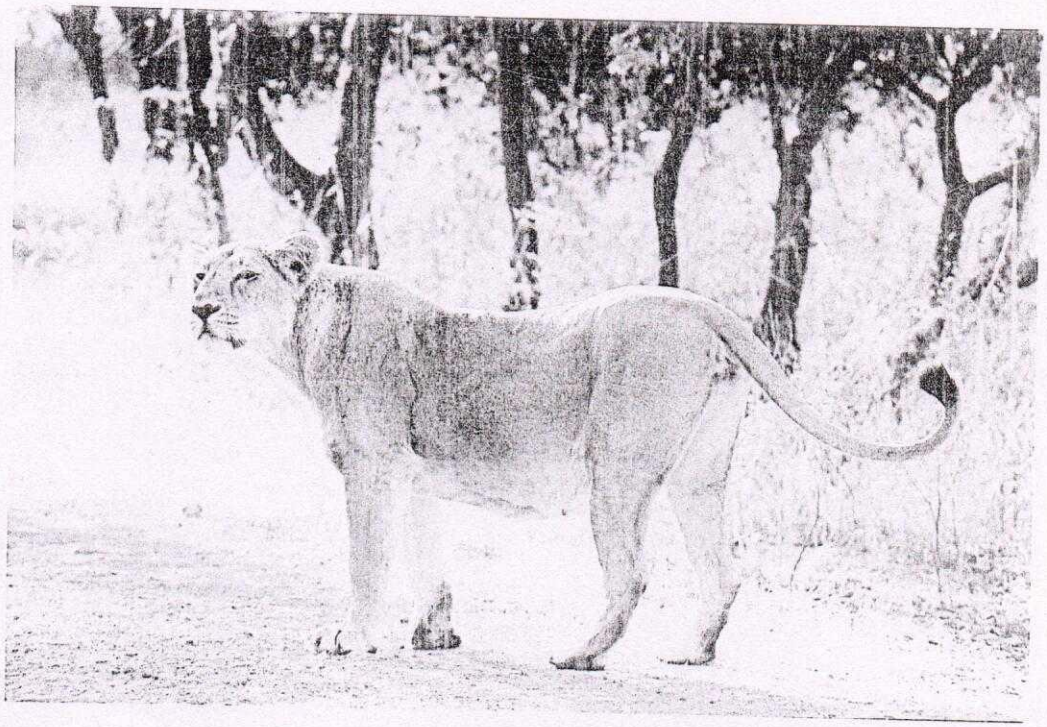


Plate I.2: Adult lioness. The belly fold is clearly visible.

CHAPTER II

THE STUDY AREA

II.1 Location and Size:

The Gir forest is in the western Indian State of Gujarat at 20°57' to 21°20' N latitude and 70°27' to 71°13' E longitude. The forest extends for about 70 km on the west to east axis and on an average for 20 km along the north to south axis. The forest is about 40 km to the north of the coast at Veraval and about 50 km south of Junagadh, the district headquarters (Junagadh district) and a large commercial centre. The Gir is the only remaining patch of natural forest in the entire Saurashtra peninsula and almost all of it has been constituted as a protected area (PA). The Gir Wildlife Sanctuary and National Park cover an area of 1,412.13 sq.km, which includes an area of 258.71 sq.km as National Park (**Fig. II.1**). The Gir PA is in the districts of Junagadh and Amreli.

II.2 History:

Prior to India's independence in 1947, the Gir forest was part of the states of Junagadh, Baroda and Jetpur. The great trigonometrical survey of 1877, estimated the area of Gir forest to be 3,107 sq.km in Junagadh state alone. Since then there has been a drastic reduction in the forest area. This has largely been due to conversion of forests into agricultural and human settlements and deforestation resulting from the increasing demands for biomass being placed by the rapidly increasing human and livestock populations. The forests have been worked for harvesting and planting teak (*Tectona grandis*). The entire area was declared as Reserve Forest in parts, first between 1882 and 1945 by notifications of the former states of Baroda and Junagadh, then again

between 1963 and 1974 by the Government of Gujarat under the Indian Forest Act 1927. In 1920 the Devalia block was declared as a Lion Sanctuary. The Gir Wildlife Sanctuary was established in 1965 and the National Park was constituted in 1975 (Government of Gujarat 1975). A notification declaring the intention to upgrade the entire PA to the status of a National Park was issued in 1982.

II.3 Topography and Geology:

The Gir is a series of low hills of volcanic origin. The altitude varies from 131 to 587 m above sea level. The PA is surrounded by flat, arid and extensively irrigated agricultural land. Five perennial rivers drain the PA, Hiran, Shingodah, Macchundhary, Raval and Zamri. All these rivers have been dammed and as a result extensive reservoirs have been created within the PA. Numerous small streams flow through the forest and all of them are seasonal, with few having deep rock pools. During the dry season, water is a limited resource, restricted to the perennial rivers, the deep rock pools and the reservoirs. The Gir forest forms a vital watershed in this semi arid region of Saurashtra. The drainage is oriented east to west and north to south. For my research purposes, I classified the terrain into six categories:

1. Flat plain
2. Gentle slope
3. Steep slope
4. Hill top
5. River bed
6. Reservoir bed

Location of kills made by lions and leopards and all animal locations including the radio locations of the lions were categorized into one of the above terrain types.

The chief geological formation is Deccan trap. It occurs in two varieties of formation, acidic dyke and basic dyke. The prevailing rock is dolomite or basalt. Limestone is also of common occurrence. Other rocks found scattered and sometimes occurring as a complex formation are gneiss, quartzite, quartz and feldspar (Joshi 1976).

Soils range from lateritic soil in much of the north and east of the Gir, to black cotton soil in the south west and along many of the valley floors.

II.4 Climate:

The climate of Gir is hot and greatly influenced by the monsoon, which is erratic. The monsoonal winds bring rain between mid-June and September. The rainy season is followed by a hot and humid post-monsoon season which extends till mid-November. The cool dry winter lasts till end of February, with the hot summer lasting till the monsoon arrives. During peak summer the day time temperature is around 45° C, while during the winter nights, it can drop to less than 10° C (**Fig. II.2**). The monsoon is unpredictable and approximately every sixth year is a drought. During the study, 1987 experienced deficient rainfall (199 mm at Kamaleshwar reservoir) resulting in severe drought conditions. In 1988, Gir received bountiful rainfall (1343 mm at Kamaleshwar reservoir) and all the reservoirs overflowed. In 1989, Gir received normal rainfall.

There is a rainfall gradient on a west to east axis. Data from Kamaleshwar reservoir in the western region, for the past 29 years and Raval reservoir in the eastern region, for the past 10 years, shows the average annual rainfall to be 1,013 mm and 633 mm respectively (**Table II.1**).

II.5 Vegetation:

The Gir forest can be broadly divided into two major vegetation types. The western two-thirds of the forest is dominated by stunted teak (**Plate II.1**), in association with various other species, chiefly *Acacia*, *Zizyphus*, and *Terminalia*. The remaining eastern portion consists of a grassland savannah interspersed with patches of thorn (*Acacia* and *Zizyphus*) (**Plate II.2**) and dry deciduous forests (*Anogeissus latifolia*) and *Boswellia serrata*), teak is absent in this region. The understorey is often sparse in the more densely wooded areas but shrubs like *Carissa opaca*, *Capparis sepiaria* and *Helicteres isora*, along with various grass species dominate the understorey in other areas. Evergreen riverine forests are found along the banks of most of the rivers and streams. *Syzygium rubicundum*, *Pongamia pinnata*, *Manilkara hexandra* and various other species are found in the riverine tracts (**Plate II.3**). The canopy height and canopy cover of the forest in the east are much lesser than that of the forest in the west. This could be a function of the lesser rainfall received in the east (**Table II.1**). The vegetation is classified as 5A/CI (very dry teak forest), 5/DSI (dry deciduous scrub forest) and 5/DS2 (dry savannah forest) by Champion & Seth (1968). I classified the vegetation into eleven broad categories:

1. Riverine forest
2. Teak forest
3. Acacia-Zizyphus woodland
4. Mixed forest
5. Acacia woodland
6. Scrubland
7. Teak-Acacia-Zizyphus woodland

8. Teak-Mixed forest

9. Teak-Acacia woodland

10. Open land

11. Agricultural land

Table II.2 gives the details of the vegetation classification mentioning the distribution of these vegetation types and the characteristic species found in each type. All animal locations and the location of kills made by the lions and leopards were classified into one of these eleven vegetation types. As the water level receded in the reservoirs, the exposed areas of the reservoir beds was available for use by lions (**Plate II.4**). These areas had limited vegetation, restricted to forbs and short grasses and were classified as Open land. This classification of vegetation is very broad and made on the basis of ocular estimation. This classification has been devised to assist in the interpretation of data on the predation ecology and habitat use by the lions.

The forest undergoes a dramatic transformation during the monsoon season. It has a luxuriant green appearance with all the trees and shrubs sprouting a full complement of leaves. This is also the growth season for the grasses. A couple of months after the monsoon and latest by November the forest begins to turn brown and especially during the hot and dry summer it has a degraded appearance. Since the Gir forest was earlier worked for timber, even now there are a few plantations of teak and other species like *Ailanthus excelsa*. In an effort to improve the forage availability the GFD has also planted various indigenous fruit bearing and fodder tree species. The incidence of forest fires is an annual feature in the Gir. Usually these are ground fires and the GFD is able

to control these fires. At times the fires do burn extensive patches of forest depleting fodder availability. In 1988 extensive areas were burnt.

II.6 Fauna :

The Gir forest has a diverse assemblage of wildlife. This section lists only the larger mammalian fauna. Apart from the lion, the other carnivores are leopard, jungle cat (*Felis chaus*), rusty spotted cat (*Felis rubiginosa*), striped hyena (*Hyaena hyaena*), jackal (*Canis aureus*), Indian fox (*Vulpes bengalensis*), ratel (*Mellivora capensis*), common mongoose (*Herpestes edwardsii*), ruddy mongoose (*Herpestes smithii*) and small Indian civet (*Viverricula indica*). The wild prey base for the larger carnivores comprises of chital (*Axis axis*), sambar (*Cervus unicolor*), nilgai (*Boselaphus tragocamelus*), chousingha (*Tetracerus quadricornis*), chinkara (*Gazella gazella*), wild pig (*Sus scrofa*), common langur (*Presbytis entellus*), porcupine (*Hystrix indica*), rufous tailed hare (*Lepus nigricollis ruficaudata*) and a large sized bird in peafowl (*Pavo cristatus*).

II.7 Administration:

The Gir Wildlife Sanctuary and National Park have been divided into 14 ranges and 38 blocks. The Conservator of Forest (Wildlife) based in Junagadh is the person responsible for matters relating to the administration and management of Gir PA. He has three Deputy Conservator of Forest (DCF) working under him. For protection purposes, the Gir is divided into two divisions, Gir West and Gir East. The territorial DCF of Gir West is based at Junagadh, and of Gir East at Dhari. The third DCF (Wildlife) is in-charge of matters related to wildlife management and is based at Sasan and holds an overlapping responsibility. The territorial DCFs are responsible for

protection work, fire and waterhole management, payment of compensation for livestock kills and attacks on people, management of maldharis and maintenance of roads and buildings. The DCF at Sasan is responsible for the management of tourism, conducting nature education camps, maintenance of the wireless network, and for the capture of problem-causing lions and leopards outside the PA. A field staff of about 300, including Range Forest Officers, Foresters and Guards are engaged in the protection and management of the PA.

II.8 People:

The maldharis, the local pastoralists are resident in the Sanctuary area of the PA, in thorn-enclosed settlements called ness. A ness is usually a cluster of 4 to 8 houses constructed out of mud and locally available timber and grass. A ness is often located on high ground, close to a perennial source of water, which is usually a river. At present, 2,200 maldharis live in 74 nesses with a resident livestock of about 14,000 (B.J. Pathak unpublished). Thirty six nesses with a maldhari population of ca. 1,200 and a livestock population of about 5,500 are resident in Sanctuary West while Sanctuary East has 38 nesses with ca. 1,000 maldharis with ca. 8,300 heads of livestock. Maldharis largely keep buffaloes and a few cattle and a camel or two, which they use as a beast of burden. The maldharis graze their herds in the Sanctuary area (**Plate II.5**) and a few sell the milk produced, directly to a co-operative dairy while the majority convert it into ghee (clarified butter) and then sell it.

The maldharis were semi-nomadic before the GFD placed restrictions on their movement, in an effort to reduce the impact on the vegetation by the maldharis and

their livestock. Most of the maldharis belong to tribes like Charan, Bharwad, Rabari, Ahir and Kathi. The present status and lifestyle of the maldharis can be termed as backward, especially with reference to access to health care and education.

The maldhari livestock are grazed in the forest during daytime. Gir being a semi arid habitat and as the vegetation is largely dry deciduous or thorn forest, grass availability is limited to a few months in a year. Maldharis lop the trees to supplement the forage available to their herd. This practice often results in the felling of trees (**Plate II.6**). The lopping and felling of trees for fodder by the maldharis is pronounced during the droughts as there is an acute shortage of grass, this can have an extremely adverse effect on the vegetation. Maldharis supplement the diet of their livestock and especially that of their lactating animals by feeding them concentrates and commercially available cattle feed. Maldharis collect the dung dropped by their livestock from the forest floor and sell it to the farmers outside the PA as biofertilizer. While removing dung, considerable quantities of top soil are also removed. This is an unsustainable export of nutrients from the ecosystem. Trampling by the livestock causes compaction of the soil and destroys seedlings and other understorey vegetation. Lions prey on the livestock of the maldharis. The GFD pays compensation to the maldharis who have lost their livestock to lion predation. Between 1974 and 1979, a maldhari resettlement scheme was implemented by the GFD. Four hundred and fifty five out of 845 maldhari families were given land outside the PA in an effort to rehabilitate these pastoralists as agriculturalists.

Berwick (1990) has done a detailed study of the socio-economic conditions of the maldharis. Apart from the maldharis, the other tribal population resident in Gir is that of the siddhis at Shirvan. Siddhis are of negroid descent. Fourteen Forest Settlement villages also exist within the PA (**Fig. II.1**). These Forest Settlement villages have a human population exceeding 3,600 and livestock numbering about 3,000. Agriculture is the major activity in these villages.

II.9 Current Uses of the Forest:

Apart from wildlife conservation the Gir PA is used for firewood, minor forest produce and grass extraction. The maldharis and a great majority of the villagers around the Gir PA are dependent on the forest for their fuelwood. The GFD also collects fallen timber and sells it to the local population to meet their fuelwood demand. Grass is also harvested by the GFD and supplied to people outside the PA. Numerous people enter the forest during the fruiting of trees like *Syzygium rubicundum*, *Zizyphus mauritiana* and *Phyllanthus emblica* to collect the fruits. The forests are grazed not only by the livestock of the resident maldharis but also by the livestock from the villages close to the PA boundaries. The PA is visited by approximately 45,000 tourists and 80,000 pilgrims every year (S. Tikadar and B.J. Pathak pers. comm.). Pilgrims visit the large temples at Kankai, Banej, Tulshishyam and Patla Mahadev (**Fig. II.1**). The five reservoirs store water. Three highways and a railway track run through the PA.

The GFD used to offer buffalo baits to lions. This was to attract them close to the road or to open areas to facilitate viewing by tourists. This the "Lion Show" was a much criticized practice. It gave the public a distorted opinion of the lions as they saw

it under artificial and contrived conditions. The lion shows were stopped in June 1987. Presently there is a move to restrict tourists to a fenced area in Devalia block (**Fig. II.1**) which has a population of ungulates of Gir and where a few captive bred lions have been released.

Table II.1 **Mean annual rainfall recorded at two sites within the Gir Protected Area.**

PLACE	PERIOD	MEAN ANNUAL RAINFALL
Kamaleshwar Reservoir Sanctuary West	1960-1988	1012.9 mm
Raval Reservoir Sanctuary East	1979-1988	632.6 mm

Table II.2 **Broad vegetation types, their distribution and composition in the Gir Protected Area.**

VEGETATION TYPE	DISTRIBUTION	CHARACTERISTIC SPECIES
1. Riverine forest	On the banks of major rivers and streams all over the PA.	*Syzygium rubicundum* *Pongamia pinnata* *Manilkara hexandra*
2. Teak forest	Hills and plains (plantations), Sanctuary West and National Park	*Tectona grandis*
3. Acacia-Zizyphus woodland	Plains, gentle slopes and hills, Sanctuary East	*Acacia nilotica* *Acacia catechu* *Zizyphus mauritiana* *Zizyphus xylopyrus*
4. Mixed Forest	Valleys, Sanctuary East	*Butea monosperma* *Anogeissus latifolia* *Terminalia crenulata* *Acacia catechu*
5. Acacia woodland	Plains and gentle slopes, especially bordering reservoirs, entire PA	*Acacia nilotica* *Acacia leucophloea*
6. Scrubland	Degraded forest, largely along the PA boundary in Sanctuary West. More widespread in Sanctuary East	*Zizyphus nummularia* *Dichrostachys cinerea* *Acacia nilotica*
7. Teak-Acacia-Zizyphus woodland	Plains, Sanctuary West and National Park	*Tectona grandis* *Acacia senegal* *Zizyphus mauritiana* *Acacia nilotica*
8. Teak-mixed forest	Valleys, Sanctuary West and National Park	*Tectona grandis* *Terminalia crenulata* *Anogeissus latifolia* *Acacia leucophloea*
9. Teak-Acacia woodland	Hills, Sanctuary West and National Park	*Tectona grandis* *Acacia catechu* *Boswellia serrata* *Sterculia urens*
10. Open	Exposed areas of reservoir beds when the water level drops, entire PA	-
11. Agricultural land	Along the PA boundaries, in Forest settlement villages and outside PA	-

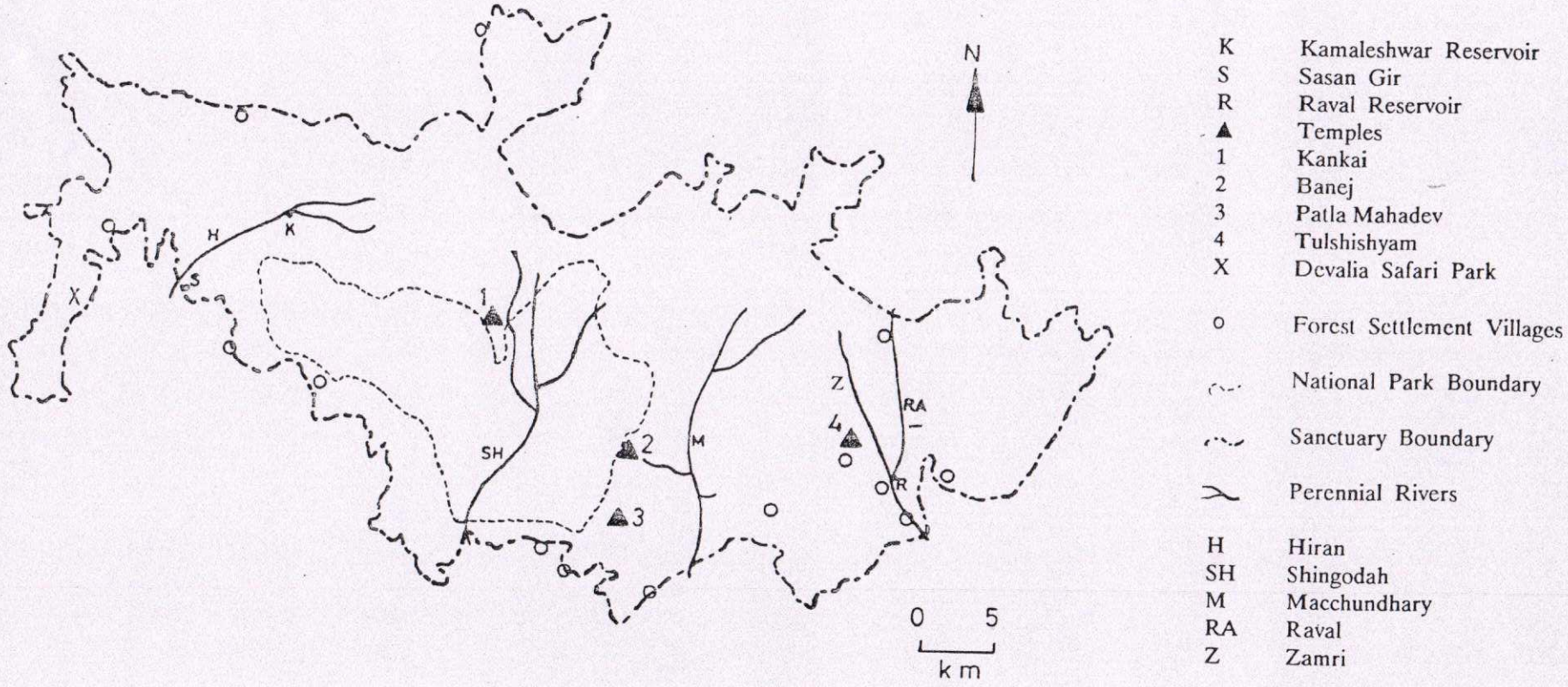


Figure II.1 : Map of the Gir Protected Area.

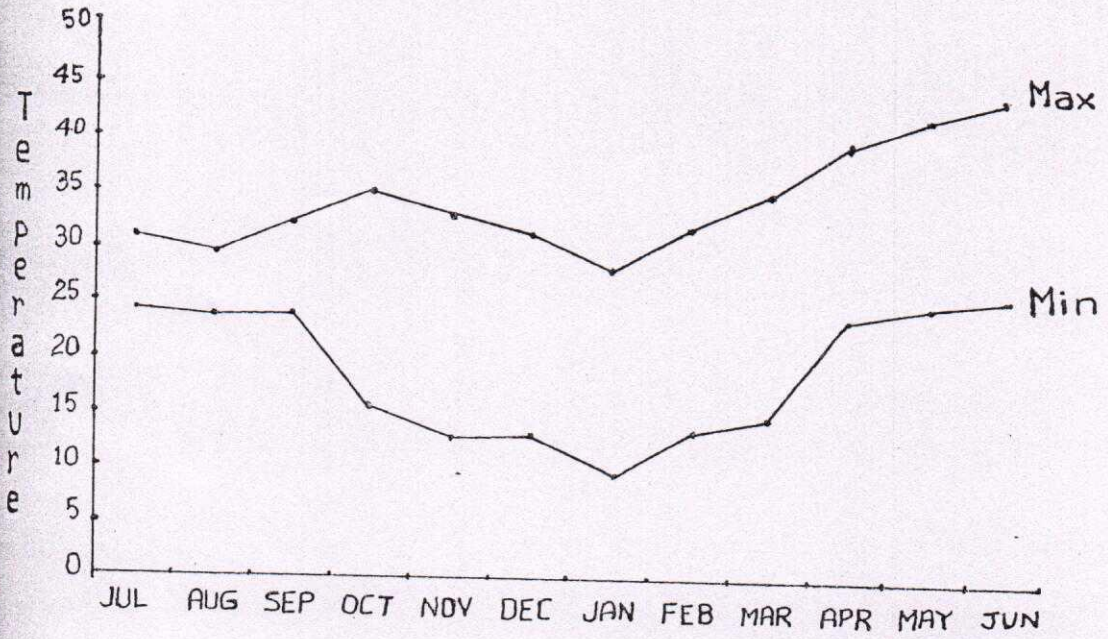


Figure II.2: Maximum and minimum temperatures (°C) recorded in Sasan Gir, Sanctuary West, July 1987 to June 1988.

Plate II.1: Dry teak dominated forest in Sanctuary West.

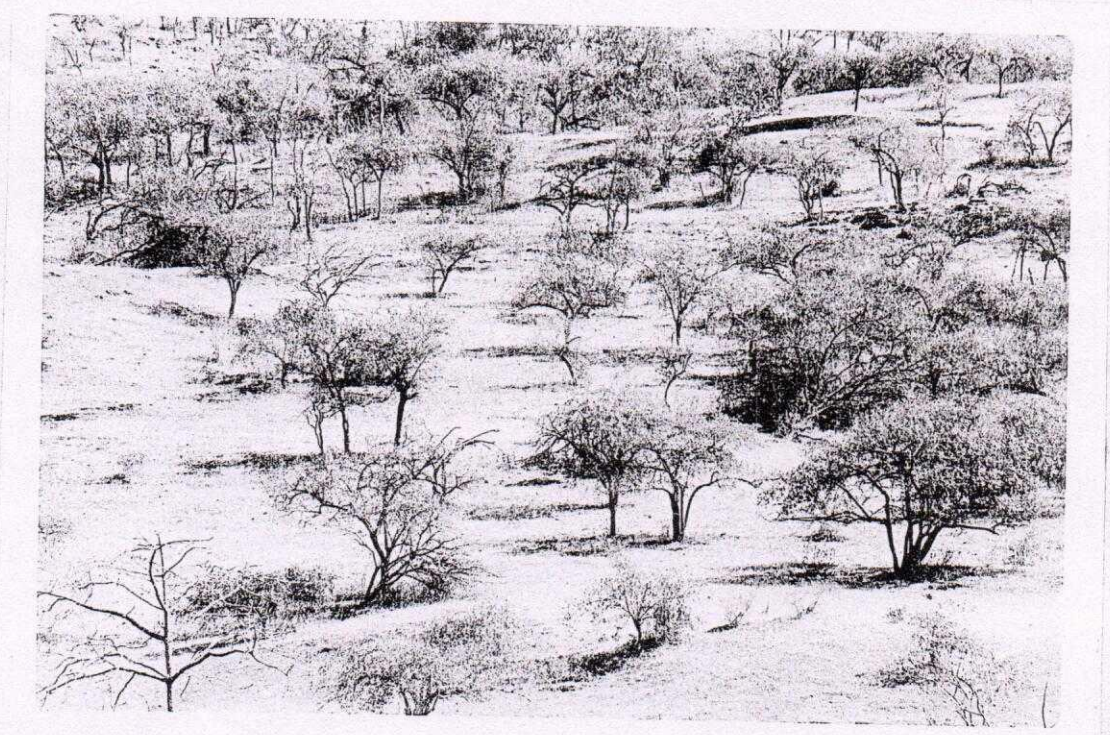


Plate II.2: Acacia-Zizyphus woodland in Sanctuary East.

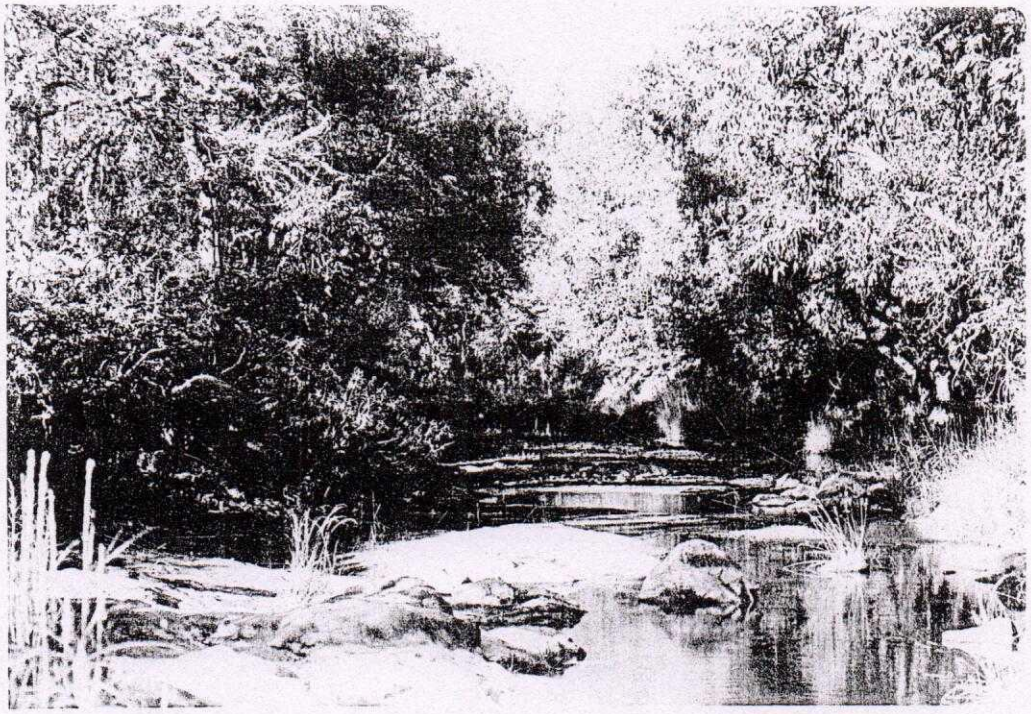


Plate II.3: Riverine forest, a crucial habitat for lions.

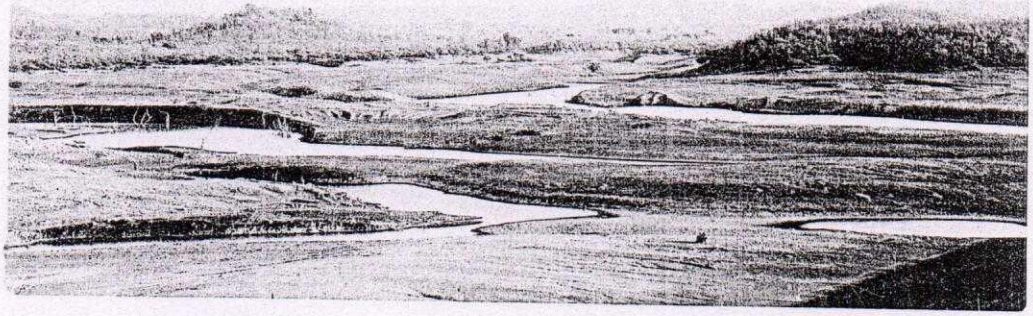


Plate II.4: Exposed portions of the Kamaleshwar reservoir, a habitat which is only available seasonally for lions.

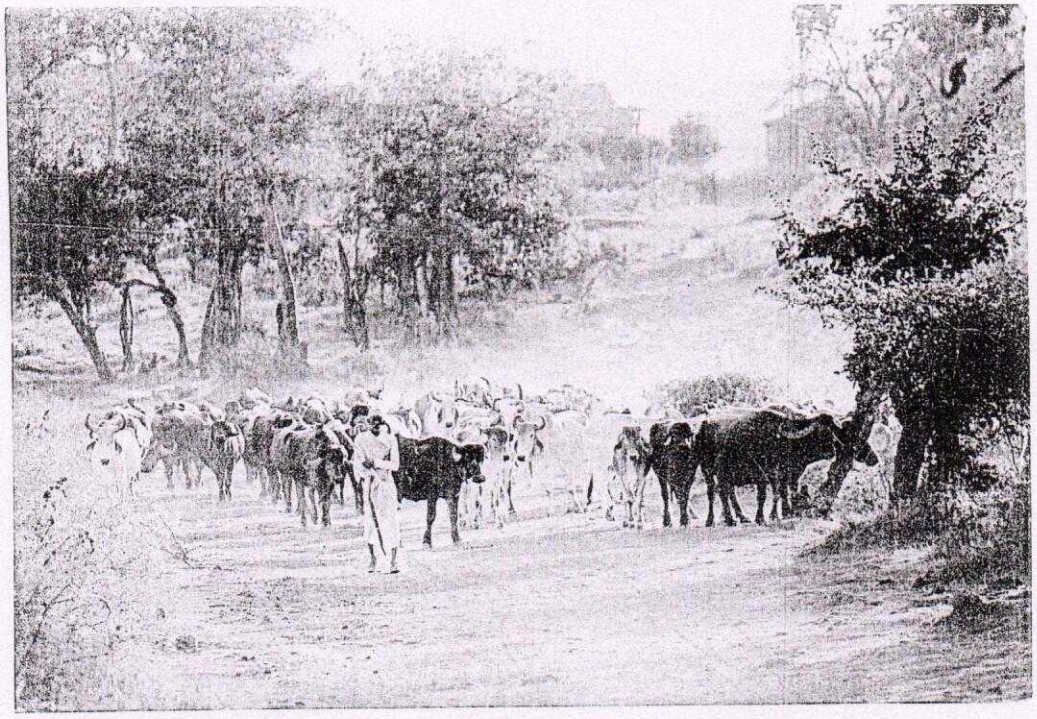


Plate II.5: A maldhari leading his herd for grazing in the forest.

Plate II.6: Trees lopped and cut by the maldharis to provide forage for their livestock.

CHAPTER III

PREY POPULATION

III.1 Introduction:

The suitability of a habitat for a predator or what is also referred to as habitat quality is often reflected by the abundance of the prey species. The prey base is by far the most crucial requirement for the survival of a thriving population of predators. To understand the predation ecology of the lion it was essential not only to gather data on the kills made by the lions and from lion scats to determine the food habits of the lions (refer Chapter IV) but also to gather information on the population size and age and sex composition of the prey species (to know what is available). This would enable the determination of prey choice by the lions and also their predation on specific sex and age classes of each species. Joslin (1973) and Berwick (1974) had earlier estimated the wild ungulate population in Gir. Joslin (1973) estimated that 5,550 wild ungulates inhabited the Gir forest and this was in close agreement with Berwick's (1974) estimate of 6,242 wild ungulates in Gir. These counts were made in the early 1970s and hence it was imperative to do a fresh count to estimate the wild ungulate population. This part of the research was a collaborative effort with J.A. Khan who was studying the ungulate-habitat ecology in Gir.

The ungulate community in Gir is an interesting group of animals. Chital, which is by far the most commonly encountered animal is a species endemic to the Indian subcontinent and is a generalist in its diet. It reaches its highest levels of abundance in areas with a large proportion of grassland-forest edge (Rodgers 1988). Sambar and wild

pig draw their origins from the Oriental realm. Sambar is an animal basically adapted to the humid forest conditions and generally speaking it can be said that it is out of place in the dry deciduous forests of the semi arid Gir. The sambar is also a generalist while the wild pig can be classified as an omnivore, not averse to scavenging. Of the bovids, chinkara draws its origin from the Ethiopian realm and is part of the dry tropical fauna inflow into India (Rodgers 1988). Nilgai, chousingha and black buck (*Antilope cervicapra*) are the native Indian species. Of these black buck has become locally extinct in the Gir within the last four decades. Chinkara and chousingha are selective feeders on the herb layer while nilgai is a browser (Rodgers 1988). Common langur and peafowl are the other important prey species in the Gir, but no attempt was made to estimate their abundance.

III.2 Methods:

III.2.1 Vehicle count: Road transects were run to gather data on wild ungulate density. The Gir PA has an excellent network of roads, covering almost all the vegetation types and this enabled the efficient coverage of the PA. Relatively open habitat conditions and the abundant sightings of wild ungulates made road transects an ideal method for ungulate population estimation in the Gir. The counts were done from an open jeep with a crew of at least four. The driver and another observer were seated in front while the other two were standing in the back of the vehicle. Counts were conducted for a maximum of two and a half hours immediately after sunrise and for the same period prior to sunset. The exact time of commencement of the vehicle count varied, depending upon the seasons. The average transect length was 20 km. The vehicle was

summers of 1987 and 1989, the winters of 1987-88 and 1988-89 (for details refer **Tables III.1** to **III.4**). Vehicle counts were not attempted during the monsoon and the post monsoon seasons as the roads were unfit for travel and the dense vegetation made sightings of animals very difficult.

Line transect sampling has been extensively used over the last six decades to obtain estimates of wildlife abundance. This method has since been established as practical, efficient and relatively inexpensive for estimating animal numbers. The line transect is a plotless method for estimating animal abundance and is distinguished by the following two features:

1. All objects that are potentially detectable from the transect will not be seen; some objects will be missed and the farther the object is from the transect centre line the greater is the probability that it will be missed.
2. Quantitative data are taken relative to the transect centre line, regarding the location of all objects detected (Burnham, Anderson & Laake 1980).

In this study the perpendicular distance from the transect line to the animal was visually estimated. In the Gir forest the animals are used to vehicles and hence it is possible to draw level with their location to estimate the perpendicular distance for each sighting.

For each animal sighting, the following data were recorded: 1. species 2. number of animals 3. age/sex 4. perpendicular distance from the centre of the animal group to the observer 5. Major habitat parameters such as broad vegetation type and terrain 6. Major activity of the group.

Grouping of perpendicular distance estimates into categories does not affect the density estimation (Burnham *et al.* 1980). The perpendicular distance from the centre of the animal group to the observer was visually estimated in 5m classes. Data from all road transects of each census (collected in 5m classes) were grouped into 10m classes to remove heaping from the data. These visual estimates were periodically checked by using a measuring tape.

It is critical that the transect line be placed randomly with respect to animal distribution; it is this random placement that justifies extrapolating results to an area larger than just the immediate vicinity of the transect line (Burnham *et al.* 1980). As the roads were used as the transect lines there was a certain bias, since the roads do not pass evenly through all the habitat types. To overcome this, stratified sampling was done. Transects were stratified into the three conservation units of Sanctuary West, Sanctuary East and National Park. Khan *et al.* (1990) have demonstrated by adopting a post facto stratification of the summer 1989 vehicle count data, with reference to terrain, that there is a difference in chital densities between hills and flat areas in the Gir PA. Interestingly this difference in densities translates into very small numbers while calculating the chital population for the entire PA.

Burnham *et al.* (1980) mention four assumptions which are critical to the achievement of reliable estimates of population abundance from line transect sampling:

1. Points directly on the line will never be missed (i.e., they are seen with probability 1). This translates to the fact that all animals on the road will be sighted.

2. Points are fixed at the initial sighting position; they do not move before being detected and none are counted twice. Ungulates are mobile animals and hence this condition is slightly violated during the vehicle counts. But we were able to fix the position of the initial sighting to estimate the perpendicular distance, the relatively open habitat allows this in the Gir. Since we were travelling in one direction and that too by jeep, the chances of counting any animal twice was extremely remote.

3. Distances and angles are measured exactly; thus, neither measurement errors nor rounding errors occur. In this study perpendicular distances were visually estimated but our estimation was periodically checked by using a measuring tape to ensure accuracy.

4. Sightings are independent events.

The first census was conducted in summer of 1987 to get an idea of herbivore densities in Sanctuary West and National Park, whereas during the second census in winter 1987-88, more attention was paid to the overall density distribution of different herbivores. During the other counts, emphasis was placed on the intensive monitoring of a few selected transects.

Road transect data was analyzed using the following three methods:

1. King census method
2. Kelker belt transect method
3. Fourier series estimators

III.2.2 Fourier series estimators: I report only on the results obtained by the use of

Fourier series estimators. Burnham *et al.* (1980) explain in detail the procedures to be adopted for this analysis. The computer programme 'Transect' was used for this analysis. The grouped data with a specified width has been used for this analysis. The distance value of the width used was either based on the maximum perpendicular distance or was decided after data truncation. Data truncation involved rejection of extreme sightings. Generally one to three percent of the sightings, were extreme sightings ('outliers') and these were removed from the grouped data. The densities were calculated according to different strata. Data sets having small sample sizes (<15) were not used for overall density estimation by Fourier series estimators. Since I was only interested in determining the prey density and their distribution in the Gir PA, I am only reporting the density estimates obtained from the most reliable vehicle count conducted in summer 1989. **Tables III.5** and **III.6** summarise the wild ungulate group sighting data for different distance class intervals and **Fig. III.5** gives the mean group size for chital; based on these animal densities were computed.

III.2.3 Distribution maps: Distribution maps for all species were prepared by plotting all the sightings of different species in one kilometre long segments, from the road transect data. A grid system of 5 X 5 km was laid over the map with animal sighting data. For each grid, total number of animals seen were divided by the total number of one km road segments. The values obtained from these grids were grouped into different levels of abundance categories as very high, high, medium, low or absent and plotted on the map for all the grids. These distribution maps were prepared based on the results of the winter 1987-88 vehicle count. **Tables III.7** and **III.8** summarise the

wild ungulate group sighting data for different distance class intervals and **Fig. III.5** gives the mean group size for chital and these formed the basis for calculating animal densities for winter 1987-88.

III.2.4 Estimation of ungulate biomass: Once the ungulate numbers were determined it was possible to estimate the biomass of the ungulate community in the Gir PA. This would provide data on the actual availability of food for the predators. For calculating the biomass, data on the average body weight of the various species was essential. This was obtained from Schaller (1967) and Berwick & Jordan (1971). Schaller (1972) proposed that for the calculation of biomass at a population level it is best to take 75% of the average body weight of an adult female of a species to represent the biomass of an individual. This would underestimate the biomass for certain classes of animals like adult males but would compensate by overestimating for young.

III.2.5 Determining the sex ratio of chital and sambar: Chital and sambar were classified into various age and sex categories during the vehicle counts. All sambar sightings were recorded and a similar classification was done. Chital sighted on specified days during the monsoon and post monsoon seasons were classified to provide year round sex ratio data.

III.3 Results:

I only present results directly relevant to the predation ecology of the lions. These relate to the estimation of the population of various species, their distribution, the biomass of ungulates in the PA and the sex ratio of chital and sambar.

III.3.1 Density and population estimates for wild ungulates: Tables III.9 and **III.10** present the data on the density of various wild ungulate species in the Gir PA. Sufficient data was available only for chital to make stratified estimates in all the three areas and also to calculate an overall density for the PA. The chital population in the entire PA is estimated to be 48501.1 ± 5898.7. For sambar, density for National Park and the overall density were calculated. The sambar population is estimated to be 937.7 ± 362.9. The overall density for nilgai and the density in Sanctuary East for chinkara were also calculated. The nilgai population in the entire PA is estimated to be 363 ± 191.5. The chinkara population in Sanctuary East is estimated to be 788.7 ± 368. Low sample sizes did not allow the estimation of the populations of chousingha and wild pig. Based on sightings of the two species, I would provide a guesstimate of at least 200 animals for these two species. **Table III.11** gives the estimated population for chital, sambar, nilgai and chinkara. Chital is by far the most numerous wild ungulate in the Gir PA, constituting 95.1% of the estimated total of 50,991 wild ungulates.

III.3.2 Distribution pattern : Based on the winter 1987-88 vehicle count, distribution maps for chital, sambar, nilgai and chinkara were prepared (**Fig. III.1 to III.4**). Chital is distributed unevenly throughout the PA (**Fig. III.1**). Densities in Sanctuary West range from very high to low, in Sanctuary East from high to low and in National Park from very high to low.

Sambar has a rather restricted distribution (**Fig. III.2**) when compared with chital. Sambar was not recorded in much of Sanctuary East and in some portions of Sanctuary West and National Park. Sambar reaches its highest density in National Park, with a

lower density in Sanctuary West and a very low density in Sanctuary East.

Nilgai is also rather patchily distributed (**Fig. III.3**) through the PA. Vast tracts of Sanctuary West, Sanctuary East and National Park do not have nilgai. Nilgai reaches its highest density in Sanctuary East and occurs in low densities in Sanctuary West and National Park.

Of the wild ungulates in Gir, chinkara has the most restricted distribution (**Fig. III.4**). It is fairly widespread in Sanctuary East and is also recorded from one grid in National Park. It is known to occur in the extreme western portions of the PA, but this area was not surveyed as part of the vehicle count.

Due to lack of access it was not possible to conduct a vehicle count in some parts of the PA. In total 1008.34 sq.km of the PA was sampled during the vehicle count; 489.7 sq.km in Sanctuary West, 262.9 sq.km in Sanctuary East and 258.7 sq.km in National Park.

III.3.3 Ungulate biomass estimates: **Tables III.12** to **III.14** present the results of the estimation of ungulate biomass (both wild and domestic ungulates) in the Gir PA. Sanctuary East has the highest ungulate biomass of 22,48,768 kg (8553.7 kg/sq.km) of which 73% is contributed by livestock. The ungulate biomass in Sanctuary West was estimated to be 21,79,214 kg (4450.1 kg/sq.km) and 49.8% of this was contributed by livestock. The ungulate biomass in National Park was 5,04,672 kg (1950.8 kg/sq.km) and it comprised only of wild ungulates. These biomass estimates do not account for non-resident livestock which come into the PA for grazing on a daily basis and return to the villages by dusk.

III.3.4 Sex ratio of chital and sambar: Chital records for 1987, 1988 and 1989, and sambar records for 1987 and 1988 were analyzed for determining their sex ratio in the population. Eight thousand eight hundred and forty four chital and 583 sambar were classified. This sample does not include the number of unclassified individuals. The adult sex ratio of chital was found to be 44.5 males : 100 females and for sambar it was 48.5 males : 100 females (spike males were included while calculating the number of adult males for both the species). Hence both chital and sambar have a sex ratio heavily skewed in favour of females in the Gir PA.

III.4 Discussion:

III.4.1 Population size: Ungulate populations appear to lack self-regulating mechanisms. They are externally checked by changing environmental conditions rather than through intrinsic regulating mechanisms. In general it can be stated that the growth rate of ungulate populations is governed by climatic conditions and sudden increase in forage availability (Peek 1980).

The most striking result that emerged from the estimation of the ungulate population in the Gir PA was the phenomenal increase in numbers exhibited by the wild ungulates, especially by chital. While comparing with data from Joslin (1973), the total ungulate population has increased by 919% and chital by 1183%; chital formed nearly 75% of the wild ungulate community and presently it forms 95% of the population. Of the other species, sambar exhibits a modest increase of 156%, nilgai a slight decrease and chinkara a pronounced increase of 1578%. There are some differences while comparing the data from this study with that of Berwick (1974). The wild ungulate

population increased by 817%, chital by 1101%, sambar by 340% and chinkara by 395%. Nilgai shows a pronounced decrease to only 36% of the population estimated by Berwick (1974).

There are some notable differences between the methods used by Joslin (1973) and Berwick (1974), and those used in this study to estimate wild ungulate numbers. Joslin (1973) based his estimate on road counts carried out at night with the help of a spotlight and the average strip width was 75m. He validated his night counts by observing animals at waterholes. Berwick (1974) also carried out road counts but these were conducted both during day and night, with fixed strip widths of 128m and 100m respectively. The mean strip width for chital in the different areas during the vehicle counts seldom exceeded 40m and I feel that by using fairly large strip widths and by counting at night, both Joslin (1973) and Berwick (1974) would have underestimated the wild ungulate population.

The comparison of the wild ungulate population estimated during this study and those reported by Joslin (1973) and Berwick (1974), suggests an eruption in the chital population in the Gir PA. This pattern of growth is on the lines of those reported for the Rocky mountain mule deer (*Odocoileus hemionus*) in the Kaibab plateau, Arizona (Burk 1973) and Himalayan tahr (*Hemitragus jemlahicus*) in New Zealand (Caughley 1970). In the Kaibab plateau, a predator control programme was initiated and sheep and cattle were banished from the area. The removal of livestock competition and predation pressure provided the impetus for this eruption in the population of mule deer (Burk 1973). In New Zealand, Himalayan tahr was an exotic and faced no competition

subsequent to its introduction and its population rapidly increased.

In the Gir PA, between 1974 and 1979 various management efforts were made to restrict the number of livestock grazing in the PA. The seasonal influx of livestock was stopped and about 50% of the resident maldhari livestock was also moved out of the PA. An area of ca. 250 sq.km was created as a National Park, thereby banning all human activity in this area. All these actions definitely reduced the impact of livestock on the habitat and released resources in the form of forage (especially grass) for the wild ungulates.

Schaller (1967), Ables (1977), Dinerstein (1979, 1980) and Rodgers (1988) state that chital is a grazer by choice and grass dominates its diet, with the deer being flexible enough to feed on browse when faced with a shortage of palatable grass. Seidensticker (1976a), Dinerstein (1980) and Rodgers (1988) state that competition from livestock negatively impacts chital. This widespread finding is in direct contrast to what has been reported by Berwick (1974) for Gir. Based on cafeteria experiments and on observations of tame animals during summer, he concluded that there was no overlap in the diets of livestock and wild ungulates and hence competition for forage from livestock was not a regulatory mechanism on the wild ungulate population in the Gir PA. The phenomenal growth in the chital population through the last two decades, can only be explained as a response to the reduced competition from livestock; a pattern conforming to what has been reported by other studies but in variance with Berwick's (1974) findings from Gir.

Peek (1980) has reviewed numerous case studies and defined the phenomena of eruption in the growth of ungulate populations. One of the preconditions for an eruption to occur, is human intervention. Both in the Kaibab plateau and in New Zealand human action facilitated the eruption of the ungulate population. In Gir, the control in livestock numbers within the PA and the creation of a National Park would constitute human intervention. Peek (1980) also characterises an eruption with a degradation in habitat quality resulting from a pronounced impact on the vegetation by the exploding population of ungulates. In Gir there is no indication as yet of the chital population negatively affecting the habitat quality by over utilising forage. This suggests that at least chital has the potential to increase in numbers if competition from livestock is further reduced. Schaller (1967), Seidensticker (1976a), Dinerstein (1979, 1980) and Rodgers (1988) report on the food habits of sambar, nilgai, chousingha and chinkara, which suggests that competition between these ungulate species and livestock would be lesser. As a result they have not benefitted to the extent that chital has from a reduction in livestock numbers. Sambar is a preferred prey for lions (refer Chapter IV) and I feel that it is currently trapped in a predator sink, thereby greatly impairing the chances for the sambar population to grow. Moreover the semi arid forest is a sub-optimal habitat for sambar.

Currently chital completely dominates the community of wild ungulates in the Gir PA as it constitutes 95% of the estimated total population of all the wild ungulates. This is in contrast to the species composition reported for the early 1970s. Chital was the dominant species even then, constituting about 70% of the wild ungulates (Joslin, 1973

and Berwick 1974).

III.4.2 Distribution: All the ungulates exhibit an uneven distribution in the Gir PA. This is a reflection of the habitat diversity, rainfall gradient and varying degrees of anthropogenic impact. Grazing by livestock, lopping and felling of trees by herdsmen and forest fires were the major human impacts on the habitat. Water availability during the drier parts of the year would also be a factor determining the distribution of species like chital and sambar.

In most of the areas were chital occurs in low density (**Fig. III.1**), it faces competition from livestock or the terrain is very hilly. For sambar Gir is the western limits of its distribution and the semi arid conditions are not really the most suitable for it to thrive. It reaches its highest densities in National Park but most of Sanctuary East and portions of Sanctuary West do not have any sambar at all (**Fig. III.2**) The more open habitat in Sanctuary East combined with a shortage of water in the dry season and greater levels of disturbance could be the limiting factors for the sambar population. The hilly terrain in Gir makes it unsuitable for nilgai to exist in high density (**Fig. III.3**). The small population of nilgai might also be trapped in a predator sink like sambar. Both nilgai and wild pig tend to raid crop fields outside the PA and may be poached. Chinkara is adapted to the more open habitats and hence the denser teak dominated forests of Sanctuary West and National Park are unsuitable habitats for it. It thrives in the savanna and open thorn forests in Sanctuary East and also occurs in the scrubland and Acacia-Zizyphus woodland in the extreme west of the PA.

III.4.3 Biomass estimates: Berwick & Jordan (1971) included the migrant livestock

while estimating the ungulate biomass in the Gir PA and their total biomass estimate was 76,90,455 kg of which 93.7% was contributed by livestock. My estimate of 49,32,654 kg as the total ungulate biomass for the Gir PA was much lower. I only included the resident maldhari livestock in my calculation and also used a lower unit body weight for all the species (75% of the adult female body weight). As reflected by the population estimate, the wild species contributed much more to the overall biomass during this study than during the early 1970s.

Numerous researchers have provided ungulate biomass estimates for different areas in Asia in the last two decades. Typically the moister habitats support much greater wild ungulate biomass than Gir does, especially in habitats where megaherbivores like Asian elephant (*Elephas maximus*) one horned rhinoceros (*Rhinoceros unicornis*) or gaur (*Bos gaurus*) occur.

Schaller (1967) estimated the ungulate biomass including livestock in Kanha to be 2637 kg/sq.km. Dinerstein (1980) calculated the biomass of wild ungulates in his intensive study area in Royal Karnali-Bardia reserve to be between 2842 and 3120 kg/sq.km. Tamang's (1982) estimate of the overall crude biomass for Royal Chitawan National Park was 2581 kg/sq.km. Johnsingh (1983) estimated the prey biomass in his intensive study area in Bandipur to be 3647 kg/sq.km and with the inclusion of wild elephants in the calculation, the biomass estimate shot up to 14,607 kg/sq.km. More recently Karanth & Sunquist (1992) have provided a biomass estimate for Nagarhole National Park. For their intensive study area they calculate the biomass to be 15,094 kg/sq.km, which included a small proportion of domestic cattle and domestic elephants.

Wild elephants and gaur contribute nearly 75% of this biomass and elephants are largely immune to predation by large carnivores.

The biomass estimates calculated for the Gir PA (**Tables III.13** and **III.14**) compare favourably with the estimates provided for other areas in India and Nepal. The wild ungulate biomass ranges from 2368 kg/sq.km to 1951 kg/sq.km depending on the area and once the residential livestock are included, this estimate shoots up to a maximum of 8554 kg/sq.km. Hence prey availability in the Gir PA (both wild and domestic ungulates) for lions and leopards seems to be adequate (see Chapter IV).

III.4.4 Sex ratio of chital and sambar: The sex ratio for both chital and sambar in Gir is heavily skewed in favour of females. This is especially so for chital when the sex ratio is compared with those reported from other studies. Berwick & Jordan (1971) also reported a very skewed sex ratio favouring females for chital and sambar. For chital the sex ratio was 35 males:100 females and for sambar it was 33 males:100 females. Historically the chital and sambar population in the Gir PA seems to have had fewer males as compared with other populations.

Schaller (1967) reported sex ratios for chital from different areas in India. In Kanha it was 60 males:100 females, in Corbett National Park it was 70 males:100 females, in Keoladeo Ghana Sanctuary it was 71 males:100 females, in West Kheri forest it was 79 males:100 females, in Vanbihar Sanctuary it was 73 males:100 females and in West Bastar district it was 69 males:100 females.

Seidensticker (1976a) has been the only exception in reporting sex ratios in favour of males for chital and sambar. His research in Chitawan National Park revealed that

the sex ratio for chital was 115 males:100 females and for sambar it was 102 males:100 females.

Ables (1977) based on studies on introduced chital in Texas reported a sex ratio of 73 males:100 females and depending on the month this ratio varied from 52 to 88 males:100 females. Tamang (1982) reported sex ratios of 54 males:100 females and 55 males:100 females for chital and sambar respectively from Chitawan.

Based on his studies in Bandipur Tiger Reserve, Johnsingh (1983) found the sex ratio of chital to be 68 males:100 females and for sambar it was 38 males:100 females. For Nagarhole, Karanth & Sunquist (1992) report sex ratios of 72:100 for chital and 42:100 for sambar.

As reported earlier, I determined the sex ratio of chital and sambar in Gir to be 45 males:100 females and 49:100 respectively. The sex ratio for sambar falls in the general observed pattern but the chital population in Gir is characterised by a very low number of males.

Various arguments have been put forth to explain the skewed sex ratios prevailing in wild ungulate populations. Karanth & Sunquist (1992) list four major reasons which render the male ungulates more vulnerable to predation. The relatively more solitary habits of males, proneness to injuries from intra-specific aggression, lack of alertness during rut and their dispersal behaviour. Ables (1977) states that mortality rates from losses before or immediately after birth, weather, or over browsed range may also result in a skewed sex ratio. Patel (1992) suggests that predators might be preferentially preying on male ungulates due to their larger body size, thereby optimising the yield of

meat for every successful hunt. There is sufficient data from this study to establish that both lions and leopards are preferentially preying on chital stags while lions preferentially prey upon sambar stags also (refer Chapter IV).

Table III.1 **Details of vehicle counts carried out in the Gir PA, Summer 1987.**

Stratum	No. of transect runs	Distance covered (Km)	Morning (Km)	Evening (Km)
Sanctuary West	15	314	153	161
Sanctuary East	3	72	27	45
National Park	11	266	144	122
Total	29	652	324	328

Table III.2 **Details of vehicle counts carried out in the Gir PA, Winter 1987-88.**

Stratum	No. of transect runs	Distance covered (Km)	Morning (Km)	Evening (Km)
Sanctuary West	16	321	140	181
Sanctuary East	7	140	40	100
National Park	10	218	109	109
Total	33	679	289	390

Table III.3 **Details of vehicle counts carried out in the Gir PA, Winter 1988-89.**

Stratum	No. of transect runs	Distance covered (Km)	Morning (Km)	Evening (Km)
Sanctuary West	21	581	135	446
Sanctuary East	3	57	18	39
National Park	17	315	165	150
Total	51	953	318	635

Table III.4 **Details of vehicle counts carried out in the Gir PA, Summer 1989.**

Stratum	No. of transect runs	Distance covered (Km)	Morning (Km)	Evening (Km)
Sanctuary West	10	212	110	102
Sanctuary East	11	222	98	124
National Park	19	414	252	162
Total	40	848	460	388

Table III.5 **Chital and Sambar group sighting frequency per distance class interval in the Gir PA, vehicle count, Summer 1989.**

Distance Interval (m)	Chital				Sambar			
	SW	SE	NP	T	SW	SE	NP	T
0 - 10	32	33	63	128	1	0	5	6
11 - 20	32	28	72	132	0	1	9	10
21 - 30	24	28	47	99	2	0	9	11
31 - 40	28	25	34	87	0	0	2	2
41 - 50	13	5	18	36	0	0	2	2
51 - 60	5	2	9	16	3	0	0	3
61 - 70	3	1	8	12	0	0	1	1
71 - 80	1	1	3	5	0	0	0	0
81 - 90	1	0	0	1	0	0	0	0
91 - 100	0	0	0	0	0	0	0	0
100 +	0	0	3	3	0	0	1	1
Total	139	123	257	519	6	1	29	36

SW - Sanctuary West; SE - Sanctuary East; NP - National Park; T - Total.

Table III.6 **Nilgai, Chousinga, Chinkara and Wild pig group sighting frequency per distance class intervals in the Gir PA, vehicle count, Summer 1989.**

Distance interval (m)	Nilgai			Chousingha			Chinkara			Wild pig		
	SW	SE	NP	SW	SE	NP	SW	SE	NP	SW	SE	NP
0 - 10	0	3	0	0	1	1	0	8	0	0	1	0
11 - 20	0	3	2	0	1	0	0	4	0	1	1	2
21 - 30	0	4	0	0	0	0	0	2	0	0	0	0
31 - 40	1	3	2	0	0	0	0	4	0	1	1	0
41 - 50	0	1	0	0	0	0	0	4	0	0	0	0
51 - 60	0	0	1	0	0	0	0	3	0	0	0	0
61 - 70	0	0	1	0	0	0	0	0	0	0	0	0
71 - 80	0	0	0	0	0	0	0	0	0	0	0	0
81 - 90	0	0	0	0	0	0	0	0	0	0	0	0
91 - 100	0	0	0	0	0	0	0	0	0	0	0	0
100 +	0	1	0	0	0	0	0	0	0	0	0	0
Total	1	15	6	0	2	1	0	25	0	2	3	2

SW - Sanctuary West; SE - Sanctuary East; NP - National Park.

Table III.7 **Chital and Sambar group sighting frequency per distance class interval in the Gir PA, vehicle count, Winter 1987-88.**

Distance Interval (m)	Chital				Sambar			
	SW	SE	NP	T	SW	SE	NP	T
0 - 10	113	25	72	210	12	1	8	21
11 - 20	83	22	37	142	8	1	2	11
21 - 30	40	11	41	92	6	0	1	7
31 - 40	41	14	30	85	1	0	4	5
41 - 50	17	7	6	30	3	1	4	8
51 - 60	10	7	4	21	0	0	1	1
61 - 70	5	4	8	17	1	0	0	1
71 - 80	1	2	2	5	0	0	0	0
81 - 90	0	0	4	4	0	0	1	1
91 - 100	0	1	0	1	0	0	0	0
100 +	2	6	12	20	1	0	1	2
Total	312	99	216	627	32	3	22	57

SW - Sanctuary West; SE - Sanctuary East; NP - National Park; T - Total.

Table III.8 **Nilgai, Chousinga, Chinkara and Wild pig group sighting frequency per distance class intervals in the Gir PA, vehicle count, Winter, 1987-88.**

Distance interval (m)	Nilgai			Chousingha			Chinkara			Wild pig		
	SW	SE	NP	SW	SE	NP	SW	SE	NP	SW	SE	NP
0 - 10	5	3	3	5	0	6	0	5	0	4	0	2
11 - 20	2	3	2	3	0	3	0	2	0	3	0	1
21 - 30	2	0	2	1	0	5	0	3	1	0	0	1
31 - 40	3	1	2	2	0	1	0	4	0	1	0	1
41 - 50	0	0	3	0	0	1	0	1	0	0	0	0
51 - 60	1	2	0	1	0	0	0	0	0	0	0	0
61 - 70	0	2	1	1	1	1	0	1	0	1	0	0
71 - 80	0	1	0	0	1	0	0	0	0	0	0	0
81 - 90	0	0	0	0	0	0	0	0	0	0	0	1
91 - 100	0	0	1	0	0	0	0	0	0	0	0	0
100 +	1	5	0	0	0	0	0	3	0	0	0	1
Total	14	17	14	13	2	17	0	19	1	9	0	7

SW - Sanctuary West; SE - Sanctuary East; NP - National Park.

Table III.9 **Density estimates of Chital by Fourier Series estimators, for grouped data, vehicle count in the Gir PA, Summer 1989.**

Stratum	No./Km^2	Std.Error	Cv	95% Cl
Overall	48.1	2.9	40.9	± 5.9
SW	48.7	4.5	52.6	± 8.9
SE	52.1	4.6	64.6	± 8.8
NP	39.6	3.1	53.4	± 6.2

SW - Sanctuary West; SE - Sanctuary East; NP - National Park; Cv - Coefficient of variation; Cl - Confidence limits.

Table III.10 **Density estimates of Sambar, Nilgai and Chinkara by Fourier Series estimators, for grouped and truncated data, vehicle count in the Gir PA, Summer 1989.**

Stratum	Species	No./Km^2	Std.Error	Cv	95% Cl
Overall	Sambar	0.9	0.18	34.9	± 0.36
NP	Sambar	1.8	0.42	40.3	± 0.85
Overall	Nilgai	0.4	0.02	31.1	± 0.19
SE	Chinkara	3.0	0.80	64.0	± 1.40

SW - Sanctuary West; SE - Sanctuary East; NP - National Park; Cv - Coefficient of variation; Cl - Confidence limits.

Table III.11 **Estimate of the population size of wild ungualtes in the Gir PA, vehicle count, Summer 1989.**

Stratum	Species	Denisty	Area censused (Km^2)	Total population
Overall	Chital	48.1 ± 5.8	1008.3	48501.1 ± 5898.7
Sanctuary West	Chital	48.7 ± 8.9	489.7	23848.3 ± 4358.3
Sanctuary East	Chital	52.1 ± 8.8	262.9	13697.0 ± 2313.5
National Park	Chital	39.6 ± 6.2	258.7	10244.5 ± 1603.9
Overall	Sambar	0.9 ± 0.4	1008.3	937.7 ± 362.9
National Park	Sambar	1.8 ± 0.9	258.7	465.6 ± 219.8
Overall	Nilgai	0.4 ± 0.2	1008.3	363.0 ± 191.5
Sanctuary East	Chinkara	3.0 ± 1.4	262.9	788.7 ± 368.0

Table III.12 **Estimation of biomass for various ungulates in different strata, based on Fourier series estimators for vehicle count data in the Gir PA, Summer 1989.**

Stratum	Species	Unit * Weight (Kg)	Density	Biomass/Km² (Kg)
Overall	Chital	42.6	48.1 ± 5.8	2049.1 ± 247.1
Sanctuary West	Chital	42.6	48.7 ± 8.9	2074.6 ± 379.1
Sanctuary East	Chital	42.6	52.1 ± 8.8	2219.5 ± 374.9
National Park	Chital	42.6	39.6 ± 6.2	1687.0 ± 264.1
Overall	Sambar	119.3	0.93 ± 0.4	110.9 ± 42.9
National Park	Sambar	119.3	1.8 ± 0.9	214.7 ± 101.4
Overall	Nilgai	136.4	0.4 ± 0.2	49.1 ± 25.9
Sanctuary East	Chinkara	13.6	3.0 ± 1.4	40.8 ± 19.0
Sanctuary West	Buffalo@	204.5	10.1	2065.5
Sanctuary East	Buffalo@	204.5	28.4	5807.8
Sanctuary West	Cattle@	136.4	1.1	150.0
Sanctuary East	Cattle@	136.4	3.2	436.5

* Ungulate body weights from Schaller (1967) and Berwick & Jordan (1971). Unit weight of each species estimated as 75% of the body weight of an adult female.
@ Population estimated from Gujarat Forest Department records.

Table III.13 Biomass estimates of the more common ungulates in the Gir PA, based on vehicle count, Summer 1989.

Strata	Biomass/Km^2 (Kg)	Area censused (Km^2)	Total biomass (Kg)
Sanctuary West[1]	4450.1	489.7	2179214
Sanctuary East[2]	8553.7	262.9	2248768
National Park[3]	1950.8	258.7	504672

1. Biomass estimate based on the biomass of chital, sambar, nilgai, buffalo & cattle.
2. Biomass estimate based on the biomass of chital, nilgai, chinkara, buffalo & cattle.
3. Biomass estimate based on the biomass of chital, sambar and nilgai.

Table III.14 Percentage contribution of the more common ungulates to the ungulate biomass in the Gir PA, based on vehicle count, Summer 1989.

Species	Sanctuary West[1]	Sanctuary East[2]	National Park[3]
Chital	46.0	25.9	86.5
Sambar	2.5	-	11.0
Nilgai	1.1	0.6	2.5
Chinkara	-	0.5	-
Buffalo	46.4	67.9	-
Cattle	3.4	5.1	-

[1] Total biomass estimate for Sanctuary West is 21,79,214 Kg.
[2] Total biomass estimate for Sanctuary East is 22,48,768 Kg.
[3] Total biomass estimate for National Park is 5,04,672 Kg.

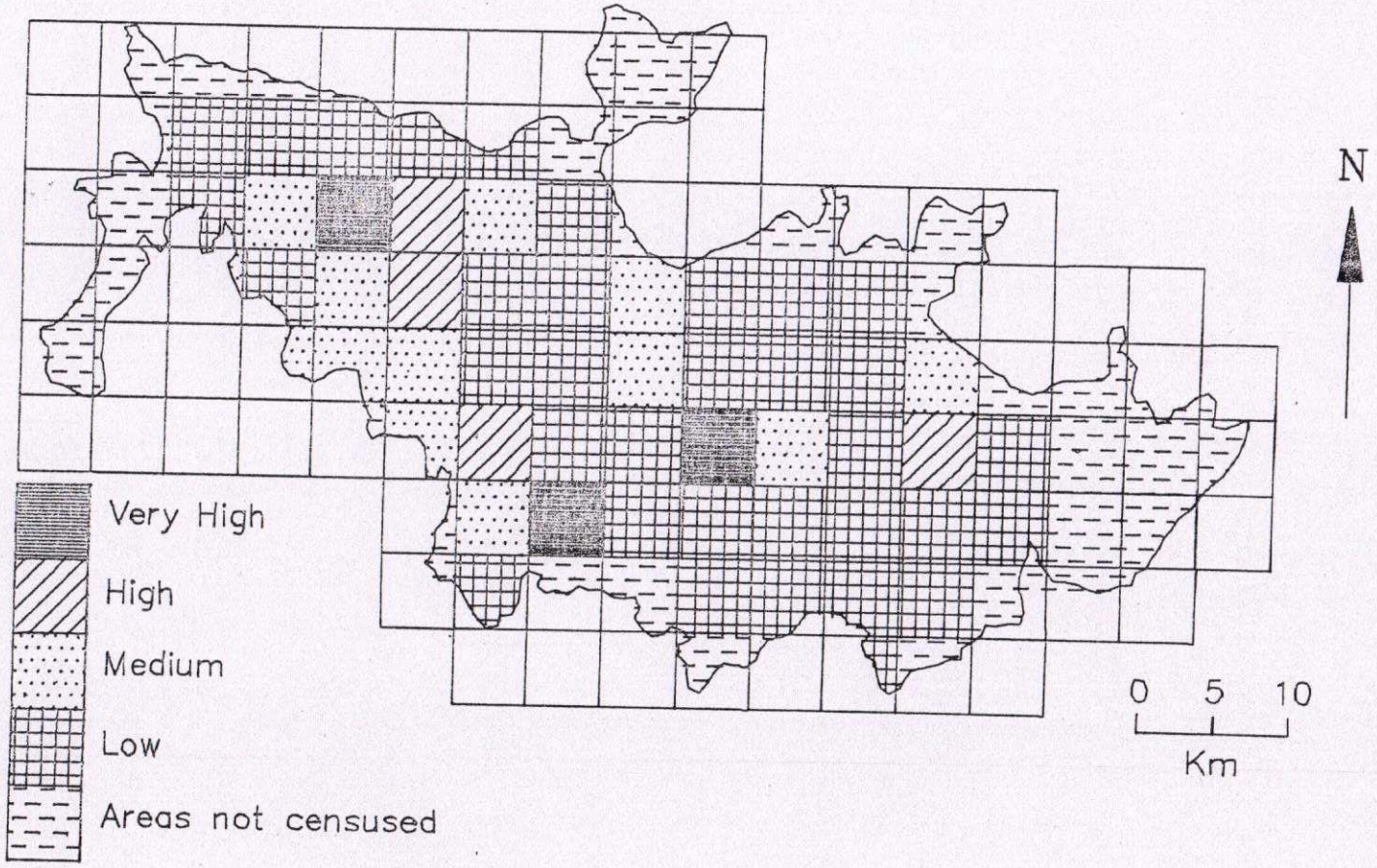


Fig. III.1 Distribution pattern of chital in the Gir PA vehicle count, winter 1987 – 88.

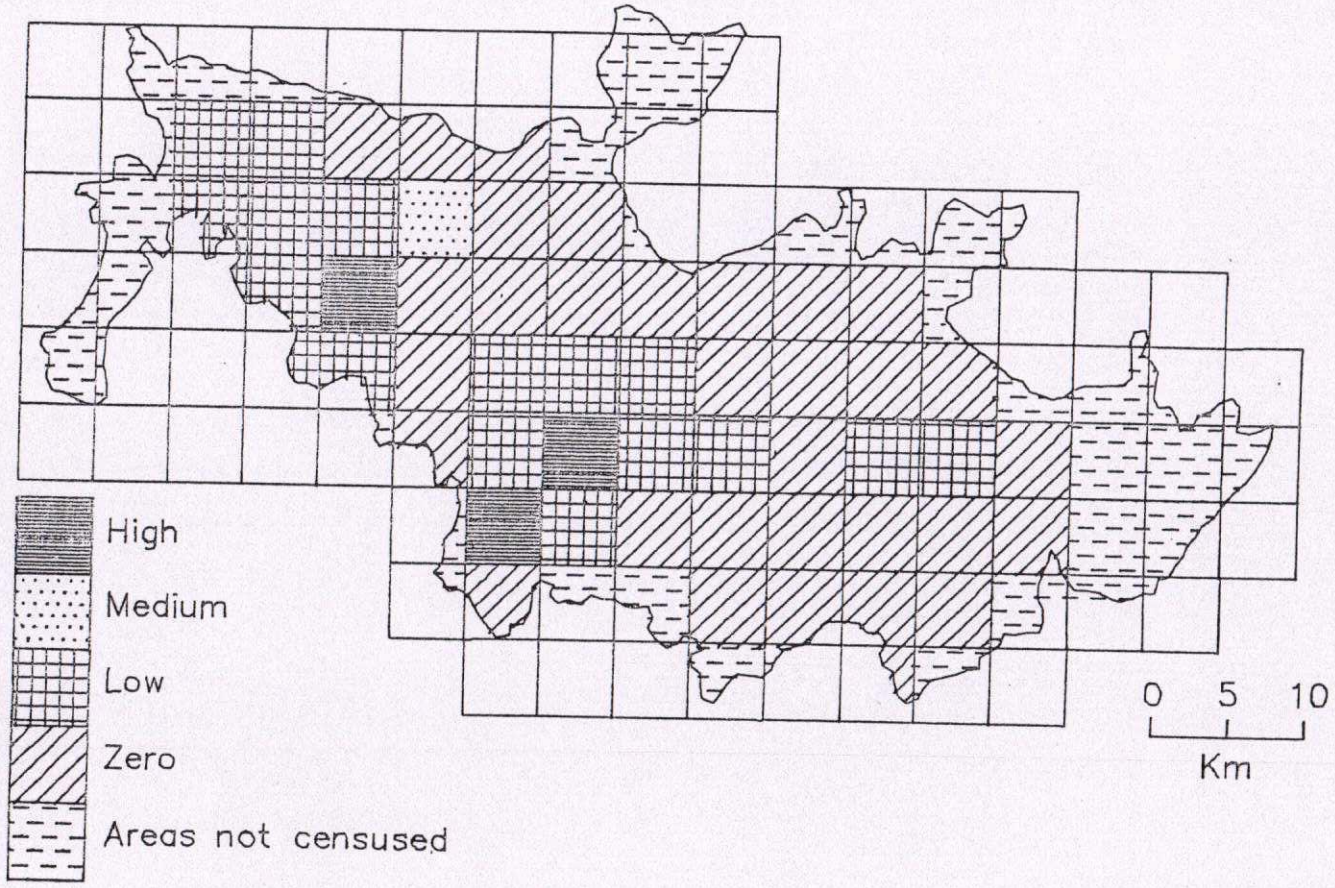


Fig. III.2 Distribution pattern of sambar in the Gir vehicle count, winter 1987 – 88.

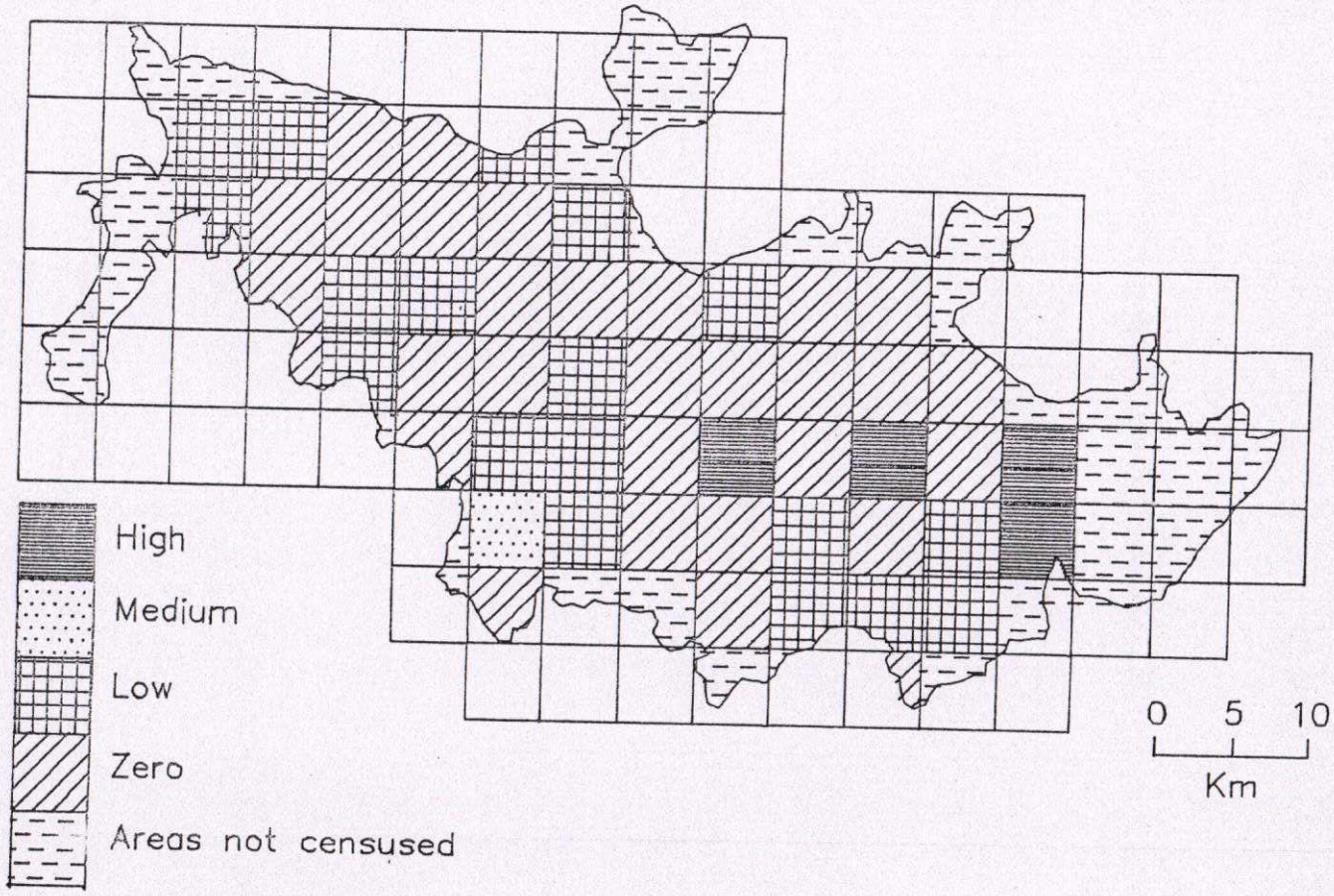


Fig. III.3 Distribution of nilgai in the Gir PA vehicle count, winter 1987 – 88.

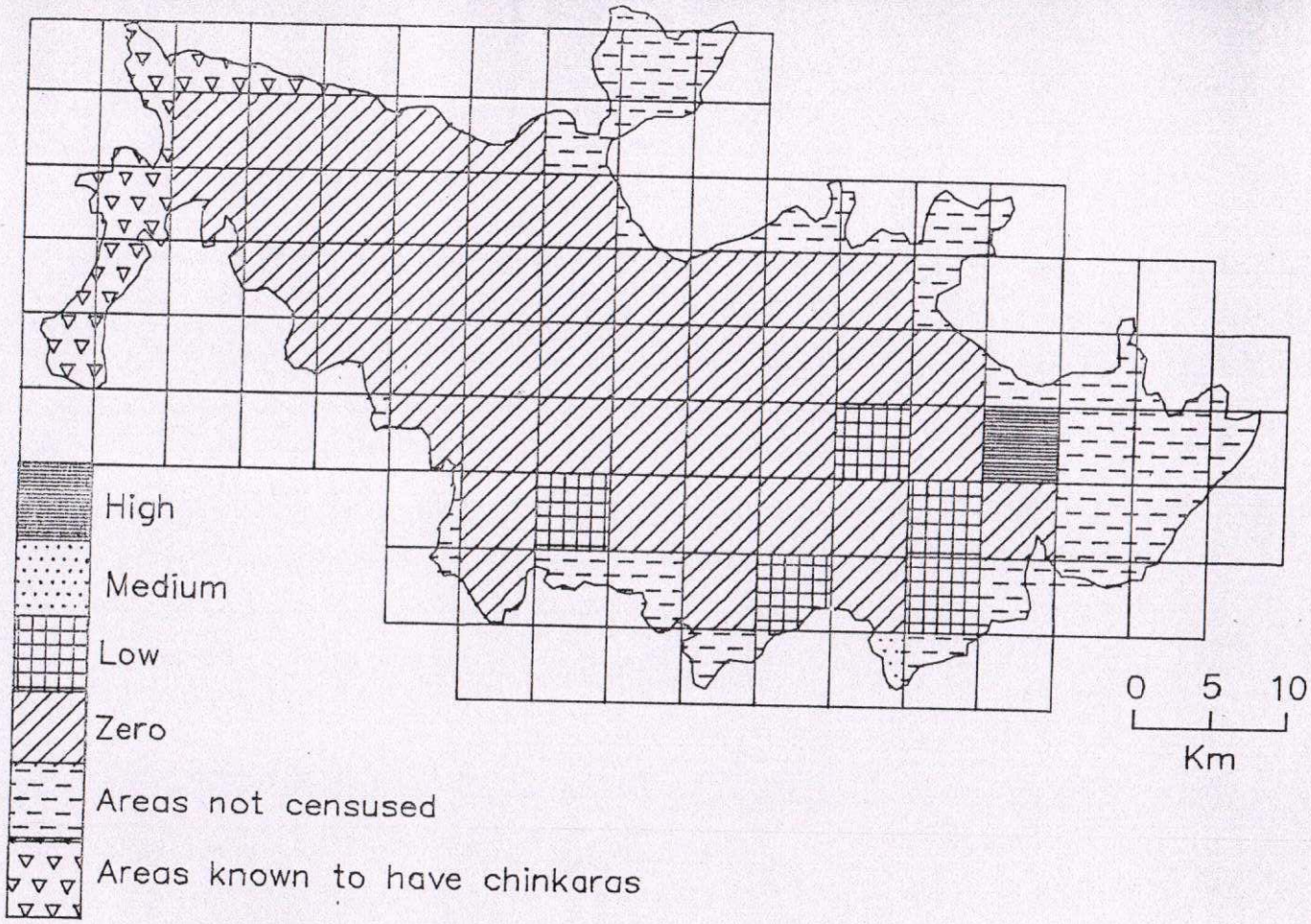


Fig. III.4 Distribution of chinkara in the Gir vehicle count, winter 1987 – 88

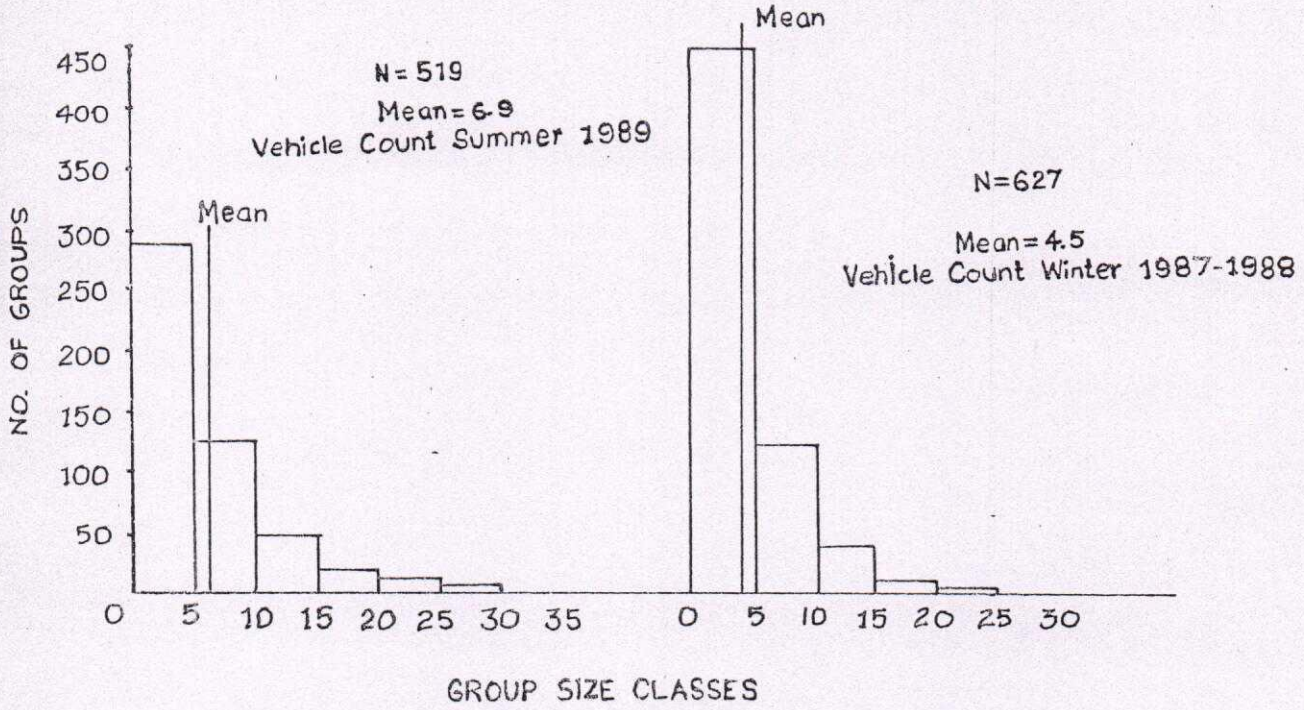


Figure III.5: Group size class frequencies of chital with mean values, summer 1989 and winter 1987-88 vehicle counts in the Gir PA.

CHAPTER IV

PREDATION ECOLOGY

IV.1 Introduction:

All large felids are highly specialised carnivores. Their predation ecology is influenced by a wide variety of ecological conditions. The first set of conditions relate to the prey species. The abundance, temporal and spatial distribution, and size of the prey, all influence the predation by large cats. The second set of conditions pertain to the habitat. The availability and distribution of ambush cover, climatic conditions, terrain, and the availability and distribution of water also play a role in the predation ecology of cats. Competition from other carnivores also influences predation ecology. The final set of conditions are contributed by the human impact on the habitat, the prey base and directly on the large cats themselves.

One of the major requirements for the survival of a flourishing population of a predator is an adequate prey population. The previous chapter on Prey Population has given the details of the abundance and distribution of the various prey species, and sex ratio of chital and sambar in the Gir PA. This chapter assesses the diet and the food habits of the lions and the effect of lion predation on the prey population. A similar assessment of the predation ecology of the leopard is also attempted and the food habits of lions and leopards are compared. Joslin (1973) and Sinha (1987) have also assessed the diet of the lions in Gir and hence there is a bench mark to compare the results of my study with their results.

Joslin's (1973) assessment of the lion's diet was based only on scat analysis. He examined livestock killed by lions to determine the factors involved in the predation of livestock and the feeding on these carcasses by the lions. Sinha's (1987) study paid only cursory attention to the examination of kills made by lions, which would enable the

determination of the age and sex of the prey killed. This study on the lion's predation ecology includes both scat analysis as well as an extensive examination of the prey (wild ungulates and domestic livestock) killed by lions and provides data on an aspect which was not researched so far.

Keeping in view the ultimate objective of this study, which is the establishment of a second free-ranging population of Asiatic lions; it was crucial to obtain data on the prevailing predation patterns of the lions in Gir. This would be invaluable in site selection and ultimately in the release and the establishment of the second lion population. The assessment of the impact of lion predation on the prey population is of significance to the management of the Gir PA.

IV.2 Methods:

Data on the diet of the lions and leopards and their predation ecology was collected by two methods:

1. Collection and analysis of scats
2. Examination of kills made by lions and leopards

IV.2.1 Scat Collection: Lion scats were collected as and when encountered during the course of fieldwork. Lion scats were easily distinguishable from those of leopards by their much larger size. Entire scats were collected in a polyethylene bag, tagged and numbered. Details of date of collection, locality, site of collection and associated evidence like pug marks were recorded. Scats of leopards were also collected.

Lion scats were collected in three distinct time periods:

i. 1986-June 1987 (Period I)

ii. July 1987-December 1987 (when there was a large scale influx of livestock into the PA) (Period II)

iii. 1989 (Period III)

Scats were also assigned to four areas with differing conservation status:

i. Sanctuary West

ii. Sanctuary East

iii. National Park

iv. Outside the PA

Sanctuary West and Sanctuary East had the full complement of wild prey species, as well as livestock. These two areas varied in their prey densities; chiefly in the density of sambar and livestock. Sanctuary West had a higher sambar density and a lower density of livestock, when compared with Sanctuary East (refer Chapter III). National Park was completely free of livestock. Areas outside the PA had only stray wild ungulates and the bulk of the prey available to the predators was livestock. Leopard scats collected in Period I, in Sanctuary West and National Park, have been analyzed to enable a comparison of the food habits of these two species.

Lions and leopards do not always defecate close to their kills and hence this spatial classification of the scats may be questioned. It is also possible that the home ranges of these felids may overlap more than one category of these areas. Nevertheless this spatial classification of the scats is only an attempt to look at differences in the prey species composition of the scats collected from different areas and to relate it to the known prey densities for these areas.

IV.2.2 Scat Analysis: Scats were washed in water using a sieve and the prey remains like hair, bones and hooves were retained. The washed scats were oven dried for at least 48 hours before the hairs were examined under a microscope for species identification. From each washed scat, ten hairs were picked at random and washed in xylene and alcohol. These hairs were dried using a filter paper and then mounted on a glass slide with glycerine. The hairs were examined with the help of a binocular

microscope. Prey species were identified using the pattern of the medullary structure, hair width and the medulla to hair width ratio (Mukherjee, Goyal & Ravi Chellam in prep.).

The frequency of occurrence of prey species in the scats was computed as the number of occurrences of each prey species divided by the total number of scats analyzed and expressed as a percentage (Corbett 1989 and Leopold & Krausman 1986). The results are also expressed as percent occurrence (number of times a specific item was found as a percentage of all items identified). Although frequency of occurrence indicates how common an item is in the diet, percent occurrence provides a better indication of the relative frequency with which each item is consumed because it accounts for scats containing the remains of more than one prey species (Ackerman, Lindzey & Hemker 1984).

IV.2.3 Collection of Kills: While the analysis of scats is an unbiased method for determining the diets of predators it does not provide data on numerous other aspects which will enable the understanding of the predation ecology of the concerned species. Hence it becomes imperative to get data from the kills made by the predators (Schaller 1967, 1972, Sunquist 1981 and Johnsingh 1983).

Kills were collected whenever encountered while carrying out all aspects of fieldwork or by active searching in the forest. The activity of crows, the presence of drag trail and the odour of decomposing flesh were factors which aided in the location of kill remains. When kills were made in open areas like hill tops and reservoir beds, the congregation of vultures provided a clue of the presence of kill remains. Maldharis, forest department staff and minor forest produce collectors were encouraged to report all encountered kills. Radio-telemetry also proved to be a valuable aid in the location of kills, when collared lions were radio-located feeding or close to the kill they had

made.

IV.2.3.1 Identification of the predator: Lion and leopard are the two large predators in Gir and both are capable of killing all the prey species present in the Gir forest. As most of the kills were examined only after the departure of the predator from the site, it became very crucial to be able to accurately determine the identity of the predator involved. Even when a predator was observed feeding on a kill, it did not provide conclusive evidence for identifying the predator which had made the kill. Lions are known to displace and steal kills from leopards. During this study leopards were also observed to scavenge on lion kills. Major evidences used in determining the identity of the predator which had made the kill were:

(i) Mode of feeding: It was observed that lions almost always started to feed from the rump of the ungulate carcass. The leopard in contrast began feeding from the abdomen.

(ii) State of the kill remains: Since lions are social animals and also much larger than the leopards, the state of the kill remains was a good indication of the predator involved in making the kill. If more than one lion had fed on the kill the carcass would be ripped apart and the remains scattered. The long bones and the ribs would be chewed and almost nothing edible would be left. By contrast when a leopard feeds the carcass would largely be intact. If the kill was cached in a tree, it was conclusive proof that a leopard had made the kill.

(iii) Pug marks: The presence of pug marks also provided proof of the identity of the predator. The pug marks of lions were much larger in size than those of leopards.

(iv) Hair of predator: The forest floor where the kill was actually made was searched thoroughly for hairs. Leopard hairs were distinct in that at least some of them would be bi-coloured (white and black or yellow and black). Lion hairs were either white or

brownish yellow in colour. If male lions were involved in making the kill their long mane hairs were invariably found. The kill remains were also searched for predator hairs (this proved to be especially useful if male lions were involved), but this evidence only indicated the identity of the predator that had fed on the kill and not necessarily of the predator which had made the kill.

(v) State of rumen sac: Leopards invariably removed the rumen sac intact from the carcass and buried it under leaf litter and soil. By contrast the lions ate up the sac on numerous occasions and scattered the contents and even if they did not eat the sac, they never made any attempts to conceal it. The leopard has to be as secretive as possible to be able to derive the maximum benefit from the kills made by it. Scattered rumen contents and the rumen sac lying in the open is bound to attract the attention of avian scavengers and in turn the lions, in which case the leopard would lose its kill.

IV.2.3.2 Age, sex and condition of the prey killed: Lower jaws and skulls were collected to determine the age and sex of the animal killed. Depending on the eruption and wear of the teeth, the jaws were categorised into three broad classes after Schaller (1967). Jaws of Classes I to III were those of fawns and yearlings; referred to as young animals in this study. Classes IV to VII were those of adults and those in Classes VIII and IX were classified as old animals. Depending on the presence or absence of horns and antlers, it was possible to determine the sex of the animal killed, even if the carcass had been completely fed on.

The physical body condition of the killed animal was determined by an examination of the bone marrow fat of the femur or the humerus. The long bone was cracked open and the colour (ranging from white, cream, pink and red; with white indicating the best condition and red the worst) and consistency of the bone marrow (ranging from solid, jelly-like, semi-solid and liquid; with solid indicating the best

condition and liquid the worst) were recorded.

IV.2.3.3 Habitat variables and other data: Once the kill remains were located, a detailed investigation was undertaken and the data recorded in a designed format. The first task was to determine the exact site where the kill had been made. Invariably the carcass would have been moved from the site where the kill was made, normally to denser vegetation cover to ward off avian scavengers. The drag trail was the best indication to the site were the kill was made. At the kill site, after the identity of the predator was established, the shrub and tree cover were estimated by 10 tree plotless method (Curtis 1959). Any stem <2 m and >0.5 m in height (excluding grass) was categorised as a shrub irrespective of the species and any stem >2 m in height was classified as a tree. This assessment of vegetation cover was done to determine the ambush or stalking cover available to the predator in making the kills. In certain situations like the deeply fissured and undulating terrain of the reservoir bed the ambush cover was provided more by the terrain than by vegetation (**Plate II.4**).

From the kill site the distances to the nearest water source and maldhari ness were estimated. The distance between the kill site and the where the carcass was opened and the distance between the kill site and where the remains were located were also measured. The terrain and vegetation type in which the kill was made was noted. If the kill was very fresh and evidence was still available, details of where and how the killing bite (canine puncture marks) was delivered was recorded.

IV.2.3.4 Livestock kills: If the prey killed was domestic livestock, attempts were made to determine the "status" of the animal killed. At times aged or sick livestock were deliberately left outside the protection of the ness by the maldharis to enable them to claim compensation from the forest department if these non-productive and soon-to-die animals were killed by lions. On occasions an animal would stray away from the herd

and the herdsman would not be able to bring it back to the protection of the ness by nightfall. These 'lost' livestock would then fall easy prey to the lions. On other occasions lions would attack a herd even when the maldharis are in the immediate vicinity, catching them unawares and kill one or more of the animals. Finally the lions at times even jumped the thorn fence around a ness and attacked the animals penned in for the night. This investigation became crucial as Joslin (1973) reported that livestock remains occurred in 78.5% of the lion scats analyzed and that 11% of 251 lion attacks on livestock took place within the ness after the lions had jumped or penetrated the thorn fence.

IV.2.4 Statistical Analyses: Differences in the diet of lion for Period I between the four different areas from which scats were collected and similarly differences between the three areas in Period III and between the three periods was assessed by using a simple Chi square test on frequency of occurrence data for each prey separately (by casting scats into a contingency table with two rows corresponding to the presence or absence of the prey, and a column for each sample from two different areas or time periods) (Reynolds & Aebischer 1991). This procedure is equivalent to comparing the proportions of the prey species in the diet across the different samples. This procedure was repeated to compare the diets of lion and leopard in Period I.

Niche overlap between lions and leopards based on scat data was calculated following Hulbert (1978);

$$\alpha\ XY = \sum_{i=1}^{n} \min (PXi, PYi)$$

where XY = resource overlap between species X and Y

Pi = fraction of use in ith stratum (each category by species X and Y).

In this study, each prey species represents a stratum.

Based on kill data, preference ratings for each prey species was calculated following Pienaar (1969);

$$\text{Preference Rating} = \frac{\text{kill frequency of prey}}{\text{relative abundance of prey}}$$

Preference ratings provide a true indication of the real food preference of a particular predator irrespective of the density of its various prey species. Preference rating values exceeding 1 indicate that a particular species is preferred. The magnitude of preference for a particular prey is indicated by the magnitude of the preference rating value exceeding 1.

Z statistics were calculated based on the sex ratio of the chital and sambar populations and the chital and sambar kills made by lions, to test for difference between the kill and population sex ratio. This procedure is similar to that used by Patel (1992).

IV.3 Results:

Schaller (1972) reports that the lions in Africa feed on a very wide variety of prey. Lion habitats, especially in eastern and southern Africa are characterized by an extremely diverse prey base. In Gir the prey base is restricted to less than a dozen species including livestock. The lions in the Gir forest are unique in regularly including livestock as a major part of their diet. The wild ungulate population in the Gir PA is resident throughout the year unlike the situation in places like Serengeti National Park, where large scale seasonal migration of prey takes place resulting in widely fluctuating availability of prey for the lions. Apart from the major prey species which were identified from lion scats, the lions in Gir are known to have killed and eaten a marsh crocodile (*Crocodylus palustris*) (R. Vyas pers. comm.) a rosy pelican (*Pelecanus*

onocrotalus) and a star tortoise (*Geochelone elegans*) (pers. obs.).

IV.3.1 Scat Analysis: Eight hundred lion scats were analyzed to identify the prey remains in them. Of these, 420 scats were collected in 1986-June 1987 (Period I), 60 scats in July-December 1987 (Period II) and the remaining 320 in 1989 (Period III). Of the 420 scats collected in Period I, 257 were from Sanctuary West, 52 from Sanctuary East, 74 from National Park and 37 from outside the PA. All the scats in Period II were collected in Sanctuary West. In Period III of the scats analyzed, 100 were from Sanctuary West, 120 from Sanctuary East and 100 from National Park.

Of these 800 lion scats, 608 (76%) contained the remains of a single prey, 184 (23%) had the remains of two prey species and 8 scats (1%) had the remains of three prey species. Twenty three scats (2.88%) contained grass. **Tables IV.1** to **IV.9** present the results of the analysis of lion scats for various periods and in different areas.

Two hundred leopard scats were analyzed and all these scats were collected in Period I. One hundred and twenty nine of these scats were from Sanctuary West and 71 from National Park. Of these 200 leopard scats, 121 (60.5%) had the remains of a single prey, 78 (39%) contained the remains of two species and one scat (0.5%) had the remains of three prey species. Only one scat (0.5%) had grass. **Tables IV.10** to **IV. 12** present the results of the analysis of leopard scats.

The results are presented both as frequency of occurrence as well as percent occurrence and the contribution to the diet by various prey species is ranked.

IV.3.1.1 Lion food habits in Period I: **Tables IV.1** to **IV.4** present the results of the analysis of lion scats for Period I. It clearly emerges that out of the eleven prey species listed, chital, cattle, buffalo, sambar and nilgai comprise the bulk of the lion's diet, irrespective of the area from which the scats were collected. Depending on the area both the choice of prey and the magnitude of choice varies as amply demonstrated by

the fluctuating ranking of the various prey species. For example, the ranking of sambar varies from 2 in National Park to 7 in Sanctuary East and it does not figure in the scats collected from outside the limits of the PA.

Based on Chi square test on frequency of occurrence data the following were determined. There is a significant difference in the choice of sambar between Sanctuary West and Sanctuary East ($X^2=9.36$, $P<0.01$, $d.f.=1$), with sambar remains occurring in 19.1% of the scats from Sanctuary West and only in 1.9% of the scats from Sanctuary East. A significant difference exists in the choice of cattle ($X^2=27.51$, $P<0.001$, $d.f.=1$), with cattle remains occurring in 25% of the scats from Sanctuary East and only in 15.6% of the scats from Sanctuary West. There was no significant difference in the choice of other species.

While comparing the results between Sanctuary West and National Park, it is evident that the lion's diet in these two areas is largely similar. There is a significant difference only in the choice of buffalo ($X^2=6.96$, $P<0.01$, $d.f.=1$), with the presence of buffalo remains detected in 31.9% of the scats from Sanctuary West and only in 16.2% of the scats from National Park.

The lion's diet in Sanctuary West and outside the PA is very different. Sambar, a high ranking prey in Sanctuary West is not even part of the diet of the lions outside the PA. Significant differences were detected in the choice of chital ($X^2=10.86$, $P<0.001$, $d.f.=1$), chital occurring in 41.6% of the scats in Sanctuary West and only in 13.5% of the scats outside the PA, and cattle ($X^2=29.51$, $P<0.001$, $d.f.=1$), cattle remains occurring in only 15.6% of the scats from Sanctuary West but in 54.1% of the scats from outside the PA. No significant difference in the choice of buffalo and nilgai was detected. Of the less frequently eaten prey only the presence of wild pig was detected in the scats from outside the PA while the scats from Sanctuary West reveal a much

wider prey choice in the lion's diet.

A comparison of the lion's diet between Sanctuary East and National Park also reveals significant differences. Sambar ranks second in the scats analyzed from National Park but only seventh in Sanctuary East (X^2=12.88, P<0.001, $d.f.$=1). Significant differences also exist in the choice of nilgai (X^2=7.58, P<0.001, $d.f.$=1) and cattle (X^2=21.93, P<0.001, $d.f.$=1).

While comparing the results of the analysis of lion scats from Sanctuary East and from outside the PA, there is a significant difference in the magnitude of choice of chital amongst the more frequently eaten prey (X^2=6.66, P<0.01, $d.f.$=1). Only five prey species were identified from the scats collected from outside the PA (**Table IV.4**).

Comparing the results of the scats analyzed from National Park and outside the PA indicates significant differences in the magnitude of choice of chital (X^2=11.38, P<0.001, $d.f.$=1), cattle (X^2=24.47, P<0.001, $d.f.$=1) and buffalo (X^2=6.42, P<0.05, $d.f.$=1). Chital remains were found more often in the scats from National Park while cattle and buffalo remains were more frequently found in the scats from outside the PA.

IV.3.1.2 Lion food habits in Period II: In Period II, lion scats were collected only from Sanctuary West. The results of the analysis are presented in **Table IV.5**. The remains of only 6 species were identified from the scats collected during this period. Buffalo and cattle were the major contributors to the diet of the lions with their remains occurring in 88.3% of the scats. The other species which contributed to the lion's diet in this period were chital, nilgai, wild pig and camel.

IV.3.1.3 Lion food habits in Period III: In Period III lion scats were collected from Sanctuary West, Sanctuary East and National Park. The results of the analysis are presented in **Tables IV.6 to IV.8. Table IV.9** sums up the 1989 scat analysis data and depicts what I feel is the most accurate picture of the lion's diet in general for the entire

Gir PA.

Between Sanctuary West and Sanctuary East, significant differences were detected in the lion's diet in the magnitude of choice of chital (X^2=9.95, P<0.01, $d.f.$=1), sambar (X^2=19.23, P<0.001, $d.f.$=1), nilgai (X^2=11.61, P<0.001, $d.f.$=1) and cattle (X^2=4.1, P<0.05, $d.f.$=1).

Between Sanctuary West and National Park, significant differences were detected in the lion's diet in the magnitude of choice of sambar (X^2=7.22, P<0.01, $d.f.$=1) and cattle (X^2=4.7, P<0.05, $d.f.$=1).

The diet of the lions was very different between Sanctuary East and National Park. Significant differences were detected in the magnitude of choice of sambar (X^2=43.65, P<0.001, $d.f.$=1), nilgai (X^2=15.62, P<0.001, $d.f.$=1), cattle (X^2=16.5, P<0.001, $d.f.$=1) and buffalo (X^2=5.17, P<0.05, $d.f.$=1).

IV.3.1.4 Comparison of lion food habits in Sanctuary West between Periods I, II and III:

Comparing the results of the analysis of scats from Sanctuary West shows a significant difference in the lion's diet between Periods I and II. There is a difference in the magnitude of choice of chital (X^2=14.89, P<0.001, $d.f.$=1), cattle (X^2=18.03, P<0.001, $d.f.$=1) and buffalo (X^2=5.77, P<0.05, $d.f.$=1).

A significant difference exists in the lion's diet in Sanctuary West between Periods II and III. There was a difference in the choice of chital (X^2=29.71, P<0.001, $d.f.$=1), cattle (X^2=14.1, P<0.001, $d.f.$=1) and buffalo (X^2=16.63, P<0.001, $d.f.$=1).

Differences are detected in the lion's diet in Sanctuary West between Periods I and III also. Significant differences were detected in the magnitude of choice of chital (X^2=8.73, P<0.01, $d.f.$=1) and buffalo (X^2=6.9, P<0.01, $d.f.$=1).

IV.3.1.5 Comparison of lion food habits in Sanctuary East between Periods I and III:

The lion's diet in Sanctuary East did not change very much between Periods I and III.

A significant difference was detected only in the choice of cattle (X^2=8.88, P<0.01, $d.f.$=1).

IV.3.1.6 Comparison of lion food habits in National Park between Periods I and III: The lion's diet in National Park did not exhibit any significant difference between periods I and III.

IV.3.1.7 Leopard food habits in Period I: **Tables IV.10** and **IV.11** present the results of the analysis of leopard scats from Sanctuary West and National Park in Period I. Chital, langur, sambar, cattle and peafowl are the most frequently eaten prey by leopards in Gir, with chital and langur as the top ranking prey. Analysis of leopard scats revealed that they fed upon civet but there was no evidence of their feeding on camel. **Table IV.12** sums up the leopard scat data for Period I in Sanctuary West and National Park.

The diet of the leopard is largely similar in Sanctuary West and National Park. A significant difference was detected only in the choice of sambar (X^2=6.01, P<0.05, $d.f.$=1), with the remains of sambar detected in 18.3% of the scats from National Park but only in 7% of the scats from Sanctuary West.

IV.3.1.8 Comparison of the diets of lion and leopard in Period I: The scat data of lion and leopard for Sanctuary West and National Park were tested using chi square test on frequency of occurrence data to determine the differences in the diets of these two large cats.

Despite chital being the top ranked prey species for both the cats, a significant difference exists in the magnitude of their choice for chital in Sanctuary West (X^2=8.53, P<0.01, $d.f.$=1). Significant differences were also found in the choice of sambar (X^2=9.82, P<0.01, $d.f.$=1), buffalo (X^2=29.62, P<0.001 $d.f.$=1), langur (X^2=82.17, P<0.001, $d.f.$=1) and peafowl (X^2=4.69, P<0.05, $d.f.$=1).

The diets of the two cats were not so different when comparing the results of scat analysis from National Park. Significant differences exist only in the choice of buffalo (X^2=5.61, P<0.05, $d.f.$ = 1) and langur (X^2=20.6, P<0.001, $d.f.$ = 1).

IV.3.1.9 Dietary overlap between lion and leopard: The overlap in the diets of lion and leopard was calculated based on scat data for Period I from Sanctuary West and National Park. Overlap values were 0.60 for Sanctuary West and 0.71 for National Park, indicating a greater degree of overlap between the diets of these two large cats in National Park.

IV.3.2 Kill Data: **Tables IV.13** to **IV.29** and **Figures IV.1** and **IV.2** present various aspects of the kill data of lions and leopards.

IV.3.2.1 Species composition: Two hundred and one kills made by lions were examined during the study. **Table IV.13** presents the species composition of all the lion kills which were collected. This sample also includes kills collected outside the PA and wild prey forms 52.2% of these kills. **Table IV.14** gives the species composition of kills collected only within the PA and of this 56.2% is wild prey. **Table IV.15** presents the most accurate picture of the species composition of the lion's diet in Gir based on collection of kills. This data set excludes the kills collected during July-December 1987, when there was a large scale influx of livestock into the PA. Wild prey constitutes about 65% of the lion kills collected with chital, sambar, cattle and buffalo being the most frequently killed species. Livestock constitutes an overwhelming majority (88.9%) of the lion kills collected during July-December 1987 (**Table IV.16**) when many thousands of livestock had illegally entered the PA.

Of the 43 leopard kills examined during this study, chital forms 72.1% and there is a very limited predation on livestock (**Table IV.17**).

IV.3.2.2 Seasonal patterns: Of the 200 kills examined (excluding the leopard cub) (**Plate IV.4**), 79 were collected in summer, 45 during monsoon, 26 during post monsoon and 50 during winter (**Table IV.18**). The per cent species composition varied across the seasons and similarly the ratio between wild and domestic ungulate kills also fluctuated across the seasons. In summer wild ungulates contributed the most with 68.3% of the kills and this was reduced to 52% during winter, 42.3% during monsoon and only 19.1% during post monsoon.

While seasonally classifying the kills of the four most often killed prey (**Fig. IV.1** and **IV.2**) a seasonal pattern emerges in lion predation on various prey species. This pattern is very distinct in the case of sambar with 64% of the sambar kills being collected in summer, 20% in winter, 12% in monsoon and only 4% in post monsoon. For chital the corresponding values were 49.2%, 30.2%, 19% and 1.6%. Buffalo and cattle exhibit a more even distribution across the four seasons. For buffalo 28.1% of the kills were collected in summer, monsoon and post monsoon respectively while 15.6% was collected during winter. In the case of cattle, 25.8% of the kills were collected in summer and monsoon, 17.7% in post monsoon and 30.6% in winter.

IV.3.2.3 Spatial patterns in lion kills: Majority of the lion kills were collected from Sanctuary West (**Table IV.19**). The number of kills collected in various areas is only a reflection of the sampling intensity, as equal time was not spent in all the areas. Moreover the amount local information which enabled me to locate kills also varied depending on the area. The composition of the kill sample from the four areas differed, possibly reflecting prey availability. In Sanctuary West the ratio between wild and domestic ungulates in the kill sample was almost even. But in Sanctuary East livestock dominates, forming 77.3% of the lion kills. In National Park wild ungulates form the bulk (79.2%) of the kills collected. Outside the PA, cattle dominates the kill sample

(68.8%).

IV.3.2.4 Age and sex of prey killed: The age and sex of 104 wild ungulates killed by lion were determined (**Table IV.20**). Adequate samples are only available for chital and sambar, to carry out statistical analyses. The male:female ratio in the kills of chital was 179 males:100 females while the sex ratio in the population was 45 males:100 females. The two ratios were significantly different ($Z=6.92$, $P<0.001$).

The sex ratio in the sambar kills was 150 males:100 females while the population sex ratio was 49 males:100 females. The ratios were significantly different ($Z=5.53$, $P<0.001$). Hence lions were preferentially preying upon both chital and sambar stags.

As accurate aging of the deer in the population was not carried out as a result no comparison is attempted between the age structure in the kill sample and in the population. It is certain that the collection of kills is biased towards the larger prey due to their greater persistence in the field and the possibility of them being detected more easily due to their larger size. Even within species this would affect the collection of the younger classes of animals which are under represented in the kill sample.

IV.3.2.5 Predation of livestock: Of the 56 livestock kills at which lions were observed feeding and when it was also possible to establish the identity of the animals making the kill; on 34 occasions male lions were observed, females or females with young were seen on 15 occasions and mixed groups were seen at 7 kills. The adult lion sex ratio in the population was 1 male: 2.2 females (Ravi Chellam unpublished). This data indicates that male lions are preying on livestock at a significantly higher level than what one would expect as a direct function of the prevailing adult sex ratio ($G=29.6$, $d.f.=1$, $P<0.001$).

IV.3.2.6 Body condition of prey killed: The body condition of 48 wild ungulates was assessed based on the colour and consistency of the bone marrow (**Table IV.21**). Of

these 48 animals, 27 (56.3%) were in Excellent, 15 (31.5%) in Good, and 6 (12.5%) in Poor condition. Lack of data on the body condition of ungulates in the population limits the value of this assessment. It only indicates that lions do not seem to be preying in any pronounced manner on ungulates in poor condition.

IV.3.2.7 Ambush cover and vegetation density at kill sites: The availability of ambush cover was assessed in 182 sites where both wild and domestic ungulates were killed by lions (**Table IV.22**). Ambush cover appears to be a much more crucial requirement for lions to kill wild ungulates than livestock. Fifty three per cent of the wild ungulates were killed by lions at sites with High ambush cover, while the remaining were killed more or less equally at sites with Low and Medium ambush cover. By contrast the majority of the livestock kills were made in sites with Low and Medium ambush cover (36% of the kills in each category) and the remaining 28% of the kills were at sites with High ambush cover.

Table IV.23 presents the distribution of sites where lions killed wild ungulates and livestock with reference to the density of vegetation. Vegetation density does not appear to have any effect on the predation of wild ungulates by lions. The kill sites were more or less equally distributed across the three vegetation density classes. By contrast livestock were killed more often (54% of the kills) in sites with lower vegetation density (0-400 stems/ha.) and only 8% of the sites had high vegetation density (>800 stems/ha.).

IV.3.2.8 Influence of water: To determine whether water had any effect on the predation ecology of the lions, the distance between the kill sites and the nearest source of water was measured for 62 chital and 24 sambar kills. This data was categorised on a seasonal basis (**Table IV.24**). Sufficient samples were available only in summer for both chital and sambar. Of the 31 chital kills examined in summer, 13 were made <25m from water and 9 at distances between 26 and 100m from water. This forms 71% of the chital

kills examined during summer. Of the sambar kills 5 were made < 25m and 7 between 26 and 100m from water, constituting 75% of the 16 kills examined during summer. Thus in summer when water is a restricted resource, most of the chital and sambar kills are made within 100m from a source of water.

IV.3.2.9 Influence of maldhari ness: To determine whether the presence of maldharis and their settlements had any effect on the predation ecology of the lions, distance between the kill sites and the closest ness was estimated. Most of the wild ungulates are killed at sites >500m away from human settlements (Table IV.25). Most of the buffaloes were killed away from the nesses. Only cattle was preyed upon close to the ness sites. This data set is slightly biased, as the nesses are not randomly distributed through the PA and National Park is devoid of any human settlements.

IV.3.2.10 Habitat types from which lion kills were collected: **Tables IV.26 to IV.28** present the data for the major prey species killed in various habitat types. Data for chital and sambar are presented on a seasonal basis while livestock kill data is summarised across all seasons. For lions riverine forest and reservoir beds are crucial hunting habitats, especially during the dry summer. Fifty five per cent of the chital kills and 44% of the sambar kills collected during summer were from riverine forest and reservoir bed. Across the seasons Teak-Acacia-Zizyphus woodland is the habitat in which chital are killed most often by lions. No pattern is discernible for the other habitat types with reference to chital or sambar kills.

Livestock are killed in a wide variety of habitats with no clear pattern emerging. As only the availability of one habitat type (riverine forest) was measured there is a limitation in trying to explain in greater detail about the selection of hunting habitat by lions.

IV.3.2.11 Preference rating for prey species: For calculating Preference Rating values the frequency of various species in the lion kills was taken from **Table IV.15** and the frequency of the prey species in the population from Chapter III. Sambar with a Preference Rating value of 15, wild pig with 13.3 and cattle with 10.5 are the highly preferred prey of lions in the Gir PA. Even though chital is the prey most often eaten it is also numerically the most abundant prey and hence it has a low Preference Rating value of 0.57. Nilgai has a value of 5 and buffalo 0.68. The Preference Rating for cattle is not a true reflection of the prevailing situation in Gir. Only resident maldhari cattle were considered available for lions, while in reality a much greater number of cattle were available. Most of the livestock brought to the PA from the nearby villages for grazing were cattle, and these were not included to calculate the prey available for lions.

IV.3.2.12 Weight classes of kills: Both the scat and kill data indicate considerable overlap in the diets of lion and leopard in the Gir PA. To further analyze the mechanisms of niche separation operating amongst these two carnivores, the kills collected were assigned to various weight classes (**Table IV.29**). For lions 51.4% of the kills weigh >100 kg and only 5.6% falls in the <25 kg class. For leopards no kill was recorded in the >100 kg class and the kills were more or less equally divided amongst the three remaining weight classes, with the 26-50 kg class having the largest number of kills (17, 39.5% of the leopard kills).

IV.3.2.13 Impact of lion predation on the prey population: With a few assumptions it is possible to work out the annual off take of meat due to lion predation in the Gir PA. Schaller (1972) based on information from captive lions mentions that 5 kg of meat would be the average daily consumption of lions. The annual requirement for the lion population in Gir is 5 x 180 x 365 = 3,28,500 kg. About 25 per cent of the carcass is either inedible or wasted by the carnivores while feeding. Adding this to the annual off

take, the total requirement of meat for the lion population is estimated to be 4,10,625 kg which is an annual off take of 8.3% of the ungulate biomass. Taking the per cent occurrence data in **Table IV.9** to represent the proportions in which lions prey on different species, the biomass off take for each prey species was calculated. Of the five most frequently killed species the annual off take for chital (7.7% of the biomass) and buffalo (2.1%) were sustainable. Sambar was losing 56.5%, nilgai 68.8% and cattle 26.7% of their biomass to lion predation every year. As already mentioned this does not represent the correct picture of the lion predation on cattle, as large numbers of cattle are available to lions from villages outside the PA. Nilgai population was probably under estimated as considerable portions of Sanctuary East were not covered as part of the vehicle counts and nilgai also have a tendency to go out of the PA, especially to feed on crops. The high percentage of removal of both sambar and nilgai due to lion predation could well be the reason for their low numbers in the Gir PA. The removal of biomass due to leopard predation is additional to the quantity consumed by lions.

IV.4 Discussion:

The predation ecology of the lions in Africa and especially in southern and eastern Africa has been well studied over the years (Wright 1960: Mitchell, Shenton & Uys 1965; Kruuk & Turner 1967; Hirst 1968; Makacha & Schaller 1969; Pienaar 1969; Schaller 1972; Rudnai 1974; Eloff 1984; Mills 1984 and van Orsdol 1984). Recently Ruggiero (1991) has reported on prey selection by lions in Central Africa. Only Joslin (1973) and Sinha (1987) have earlier reported on the food habits of the lions in Gir.

The scat data indicates a very pronounced change in the food habits of the lions from those earlier reported. In 1989 only 25.9% of the items identified from lions scat were livestock. Joslin (1973) reported that 78.5% of the scats he analyzed contained livestock remains, so a complete reversal in the pattern of lion predation has taken place

in the Gir PA. The lions seem to have tracked the increasing availability of wild prey since the early 1980s (refer Chapter III). This change seems to have gradually occurred with the lions increasingly preying on wild prey. Sinha (1987) reports that 52% of the scats he analyzed contained wild prey.

Since sufficient scats were collected from various areas, it was possible to establish some statistically significant differences in the lion's predation pattern between these areas. These differences reflect the differences in prey availability. For instance, in Period I, the presence of sambar remains in lions scats was significantly greater in Sanctuary West than in Sanctuary East where sambar occurs in very low density. Cattle remains occur more in scats from Sanctuary East which has a greater cattle density when compared with Sanctuary West.

During Period I lions were being offered buffalo baits to enable viewing by tourists. This biased the scat data from Sanctuary West towards an increasing occurrence of buffalo. Between National Park and Sanctuary West, the only difference in the diet of the lions was the significantly greater presence of buffalo remains in the lion scats from Sanctuary West. Apart from the buffalo baits offered to the lions in Sanctuary West, there were no livestock resident in National Park and these factors contributed to the greater presence of buffalo remains in the scats from Sanctuary West.

About 75% of the lions scats collected from outside the PA had livestock remains and chital, nilgai and wild pig remains were also detected. This is a very different pattern from what was observed in the three areas within the PA. With very few wild ungulates existing outside the PA boundaries the lions had to more or less completely depend on livestock for its food.

Similar differences in the lion's diet between the different areas were detected in Period III also.

The scats collected during Period II have a high presence of livestock, per cent occurrence >75%. During this period there was a severe drought prevailing in the area and the forest department staff were also on strike. This provided both the impetus and the opportunity for a large scale invasion of the PA by livestock from places even as far as a couple of hundred kilometres. This suddenly increased livestock availability and this is reflected in the scat data (**Table IV.5**) as well as in the kill data (**Table IV.16**). Comparing the scat data between the three Periods for Sanctuary West shows that during Period II significantly more livestock remains were identified in the scats than during the other Periods. While comparing scat data between Period III and Period I there was a reduction in the frequency of occurrence of buffalo remains, due to the stoppage of the practice of offering buffalo baits.

While comparing the scat and kill data it becomes evident that livestock forms a greater percentage of the kill samples but its occurrence in the scats is lower. This is due to the inherent sampling bias. Livestock kills can be detected very easily as compared with wild ungulates carcasses. Livestock kills are often made in relatively more open areas, closer to human habitation and are also more frequently reported by people. But scats are collected at random and their collection is not influenced by the prey remains they contain. Hence the scat data is probably a better representation of the diet of the lions in the Gir PA.

A seasonal pattern was observed in the composition of lion kills (**Table IV.18**). This is due to the varying habitat conditions through the year. The comparatively high number of livestock kills during the monsoon and post-monsoon is partly due to the kills collected during Period II and also because the denser vegetation cover during these two seasons probably allows the lions to hunt livestock more efficiently. In Gir the livestock are herded by people who actively defend their stock from the lions if they are able to

locate the lions at a distance.

Lion predation on sambar shows a most distinct seasonal pattern (**Fig. IV.1**). Sambar usually prefers hilly terrain which is not so often used by the lions. During summer sambar is forced to come down for water which is restricted to the rivers and reservoirs. Sambar due to its crepuscular and more solitary habits renders itself more vulnerable to lion predation than other species during summer.

As with scat data the kills also vary in their composition depending on the area from which they were collected. This is once again a function of prey availability.

Lions kill significantly more chital and sambar stags than expected in Gir. This follows the pattern that has been established by Johnsingh (1983) for dhole predation in Bandipur and Patel (1992) who reanalysed Johnsingh's (1983) data. Many reasons have been attributed for the greater predation on males. Hornocker (1970) suggests that stags are weakened after rut and would hence fall easy prey. Sharatchandra & Gadgil (1978) indicate that chital stags show much lesser vigilance than the rest of the herd. Patel (1992) suggests that the larger body size of the stags might make them more attractive to hunt as the predators stand to gain more per hunt-effort.

The greater predation by male lions on livestock is a "high risk - high gain" strategy, typical of polygynous species (Sukumar 1991). Males by killing livestock gain much more meat per hunt effort as both cattle and buffalo are much heavier than the most frequently killed chital. Killing livestock involves a certain element of risks as the lions have to deal with the herdsmen taking care of the herd. Females, especially those with cubs would probably avoid such situations of possible conflict with Man. The chances of being disturbed on livestock kills are also much greater when compared with wild ungulate kills. For the male lions, livestock is a relatively easy prey to secure compared with the fleet footed and vigilant wild ungulates. This possibly is one of the

reasons for the observed variation in the pattern of social organisation amongst the lions in Gir when compared with what is reported from east Africa (refer Chapter V).

Lions in Gir tend to drag their kills into fairly dense cover to protect them from avian scavengers (**Plate IV.3**). This enables them to utilize the carcasses with greater efficiency. Vegetation density does not seem to be hampering the predation success of the lions. From the limited observations of successful and unsuccessful hunts (N = 7) it seems that the lion lies in wait for its prey in certain areas like the riverine forest and then makes the charge from very short range. It is likely that quite a bit of the hunting is opportunistic.

The high number of lion kills collected close to water and in riverine forests and reservoir beds during late winter and summer, establishes the rather crucial role of this habitat in the predation ecology of the lions. Distribution of water governs the distribution of prey, especially for species like chital and sambar. During the drier parts of the year as naturally occurring water is restricted to the riverine tracts and reservoir beds, lions seem to be concentrating their hunting in these two habitats.

The diets of lion and leopard in Gir have an overlap value ranging from 0.61 to 0.71. Schaller's (1967) data shows a 0.75 overlap between the diets of tiger and leopard in Kanha and Johnsingh's (1983) study showed an overlap of 0.59 between tiger and leopard in Bandipur. The overlap between the diets of lion and leopard is of the reported magnitude for leopard and tiger. In Gir chital is a top ranking prey for both the species. While livestock contributes a significant portion to the lion's diet, langur is the second ranking prey for leopard. This partition between their diets enables the two carnivores to coexist. Aggressive interactions do take place between the two species. Leopards being much smaller in size always have to seek refuge, normally the tactic is to climb a tree. At times the leopard might not be quick or alert enough and it would

be caught and killed and even eaten by lions (**Plate IV.4**). Lions also dispossess leopards of their kills. In an attempt to avoid such a loss, leopards carry their kills up trees in Gir.

The major difference that emerges from a comparison of scat data for lion and leopard is the much greater predation on langurs by leopards and on buffaloes by lions.

When the kills collected are categorised into various weight classes (**Table IV.29**) a distinct separation in the prey choice between these two cats emerges. Heavier prey (>100 kg) forming a greater proportion of the lion kills with none of the leopard kills falling in this category. This pattern conforms to Bourliere's (1963) prediction that carnivores usually prey upon herbivores of about their own size and weight.

Seidensticker (1976b) reports a similar pattern of separation in prey size taken by tiger and leopard in Chitawan National Park. Johnsingh (1983) found that 15.5% of the leopard kills collected in Bandipur were in the >100 kg class. This was because eight of the nine kills recorded in this category were livestock. From Africa Kruuk & Turner (1967), Pienaar (1969) and Schaller (1972) all report that leopards rarely kill prey heavier than 100 kg.

In Gir where lions exist at a high density it does not benefit the leopard to kill heavier prey as it would not be able to efficiently utilize it, often losing them to lions. I have recorded at least six instances when lions robbed kills from leopards.

Even though chital forms the top-ranking prey for lion and leopard in Gir, the abundant availability of the deer reduces competition. Leopard by preying on langur and smaller prey like peafowl further reduces competition with lion which preys on heavier animals like sambar, cattle and buffaloes.

The last 20 years have witnessed a complete change in the predation pattern of the lions in the Gir PA. This is a result of the change in the availability of prey species.

In the early 1970s there were very few wild ungulates but since then the wild ungulate population, especially that of chital has increased tremendously. The chital population is capable of sustaining the current predation pressure but both nilgai and sambar are facing extremely high and possibly unsustainable rates of predation. Livestock still significantly contributes to the diet of the lions and any attempt at removing them from the PA has to be a gradual process. The predation pattern of the lion needs to be constantly monitored to be able to assess the effect of lion predation on prey population and the changes in this pattern in response to the changing conservation situation.

Table IV.1: Composition of lion diet in Sanctuary West of the Gir PA in 1986-87, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence ($N^{\bullet}$=257)	Percent occurrence ($N^{@}$=329)	Rank
1	Chital	41.6 (107)	32.5	1
2	Sambar	19.1 (49)	14.9	3
3	Nilgai	7.4 (19)	5.8	5
4	Cattle	15.6 (40)	12.2	4
5	Buffalo	31.9 (82)	24.9	2
6	Wild Pig	5.1 (13)	4.0	6
7	Langur	1.2 (3)	0.9	9
8	Peafowl	3.9 (10)	3.0	7
9	Porcupine	0	0	-
10	Chousingha	0.8 (2)	0.6	10
11	Camel	1.6 (4)	1.2	8

$N^{\bullet}$ = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.2: Composition of lion diet in Sanctuary East of the Gir PA in 1986-87, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence ($N^{*}=52$)	Percent occurrence ($N^{@}=73$)	Rank
1	Chital	38.5 (20)	27.4	2
2	Sambar	1.9 (1)	1.4	7
3	Nilgai	19.2 (10)	13.7	4
4	Cattle	48.1 (25)	34.2	1
5	Buffalo	21.2 (11)	15.1	3
6	Wild Pig	5.8 (3)	4.1	5
7	Langur	3.8 (2)	2.7	6
8	Peafowl	1.9 (1)	1.4	7
9	Porcupine	0	0	-
10	Chousingha	0	0	-
11	Camel	0	0	-

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.3: Composition of lion diet in National Park of the Gir in 1986-87, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence ($N^{*}=74$)	Percent occurrence ($N^{@}=86$)	Rank
1	Chital	45.9 (34)	39.5	1
2	Sambar	25.7 (19)	22.1	2
3	Nilgai	4.1 (3)	3.5	6
4	Cattle	10.8 (8)	9.3	4
5	Buffalo	16.2 (12)	14.0	3
6	Wild Pig	1.4 (1)	1.2	8
7	Langur	6.8 (5)	5.8	5
8	Peafowl	1.4 (1)	1.2	8
9	Porcupine	2.7 (2)	2.3	7
10	Chousingha	1.4 (1)	1.2	8
11	Camel	0	0	-

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.4: Composition of lion diet outside the Gir PA in 1986-87, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence (N^{*}=37)	Percent occurrence ($N^{@}$=45)	Rank
1	Chital	13.5 (5)	11.1	3
2	Sambar	0	0	-
3	Nilgai	13.5 (5)	11.1	3
4	Cattle	54.1 (20)	44.4	1
5	Buffalo	37.8 (14)	31.1	2
6	Wild Pig	2.7 (1)	2.2	5
7	Langur	0	0	-
8	Peafowl	0	0	-
9	Porcupine	0	0	-
10	Chousingha	0	0	-
11	Camel	0	0	-

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.5: Composition of lion diet in Sanctuary West of the Gir PA in July-December 1987, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence ($N^{*}=60$)	Percent occurrence ($N^{@}=70$)	Rank
1	Chital	15.0 (9)	12.9	3
2	Sambar	0	0	-
3	Nilgai	8.3 (5)	7.1	4
4	Cattle	40.0 (24)	34.3	2
5	Buffalo	48.3 (29)	41.4	1
6	Wild Pig	3.3 (2)	2.9	5
7	Langur	0	0	-
8	Peafowl	0	0	-
9	Porcupine	0	0	-
10	Chousingha	0	0	-
11	Camel	1.7 (1)	1.4	6

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.6: Composition of lion diet in Sanctuary West of the Gir PA in 1989, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence ($N^{*}=100$)	Percent occurrence ($N^{@}=126$)	Rank
1	Chital	59.0 (59)	46.8	1
2	Sambar	21.0 (21)	16.7	2
3	Nilgai	5.0 (5)	4.0	5
4	Cattle	14.0 (14)	11.1	4
5	Buffalo	18.0 (18)	14.3	3
6	Wild Pig	4.0 (4)	3.2	6
7	Langur	2.0 (2)	1.6	7
8	Peafowl	1.0 (1)	0.8	8
9	Porcupine	1.0 (1)	0.8	8
10	Chousingha	0	0	-
11	Camel	1.0 (1)	0.8	8

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.7: Composition of lion diet in Sanctuary East of the Gir PA in 1989, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence ($N^{*}=120$)	Percent occurrence ($N^{@}=150$)	Rank
1	Chital	37.5 (45)	30.0	1
2	Sambar	2.5 (3)	2.0	7
3	Nilgai	20.8 (25)	16.7	3
4	Cattle	25.0 (30)	20.0	2
5	Buffalo	20.0 (24)	16.0	4
6	Wild Pig	9.2 (11)	7.3	5
7	Langur	6.7 (8)	5.3	6
8	Peafowl	1.7 (2)	1.3	8
9	Porcupine	0	0	-
10	Chousingha	0	0	-
11	Camel	1.7 (2)	1.3	8

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.8: Composition of lion diet in National Park of the Gir PA in 1989, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence ($N^{\bullet}$ = 100)	Percent occurrence ($N^{@}$ = 121)	Rank
1	Chital	50.0 (50)	41.3	1
2	Sambar	37.0 (37)	30.6	2
3	Nilgai	3.0 (3)	2.5	7
4	Cattle	5.0 (5)	4.1	5
5	Buffalo	9.0 (9)	7.4	3
6	Wild Pig	7.0 (7)	5.8	4
7	Langur	5.0 (5)	4.1	5
8	Peafowl	2.0 (2)	1.7	8
9	Porcupine	2.0 (2)	1.7	8
10	Chousingha	1.0 (1)	0.8	10
11	Camel	0	0	-

$N^{\bullet}$ = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.9: Composition of lion diet in the Gir PA in 1989, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence (N^{*}=320)	Percent occurrence ($N^{@}$=397)	Rank
1	Chital	48.1 (154)	38.8	1
2	Sambar	19.1 (61)	15.4	2
3	Nilgai	10.3 (33)	8.3	5
4	Cattle	15.3 (49)	12.3	4
5	Buffalo	15.9 (51)	12.8	3
6	Wild Pig	6.9 (22)	5.5	6
7	Langur	4.7 (15)	3.8	7
8	Peafowl	1.6 (5)	1.3	8
9	Porcupine	0.9 (3)	0.8	9
10	Chousingha	0.3 (1)	0.3	11
11	Camel	0.9 (3)	0.8	9

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.10: Composition of leopard diet in Sanctuary West of the Gir PA in 1986-87, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence ($N^{*}=129$)	Percent occurrence ($N^{@}=178$)	Rank
1	Chital	57.4 (74)	41.6	1
2	Sambar	7.0 (9)	5.1	5
3	Nilgai	6.2 (8)	4.5	7
4	Cattle	10.1 (13)	7.3	3
5	Buffalo	7.0 (9)	5.1	5
6	Wild Pig	2.3 (3)	1.7	9
7	Langur	32.6 (42)	23.6	2
8	Peafowl	9.3 (12)	6.7	4
9	Porcupine	1.6 (2)	1.1	10
10	Chousingha	0.8 (1)	0.6	11
11	Civet	3.9 (5)	2.8	8

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.11: Composition of leopard diet in National Park of the Gir PA in 1986-87, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence ($N^{*}=71$)	Percent occurrence ($N^{@}=102$)	Rank
1	Chital	53.5 (38)	37.3	1
2	Sambar	18.3 (13)	12.7	3
3	Nilgai	4.2 (3)	2.9	7
4	Cattle	7.0 (5)	4.9	4
5	Buffalo	4.2 (3)	2.9	7
6	Wild Pig	4.2 (3)	2.9	7
7	Langur	38.0 (27)	26.5	2
8	Peafowl	5.6 (4)	3.9	5
9	Porcupine	5.6 (4)	3.9	5
10	Chousingha	0	0	-
11	Civet	2.8 (2)	2.0	10

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.12: Composition of leopard diet in the Gir PA in 1986-87, based on analysis of scats.

SNo	Prey Species	Frequency of occurrence (N^{*}=200)	Percent occurrence ($N^{@}$=280)	Rank
1	Chital	56.0 (112)	40.0	1
2	Sambar	11.0 (22)	7.9	3
3	Nilgai	5.5 (11)	3.9	7
4	Cattle	9.0 (18)	6.4	4
5	Buffalo	6.0 (12)	4.3	6
6	Wild Pig	3.0 (6)	2.1	9
7	Langur	34.5 (69)	24.6	2
8	Peafowl	8.0 (16)	5.7	5
9	Porcupine	3.0 (6)	2.1	9
10	Chousingha	0.5 (1)	0.4	11
11	Civet	3.5 (7)	2.5	8

N^{*} = number of scats analyzed.

$N^{@}$ = number of prey items identified.

Figures in parenthesis are the actual number of occurrences of the remains of that particular species in the scats analyzed.

Table IV.13 Species composition of prey killed by lions in and around the Gir PA, 1987-1990 (N=201).

SPECIES	NO. OF KILLS	% COMPOSITION
Chital	63	31.3
Sambar	25	12.4
Nilgai	9	4.5
Wild pig	7	3.5
Leopard	1	0.5
TOTAL WILD PREY	105	52.2
Cattle	62	30.9
Buffalo	32	15.9
Camel	2	1.0
TOTAL LIVESTOCK	96	47.8

Table IV.14 Species composition of prey killed by lions only within the Gir PA, 1987-1990 (N = 169).

SPECIES	NO. OF KILLS	% COMPOSITION
Chital	62	36.7
Sambar	22	13.0
Nilgai	5	3.0
Wild pig	5	3.0
Leopard	1	0.6
TOTAL WILD PREY	95	56.2
Cattle	40	23.7
Buffalo	32	18.9
Camel	2	1.2
TOTAL LIVESTOCK	74	43.8

Table IV.15 Species composition of prey killed by lions within the Gir PA, excluding the kills collected during the influx of livestock (July - December, 1987) 1987-1990 (N=142).

SPECIES	NO. OF KILLS	% COMPOSITION
Chital	61	43.0
Sambar	21	14.8
Nilgai	4	2.8
Wild pig	5	3.5
Leopard	1	0.7
TOTAL WILD PREY	92	64.8
Cattle	30	21.1
Buffalo	18	12.7
Camel	2	1.4
TOTAL LIVESTOCK	50	35.2

Table IV.16 **Species composition of prey killed by lions within the Gir PA, during the influx of livestock (July - December, 1987) (N=27).**

SPECIES	NO. OF KILLS	% COMPOSITION
Chital	1	3.7
Sambar	1	3.7
Nilgai	1	3.7
Cattle	10	37.0
Buffalo	14	51.9

Table IV.17 **Species composition of prey killed by leopards in and around the Gir PA, (1987-1990) (N=43).**

SPECIES	NO. OF KILLS	% COMPOSITION
Chital	31	72.1
Peafowl	4	9.3
Langur	3	7.0
Sambar	1	2.3
Nilgai	1	2.3
Porcupine	1	2.3
Wild pig	1	2.3
Cattle	1	2.3

Table IV.18 Seasonal percentage composition of prey killed by lions in and around the Gir PA, (1987-1990) (N=200).

Prey species	Summer (N=79)	Monsoon (N=45)	Post Monsoon (N=26)	Winter (N=50)
Chital	39.2	26.7	3.8	38.0
Sambar	20.3	6.7	3.8	10.0
Nilgai	6.3	2.2	11.5	0
Wild pig	2.5	6.7	0	4.0
Total wild prey	68.3	42.3	19.1	52.0
Buffalo	11.4	20.0	34.6	10.0
Cattle	20.3	35.6	42.3	38.0
Camel	0	2.2	3.8	0
Total livestock	31.7	57.8	80.7	48.0

Table IV.19 Species composition of prey killed by lions in the four different areas in and around Gir PA, (1987-1990) (N=200).

Prey species	Sanctuary West	Sanctuary East	National Park	Outside
Chital	45 (38.5)	2 (9.1)	15 (51.7)	1 (3.1)
Sambar	14 (12.0)	1 (4.5)	7 (24.1)	3 (9.4)
Nilgai	2 (1.7)	2 (9.1)	1 (3.4)	4 (12.5)
Wild pig	5 (4.3)	0 (0)	0 (0)	2 (6.3)
Buffalo	26 (22.2)	4 (18.2)	2 (6.9)	0 (0)
Cattle	24 (20.5)	13 (59.1)	3 (10.3)	22 (68.8)
Camel	1 (0.85)	0 (0)	1 (3.4)	0 (0)
TOTAL	117	22	29	32

Figures in parenthesis denotes percentages.

Table IV.20 **Age and Sex composition of wild ungulate prey killed by lions in and around the Gir PA, 1987-1990 (N=104).**

Prey Species	Young			Prime Adults			Old Adults		
	M	F	U	M	F	U	M	F	U
Chital (N=63)	4	1	5	21	14	2	9	5	2
Sambar (N=25)	0	0	0	8	7	0	7	3	0
Nilgai (N=9)	1	0	0	6	2	0	0	0	0
Wild pig (N=7)	0	0	0	1	4	2	0	0	0

M = Male; F = Female; U = Unsexed.

Table IV.21 **Body condition of wild ungulate prey killed by lions in and around the Gir PA, based on an assessment of bone marrow fat 1987-1990 (N=48).**

Body condition	Chital (N=27)			Sambar (N=13)		Nilgai (N=5)		Wild pig (N=3)	
	M	F	U	M	F	M	F	F	U
Excellent	10	1	2	5	4	4	0	0	1
Good	7	3	0	2	1	0	0	2	0
Poor	1	3	0	1	0	0	1	0	0
Very poor	0	0	0	0	0	0	0	0	0

M = Male; F = Female; U = Unsexed.

Table IV.22 Availability of ambush cover at sites where wild ungulates (N=102) and livestock (N=80) were killed by lions in and around the Gir PA 1987-1990.

Prey	Ambush cover categories					
	Low	%	Medium	%	High	%
Wild	25	24.5	23	22.5	54	52.9
Livestock	29	36.3	29	36.3	22	27.5

Table IV.23 Vegetation density at sites where wild ungulates (N=55) and livestock (N=24) were killed by lions in and around the Gir PA 1988-1990.

Prey	Tree and shrub stems/ha.					
	0-400	%	400-800	%	>800	%
Wild	17	30.9	18	32.7	20	36.4
Livestock	13	54.2	9	37.5	2	8.3

Table IV.24 **Distance of sites where lions killed chital (N=62) and sambar (N=24) from a water source, in and around the Gir PA, 1987-1990.**

Season & Prey		Distance from water (m)				
		<25	26-100	101-300	301-500	>500
Summer	Chital	13	9	7	2	0
	Sambar	5	7	1	1	2
Monsoon	Chital	2	4	1	2	3
	Sambar	1	0	1	1	0
Post monsoon	Chital	0	0	0	0	1
	Sambar	0	1	0	0	0
Winter	Chital	4	3	4	3	4
	Sambar	0	2	2	0	0

Table IV.25 **Distance of sites where lions killed wild ungulates (N=101) and livestock (N=96) from a Maldhari ness or a village in and around the Gir PA, 1987-1990.**

Species	Distance from a Ness (m)				
	<25	26-100	101-300	301-500	>500
Chital (N=62)	0	2	4	7	49
Sambar (N=24)	0	0	1	2	21
Nilgai (N=8)	0	1	0	0	7
Wild pig (N=7)	0	0	0	2	5
Buffalo (N=32)	0	1	3	2	26
Cattle (N=62)	7	1	13	6	35
Camel (N=2)	0	0	0	0	2

Table IV.26 Habitat types in which lions killed chital (N=62) in different seasons, in and around the Gir PA, 1987-1990.

Habitat types	Seasons			
	Summer (N=31)	Monsoon (N=12)	Post Monsoon (N=1)	Winter (N=18)
Reservoir bed	4	0	0	0
Riverine Forest	13	0	0	3
Teak-Mixed Forest	4	2	0	3
Teak Forest	1	2	0	0
Teak-Acacia Woodland	0	1	0	0
Teak-Acacia-Zizyphus Woodland	5	6	1	9
Acacia Woodland	1	1	0	3
Acacia-Zizyphus Woodland	2	0	0	0
Agricultural land	1	0	0	0

Table IV.27 **Habitat types in which lions killed sambar (N=24) in different seasons, in and around the Gir PA, 1987-1990.**

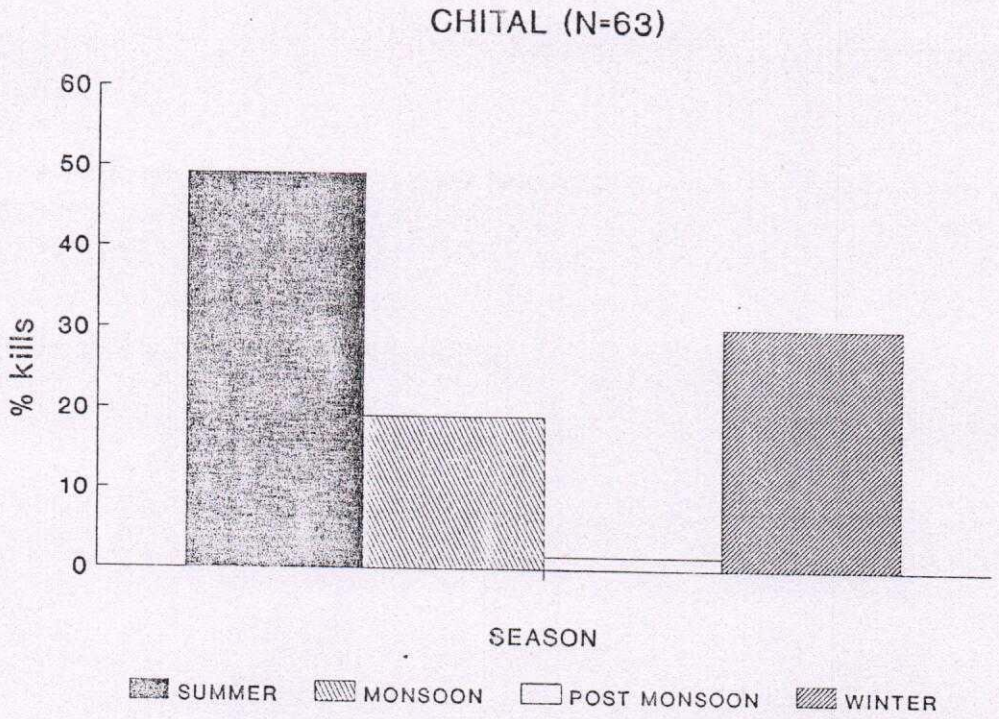
Habitat types	Seasons			
	Summer (N=16)	Monsoon (N=3)	Post Monsoon (N=1)	Winter (N=5)
Reservoir bed	2	0	0	1
Riverine Forest	5	0	1	0
Teak-Mixed Forest	3	0	0	0
Teak Forest	1	2	0	1
Teak-Acacia Woodland	0	1	0	0
Teak-Acacia-Zizyphus Woodland	2	0	0	2
Mixed Forest	1	0	0	0
Agricultural land	2	0	0	0

Table IV.28 **Habitat types in which lions killed buffalo (N=32), cattle (N=60) and camel (N=2) in and around the Gir PA, 1987-1990.**

Habitat types	Buffalo	Cattle	Camel
Reservoir bed	4	2	0
Riverine Forest	4	8	1
Teak-Mixed Forest	9	6	1
Teak Forest	3	9	0
Teak-Acacia Woodland	0	6	0
Teak-Acacia-Zizyphus Woodland	7	7	0
Mixed Forest	1	2	0
Acacia Woodland	1	1	0
Scrubland	1	4	0
Acacia-Zizyphus Woodland	2	9	0
Agricultural land	0	6	0

Table IV.29 **Weight classes of 142 lion kills and 43 leopard kills in the Gir PA, 1987-1990.**

Predator	Weight classes in Kg.			
	< 25	26-50	51-100	> 100
Lion				
Number of kills	8	29	32	73
Percentage	5.6	20.4	22.5	51.4
Leopard				
Number of kills	12	17	14	0
Percentage	27.9	39.5	32.6	0



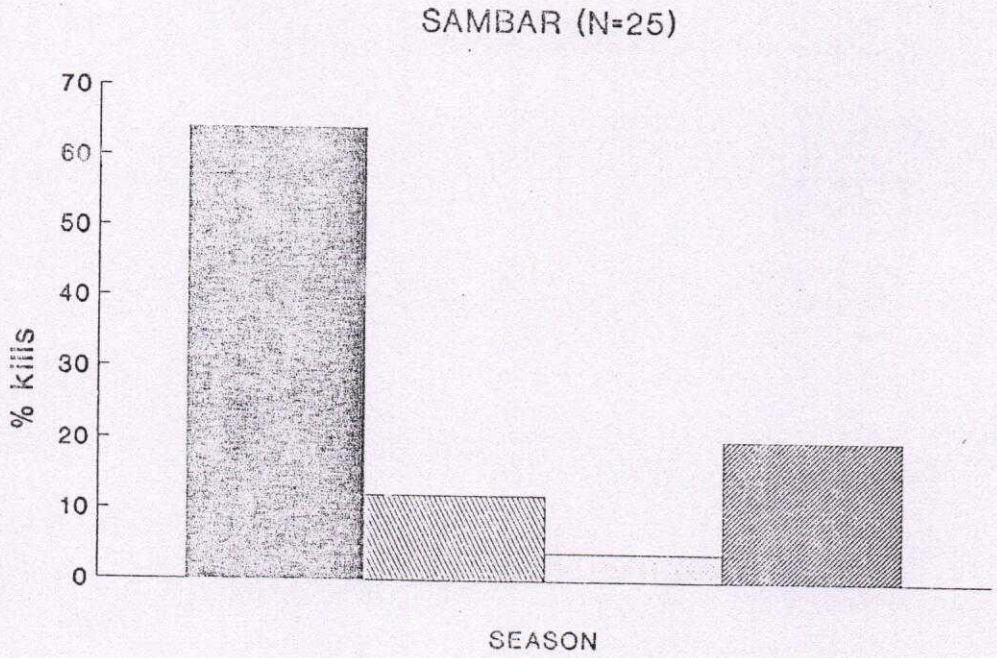
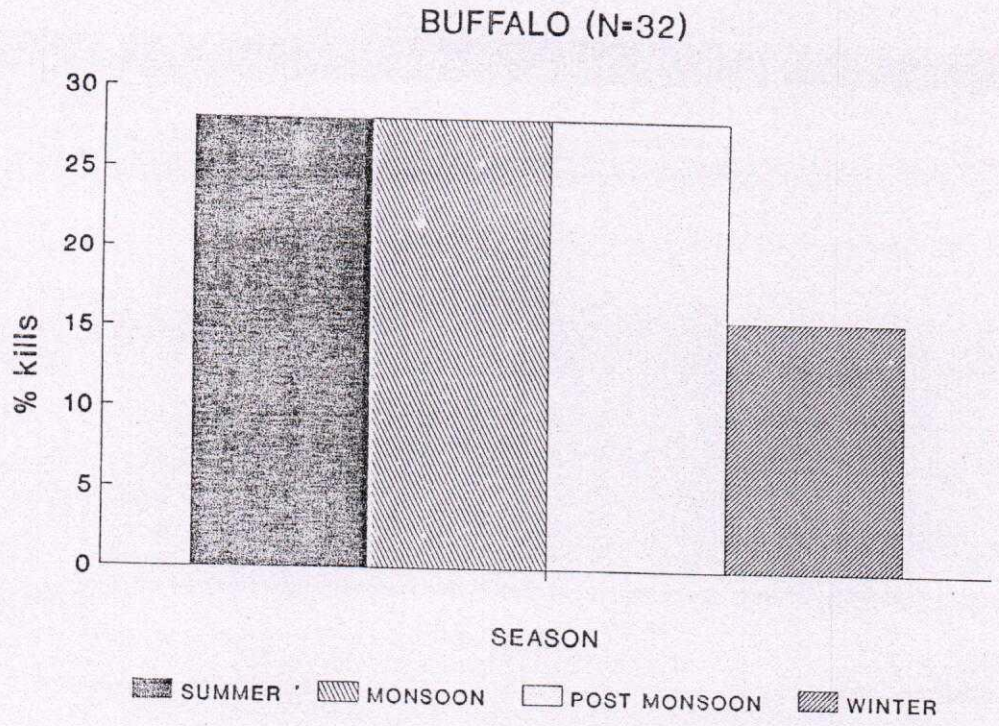


Fig. IV.1 Percentage composition of chital & sambar kills collected in four seasons (1987-90) in the Gir PA.



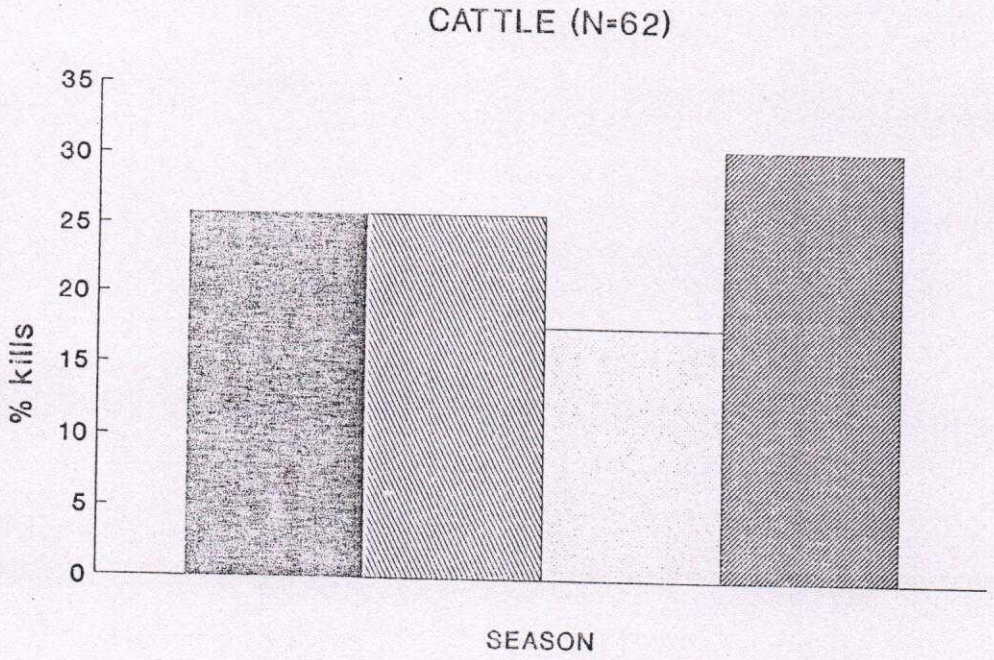


Fig. IV.2 Percentage composition of buffalo & cattle kills collected in four seasons (1987-90) in the Gir PA.

Plate IV.1: A male lion feeding on a chital stag.

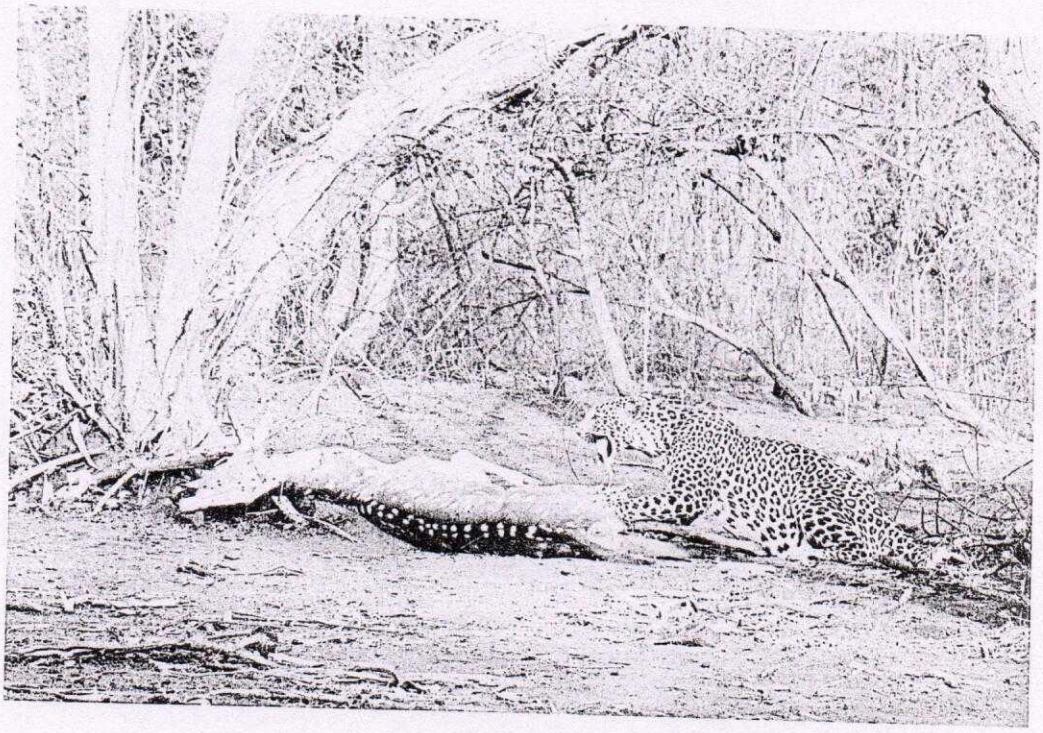


Plate IV.2: A leopardess feeding on a chital stag.
Photo: J.A. Khan

Plate IV.3: A lion kill dragged into dense vegetation to protect it from avian scavengers.

Plate IV.4: The head of a leopard cub killed and eaten by lions.

CHAPTER V

SOCIAL ORGANISATION

V.1 Introduction:

Lions are exceptional amongst felids in living in permanent social groups (Schaller 1972; Bertram 1975b; and Packer 1986). In Africa a group of related adult females form the nucleus of a pride along with their young. Adult males ranging in group size from 1 to 7 associate with these prides for varying lengths of time and mate with the pride females (Schaller 1972; and Bertram 1975b). These groups of males are referred to as male coalitions. There has been much debate about the factors that have induced the lion to become a social cat (Packer 1986). The Asiatic lions are also social and their social organisation broadly follows the general pattern reported by Schaller (1972) and Bertram (1975b) but with certain variations.

It has become important to understand the social organisation of the lion population in Gir as this would influence other aspects of their ecology, especially home range size, dispersion and regulation of the size of their population. Bearing in mind the ultimate objective of establishing a second free ranging lion population, it was essential to understand the prevailing pattern of social organisation amongst the lions to be able to choose a well settled and established social unit for translocation. This would in many respects give a much greater chance for the reintroduction to succeed. A good knowledge of the lion's social organisation would also enable the prediction of how the reintroduced lion population would behave as it settles down and starts growing in size.

V.2 Methods:

Data from radio-locations was used in this aspect of the study. As lions were visually located they were aged based on their body size, colour of pelage, presence/absence of spots on their body and by the colour and condition of their teeth.

Lions younger than one year were classified as cubs and females between the ages of one and three years as subadults. Subadult males were between the ages of one and five years. Since lionesses are capable of reproducing by the age of three they are classified as adults at an younger age than the males. Males are seldom able to acquire their own territory before the age of five and in fact till the age of five they are growing in body size and maturing into adult animals.

The cubs and the younger subadults have a light coloured coat marked with spots, which tend to disappear as they grow older. The colour of the skin also tends to darken, especially in the case of adult males. The thigh region and the hind limbs in general tend to acquire a dark hue of grey as the lions grow older.

Once the permanent set of teeth are in place, they are white in colour and very sharp in the young and prime aged adults. As they grow older and with continuous use they become discoloured and also tend to chip and break. As the lions cease to grow after a certain point in time, their teeth are by far the best indicators of their age.

V.3 Results:

Lion group size and group composition data from 292 radio-locations was analyzed for determining mean group size and grouping tendencies. Of these 292 locations, 63 were of a subadult male (SA male) in its natal home range; 109 of an adult female (C female); 72 of an adult male (J male) and 48 of another adult male (L male).

V.3.1 Group size: The mean group size of the lions varied depending on the age, sex and social status of the animal. C female was a resident pride female. She had two cubs and she was often located with another lioness having three cubs. The mean group size for C female was 4.5 and the group size varied from 1 to 11.

J male was a member of a male coalition which numbered five. The mean group size for J male was 2.2 and it varied from 1 to 5.

L male was a member of a two male coalition and its mean group size was 2.1 with the group size varying between 1 and 3.

The SA male had a mean group size of 4.1 when data was pooled for all the 63 locations. This included one sighting of 16 lions on a buffalo bait. Excluding this artificially induced congregation, the group size of SA male varied between 1 and 7. By November 1987, SA male was beginning to show signs of dispersing from his natal home range. If the mean group size values are calculated separately for the locations before and after November 1987, a distinct difference emerges. The mean group size was 4.5 prior to November 1987 and it dropped to 2 subsequently.

V.3.2 Grouping tendencies: C female was either located alone or with varying number of lions belonging to her pride. Out of the 109 locations, she was located with an adult male, only once.

J male was usually located with his coalition partners or alone. On six occasions he was located with an adult female. Of these 6 locations, J male was mating with the female four times, another male of his coalition was mating once and only once was the association with an adult female not related to mating.

L male was located 7 times with an adult female. On all these occasions the coalition partner was also present. No mating was observed during these 7 locations.

SA male was consistently located with his natal pride which included his litter mates, till November 1987. Out of 52 locations, only thrice was he located alone. Subsequent to November 1987, 11 locations of SA male were made and of these on 9 occasions SA male was located alone.

V.4 Discussion:

C female has a larger mean group size when compared with J male and L male. The close bonds between the pride females and her cubs was the reason for this. SA

male had a mean group size equalling that of C female when he was part of his natal pride. From November 1987, SA male was probably beginning to disperse, which was reflected in his more solitary existence. SA male was then ca. 30 months old.

Joslin (1973) reports a mean group size of 1.6 ± 0.1 for males and 2.1 ± 0.2 for females in the early 1970s from Gir. The mean group size for males has not changed much over the years but for females it has more than doubled. Joslin's data was not based on specific individuals but is a population wide data based on all encountered lion groups. He also mentions that the social bonds between males and females were weak and both the sexes were observed together largely while mating and only once on a kill.

Mean group size data for lions from Africa is largely similar to what I recorded in the Gir PA. Mitchell *et al.* (1965) reported a mean group size of 4 to 5 from Kafue National Park, Pienaar (1969) 3 to 4 from Kruger National Park and Schaller (1972) reports mean group sizes of 3.1 and 5.4 for his two study prides in Serengeti National Park.

The most significant fact that emerges out of an analysis of lion grouping tendencies in the Gir PA is the minimal association between resident pride females and the resident coalition males. L male was observed on 14.6% of the locations with a female and J male only on 8.3% of its locations. With L male the identity and social status of the associating adult female was not known. J male was largely associating with a female for mating. C female was located only on 0.9% of its locations with an adult male. The presence of young cubs probably proved to be a deterrent for a closer association of C female with adult males.

Schaller (1972) found that adult males of his study prides associated with females and the rest of the pride in 70% to 90% of the locations. Bertram (1975b) reports from his research in Serengeti National Park that the lionesses do most of the hunting in the

resident lion population. The females are probably more efficient as they lack the conspicuous mane (which is probably a handicap in the open grasslands while stalking prey) and are lighter in body weight and hence more agile. Males by virtue of their larger size dominate the females while feeding on the kills and get a large share of the meat. Packer (1986) states that sociality amongst lions in Africa is the result of the unique combination of three factors; lion's preference for large prey, openness of habitat and their high population density. Packer, Scheel & Pusey (1990) further develop the reasoning for lion sociality and conclude that apart from foraging considerations, cooperative defence of cubs, group territoriality which enables long distance movements by lion groups to secure prey during periods of scarcity and the synchronized reproductive patterns of the females are all important reasons which induces social living amongst lions in the savannas of east Africa.

There are significant ecological differences between the Gir forest and the African lion habitats. The Gir forest is a more densely vegetated and closed habitat. The prey population is resident through the year. It has already been established that the male lions preferentially feed on livestock (refer Chapter IV). The availability of an extremely vulnerable prey (livestock) and a more closed habitat offering denser ambush cover enables the males to hunt efficiently and this accounts for their much weaker social bonds with the females, as they no longer depend on them for their food. Moreover the lions face no competition from other carnivores and there is no need for them to defend their kills. Gir probably represents a gradual breaking down in the social bonds of the lions, at least between the sexes. Another factor that could contribute to this situation is the rather small size of chital the modal prey. If males were to spend a larger proportion of their time with the females they would be competing with the rest of the pride for food. There would be nothing left for the pride

to feed on from a 45 kg chital carcass after a couple of male lions have fed on it.

Males roar and mark their territories regularly and hence they are territorial in Gir. Lionesses in Gir roar very rarely and inter pride interactions between females were not observed. Lions in Gir exist in fairly high densities ca. 1 lion per 8 sq.km (Ravi Chellam unpublished) and their home ranges are large (refer Chapter VI). The lions in Gir are part of the Ethiopian faunal inflow from Africa. Despite the very different ecological conditions in Gir when compared with the east African savannas, phylogenetic inertia induces the lions to retain their sociality, but with a slight variation which is reflected in the weak social bonds between resident coalition males and resident pride females.

In the denser forest habitat of Manovo-Gounda-St. Floris National Park in Central African Republic, the males were seldom seen with the female lions, unless they were mating (R.G. Ruggiero pers. comm.). Hence ecological conditions seem to be modifying the social organisation of lions in the forested Gir PA, when compared with the classic pattern reported from the savannas of east Africa, the habitat in which the lion had evolved.

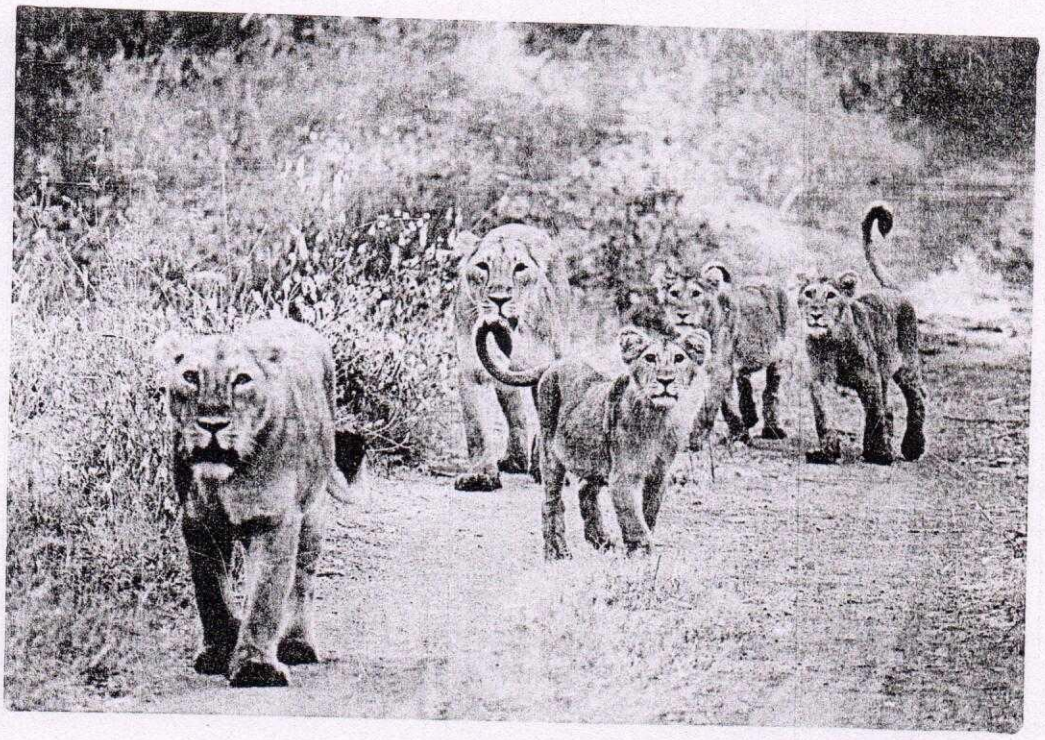


Plate V.1: Adult lionesses with cubs, the core unit of a pride.

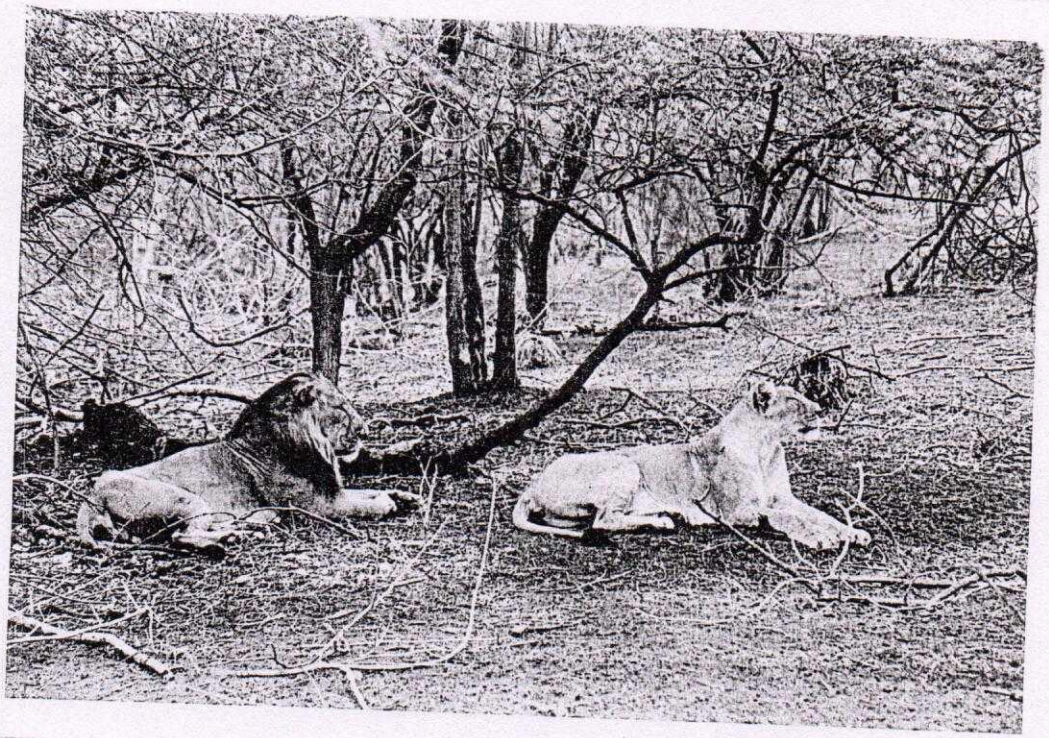


Plate V.2: A courting pair of lions.

CHAPTER VI

HOME RANGE AND HABITAT USE

VI.1 Introduction:

The concept of home range has been variously defined but Burt's (1943) definition 'A home range is that area traversed by the individual in its normal activities of food gathering, mating, and caring for the young' is the most widely applied. Normally the home range is constant for a given period of time and does not include areas crossed on occasional long forays of possibly exploratory nature. The home range is an area of knowledge; a familiar setting with which its members have learned to identify through daily usage (Washburn & Hamburg 1965). Territorial species defend a portion of their home range as their territory. Territory boundaries are marked and patrolled. A defended portion of an animal's home range is its territory.

In this study the size of the lion's home range had to be estimated to learn about the spatial requirements of the species. While gathering data on home range, data on habitat use was also collected.

VI.2 Methods:

Radio telemetry was used to determine the seasonal and annual home ranges of the lions. Lions were tranquillised using a drug combination of ketamine and xylazine (Sale & Berkmuller 1988). Darts were fired either from a 'Teleinject' gun which was powered by compressed air or from a 'Distinject' gun which had a powder charge. Lions were offered buffalo baits and then tranquillised. Radio collars were then fitted around the neck of the tranquillised lion and the animal was allowed to recover.

The collared lions were tracked with the help of a portable tracking system which consists of a receiver, a three element yagi antenna and a pair of headphones. An efficient way to receive radio signals was to climb hills and check for signals. This

enhanced the range of reception. Since I needed to gather information on the activity, group composition and the exact location of the lions, I homed in on the collared animals and was able to visually locate them. This eliminated the errors that can result from triangulation. The homing technique has been described in detail by Mech (1983). All lion locations were plotted on a 1:50,000 scale Survey of India map. The home range was estimated by the minimum area polygon (Mohr 1947). The minimum area polygon is constructed by connecting the outer locations to form a convex polygon. The area of the polygon was then measured by using a grid overlay in which each 1 sq.cm grid was equal to 0.25 sq.km. Seasonal home ranges were calculated for C female and J male and annual home ranges were calculated for C female, J male and L male. The natal home range size and dispersal distance were calculated for SA male. The year was divided into wet (monsoon and post monsoon) and dry (winter and summer) seasons. Radio collared males were tracked through the night, and for many days at a stretch (the longest period of continuous tracking was for 13 days) to get a good idea of their ranging behaviour.

Since all locations of the collared lions involved actual sightings it was possible to classify each location to a specific habitat type. The vegetation classification in **Table II.2** was followed for this purpose. Habitat use was determined for wet and dry seasons for C female and J male. The area of riverine forest within the seasonal home ranges of C female was measured to determine the availability of this crucial habitat. This done by measuring the length of the riverine tracts from the map with a map measurer and then multiplying this by a standard value of 100m to represent the width of the riverine forest on either bank including the river bed. A width of 100m would actually be an overestimate in most cases.

VI.3 Results:

VI.3.1 Home range: The dry season home range of C female was 84.75 sq.km (**Fig. VI.1**) and the wet season home range measured 67 sq.km (**Fig. VI.2**). The annual home range was 121.5 sq.km (**Fig. VI.3**). The males had much bigger home ranges than C female. The dry season home range of J male was 144 sq.km (**Fig VI.4**) and of this 41.75 sq.km (29%) was outside the PA. The wet season home range of J male was 148.25 sq.km (**Fig VI.5**) and 50.4% (74.75 sq.km) was outside the PA. The annual home range of J male (**Fig. VI.6**) was 201.75 sq.km. The annual home range of L male (**Fig. VI.7**) measured 231.75 sq.km.

VI.3.2 Dispersal of SA male: SA male was radio collared in January 1987 when he was approximately 18 months old. Till November 1987, SA male was consistently located with its natal pride. From November 1987 SA male began show signs of dispersing, initially by becoming solitary. Unfortunately the radio transmitter began to function erratically in early 1988 and from February 1988 I lost contact with SA male. Assuming that SA male moved out of its natal home range in February 1988, he was then 30 months old. The natal home range of SA male was 105.25 sq.km (**Fig. VI.8**). In June 1988 I relocated SA male. He was alone when he had dispersed but by June 1988 he had joined another male of about his age. I tracked SA male for one week continuously and these locations are marked in **Fig. VI.8** as the initial dispersal area. Subsequent to June 1988 I completely lost contact with SA male till I located him and his companion male outside the PA close to Jhakia forest check post in May 1990.

SA male had moved 16.5 km from the centre of his natal home range to the area of initial dispersal and his location in May 1990 was 37 km away from the centre of his natal home range.

Forest guards and the local villagers informed me that SA male and its coalition partner were largely living outside the PA and preying regularly on the village livestock.

VI.3.3 Habitat use: Sufficient locations were available on a seasonal basis only for C female and J male.

VI.3.3.1 Dry season habitat use: J male was located 41 times during the dry season and out of this 30 locations were in Teak-Acacia-Zizyphus forest, 6 in riverine and 5 in other habitats. C female showed a very distinct preference for riverine habitat during the dry season. Forty three out of 67 dry season locations (64%) were in the riverine tracts. But the riverine habitat available within C female's dry season home range was only 6.15 sq.km or 7.3% of the home range. This clearly establishes the high preference for riverine habitat by C female.

VI.3.3.2 Wet season habitat use: During the wet season J male was largely located in Teak-mixed forest (52%) and 11 out of 16 locations were atop a hill. C female reduced its use of the riverine forest during the wet season and most of the locations were in Teak-Acacia-Zizyphus and Teak-Acacia (forming 69% of the locations).

VI.3.4 Ranging behaviour: C female and her pride were shy animals and hence it was not possible to maintain prolonged visual contact or track them continuously without causing disturbance. The males on the other hand were more tolerant. J male despite belonging to a resident male coalition consistently used areas outside the PA. Static interference caused by electricity restricted tracking of J male outside the PA. L male regularly visited ness sites, almost every night. While tracking the animal through the night it was found that L male's travel route regularly connected various ness sites. L male travelled through an enormous range. On two occasions L male was challenged by other males and he and his partner were forced to flee. This suggests that only part of his home range forms his territory.

VI.4 Discussion:

L male and J male both have large annual home ranges. Joslin (1973) based on sightings of his study prides estimated the home range for males to be 74.3 sq.km and 188.3 sq.km. For females his estimate was 72 and 81.1 sq.km. The home range estimated for C female, J male and L male do not represent the size of their territories. Intensive tracking of the collared animals and monitoring of lions in adjacent territories is crucial to understand the spacing mechanisms of the lions in Gir.

The dispersal of SA male to a location outside the PA is indicative of the high lion population density within the PA which results in the lack of dispersal area for the subadults.

The intensive use of riverine forests by C female during the dry season and the location of most of the kills close to water during summer, emphasize the importance of the riverine forest for the lions in Gir.

Males probably tend to use hill tops during the wet season to gain relief from biting insects. The hill tops are relatively dry and also get more breeze than down in the flats.

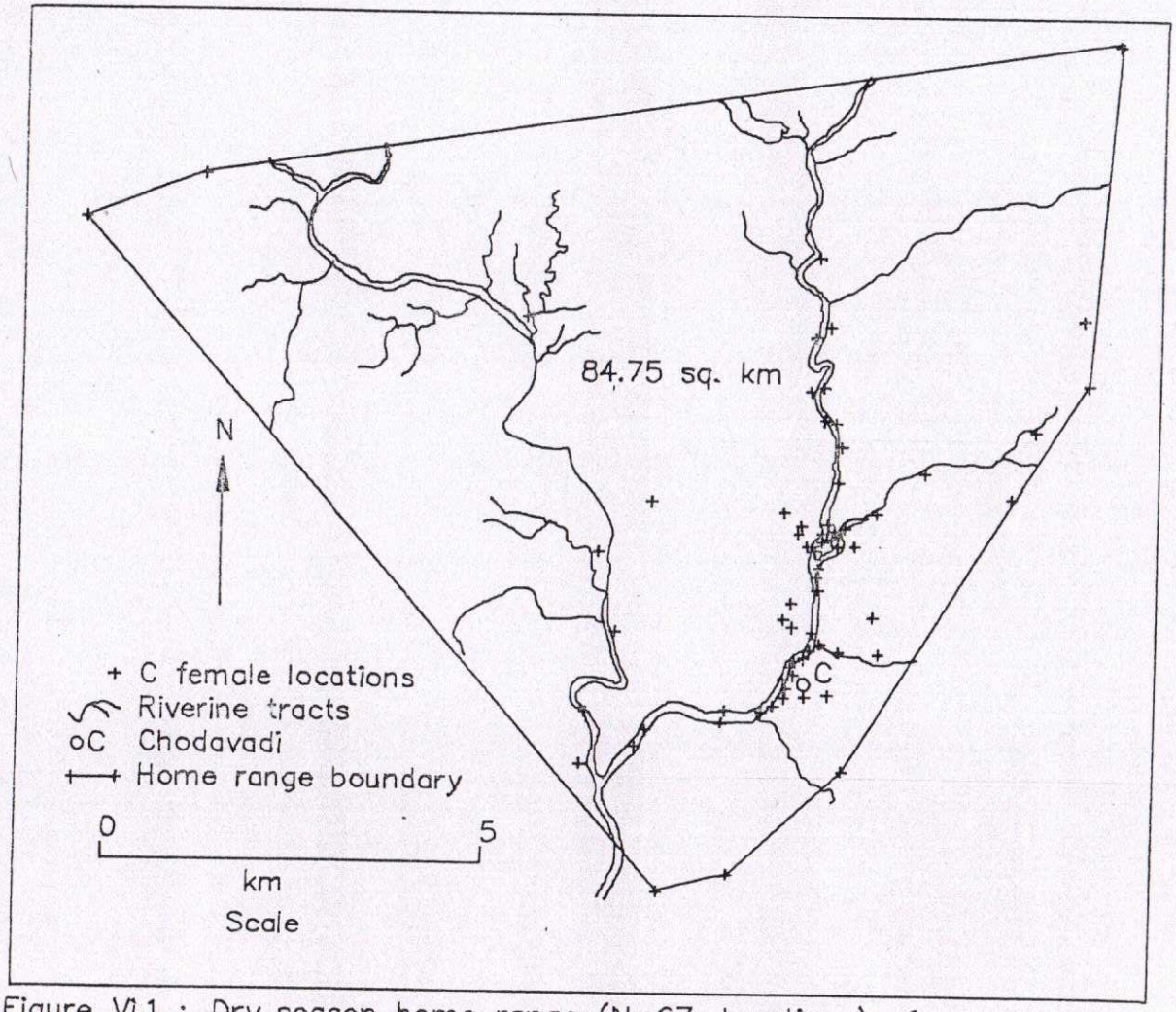


Figure VI.1 : Dry season home range (N=67, locations) of C female (winter 1988–89 & 1989–90 and Summer 1989) in the Gir PA.

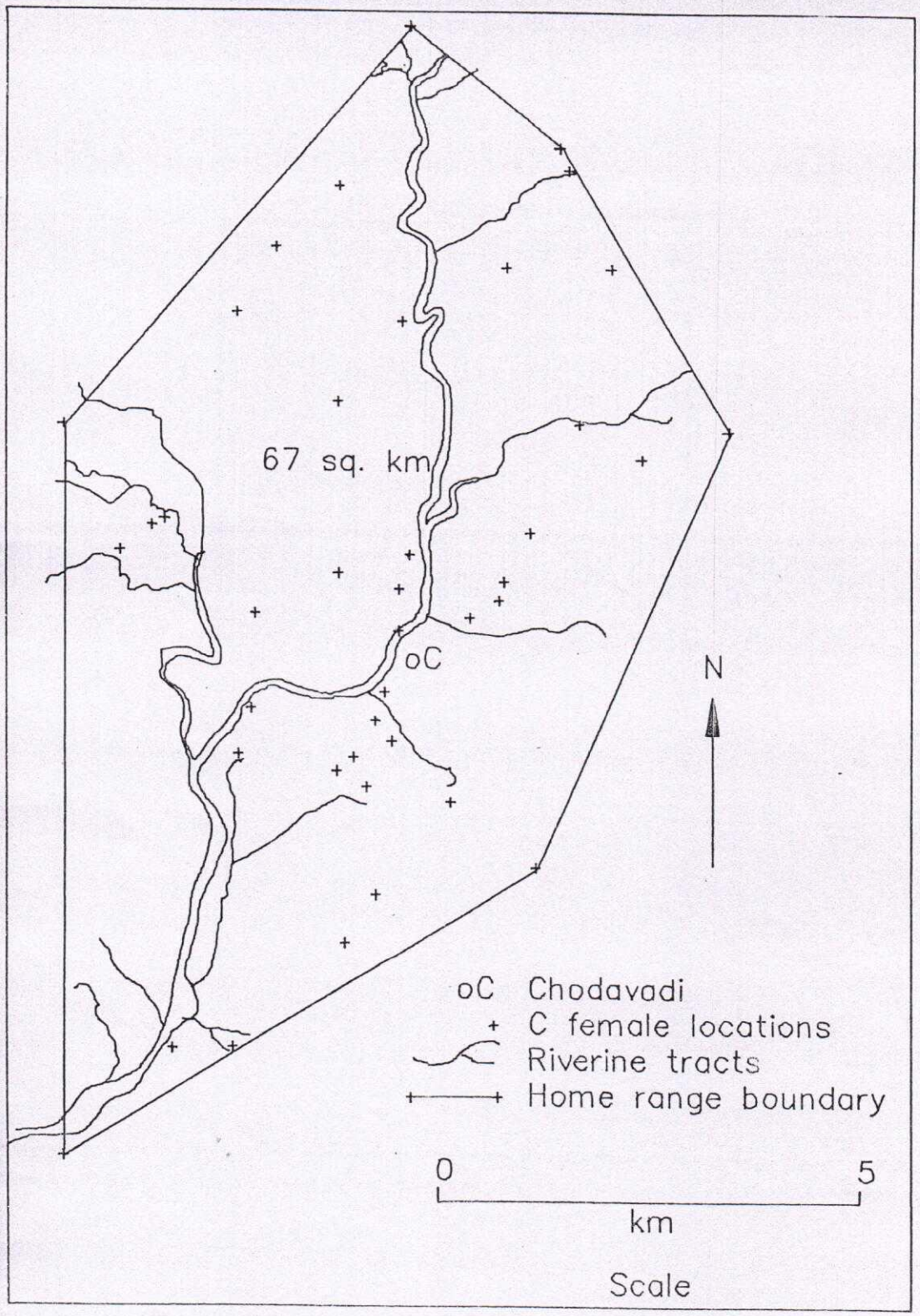


Figure VI.2 : Wet season home range (N=42 locations) of C female (monsoon and post monsoon 1989) in the Gir PA.

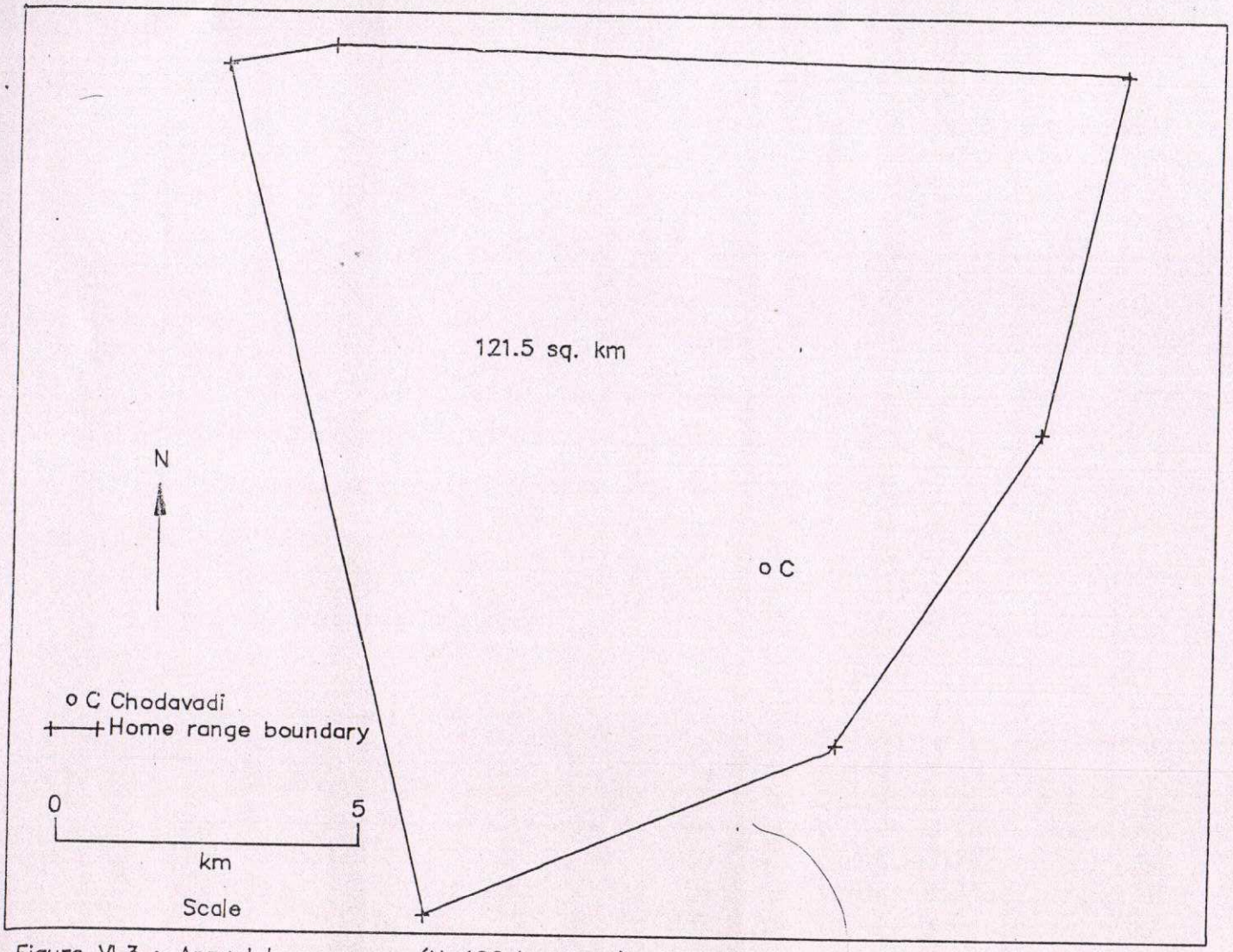


Figure VI.3 : Annual home range (N=109 locations) of C female (January 1989 to February 1990) in Gir PA.

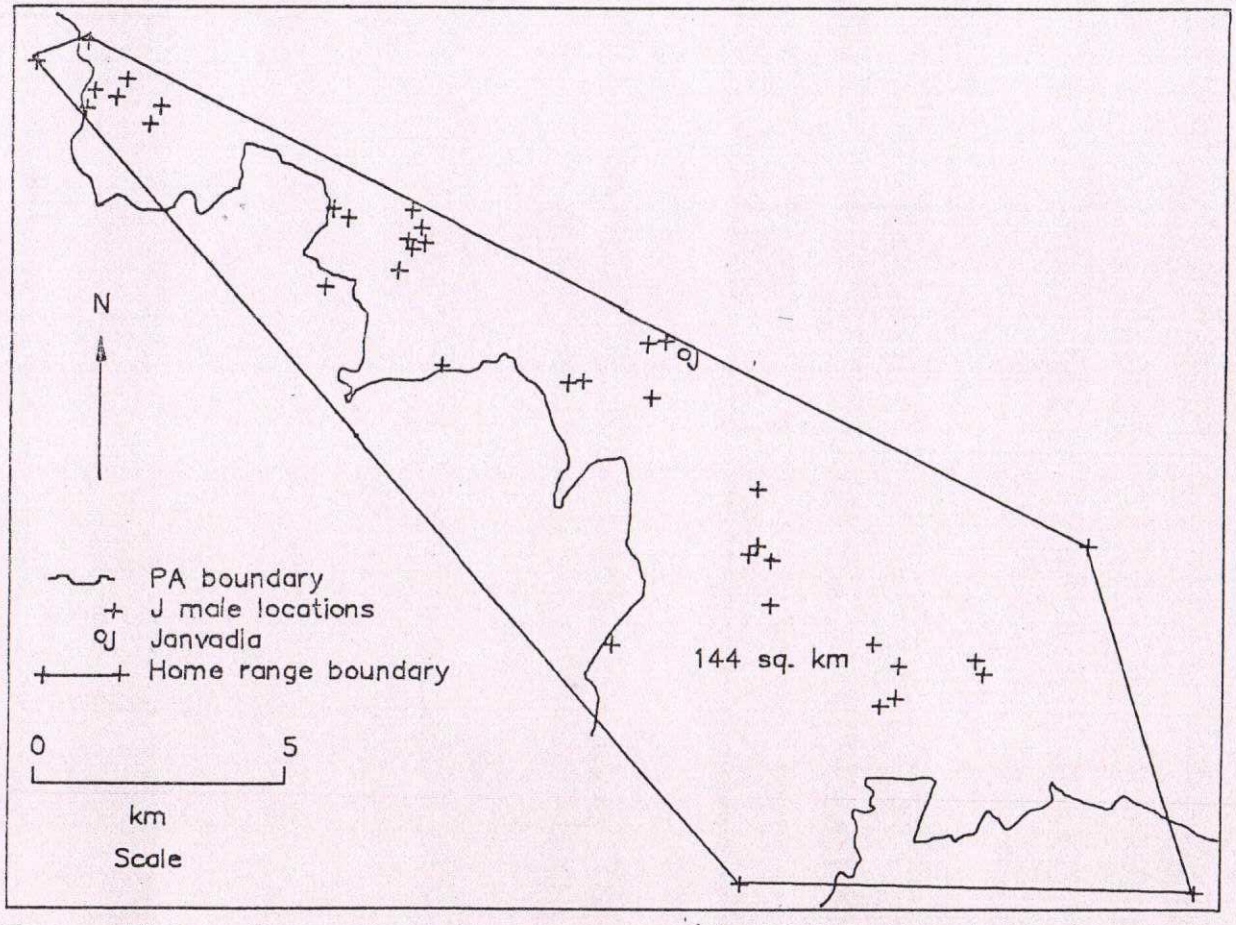


Figure VI.4 : Dry season home range (N=41 locations) of J male (winter 1988–89 & 1989–90 and summer 1989) in the Gir PA. 41.75 sq. km of the home range was outside the PA.

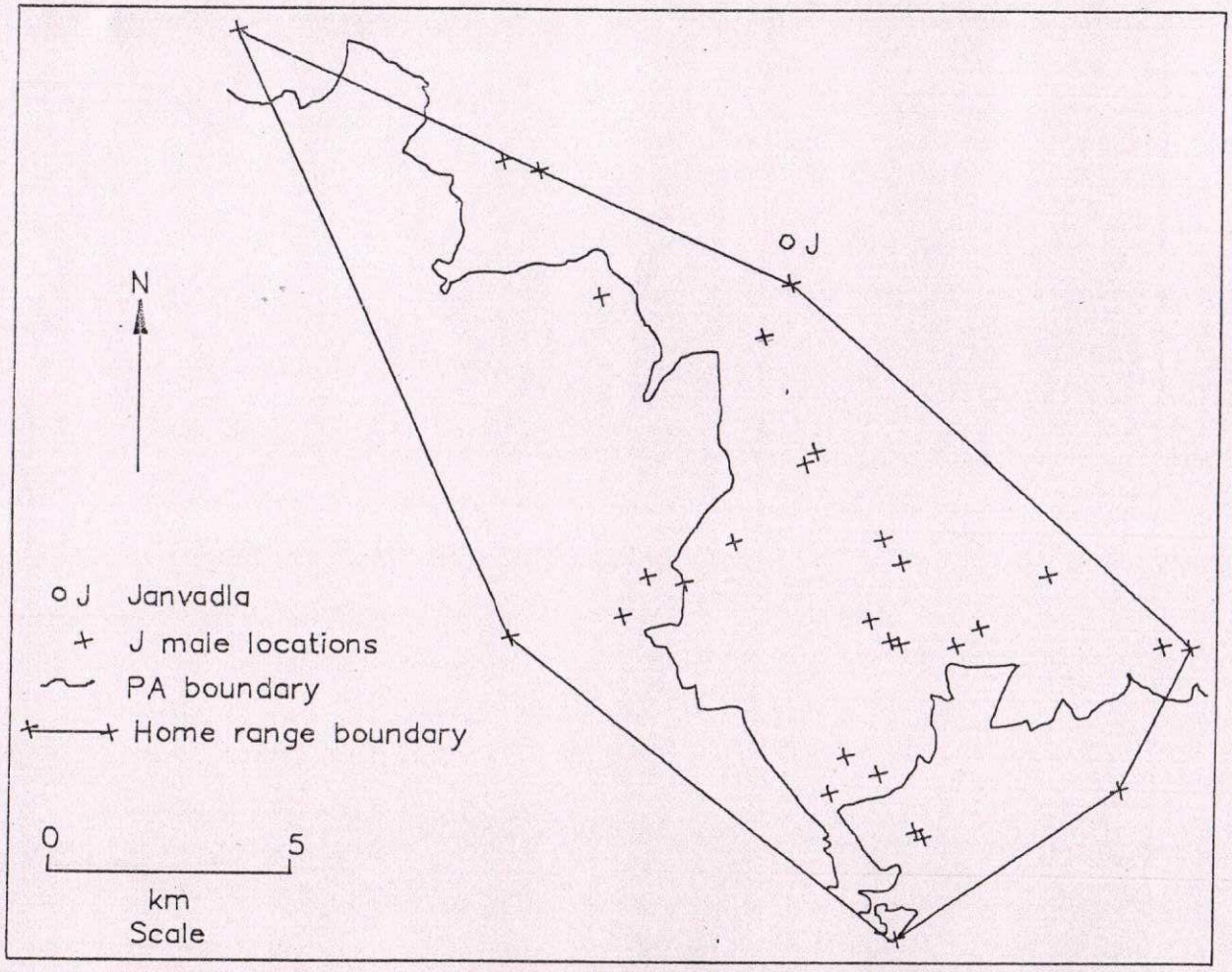


Figure VI.5 : Wet season home range (N=31 locations) of J male (monsoon and post monsoon 1989) in the Gir PA. 74.75 sq. km of the home range was outside the PA.

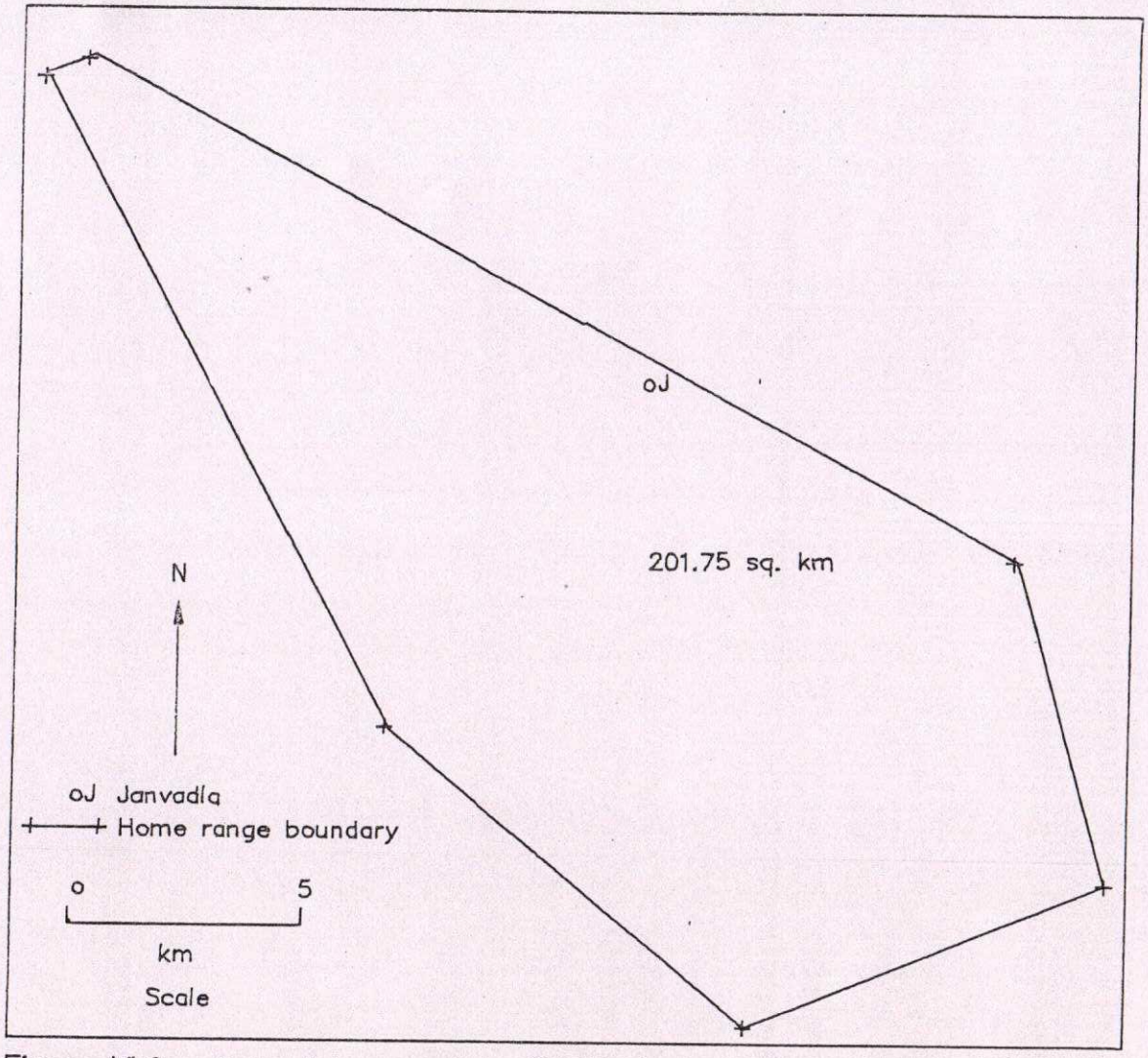


Figure VI.6 : Annual home range (N=72 locations) of J male (November 1988 to December 1989) in the Gir PA.

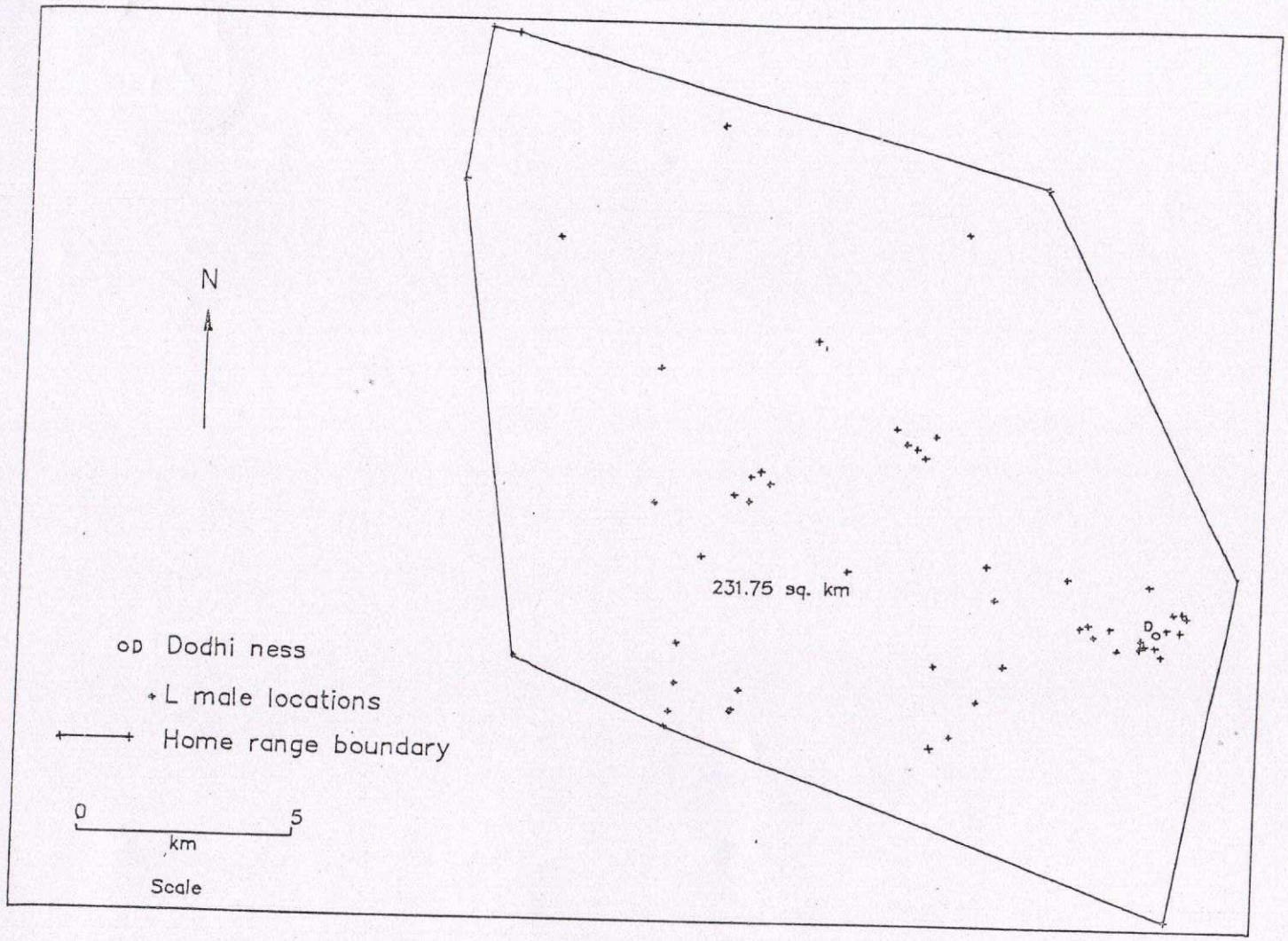


Figure VI.7 : Annual home range (N=54, locations) of L male (January 1989 to December 1989) in the Gir PA.

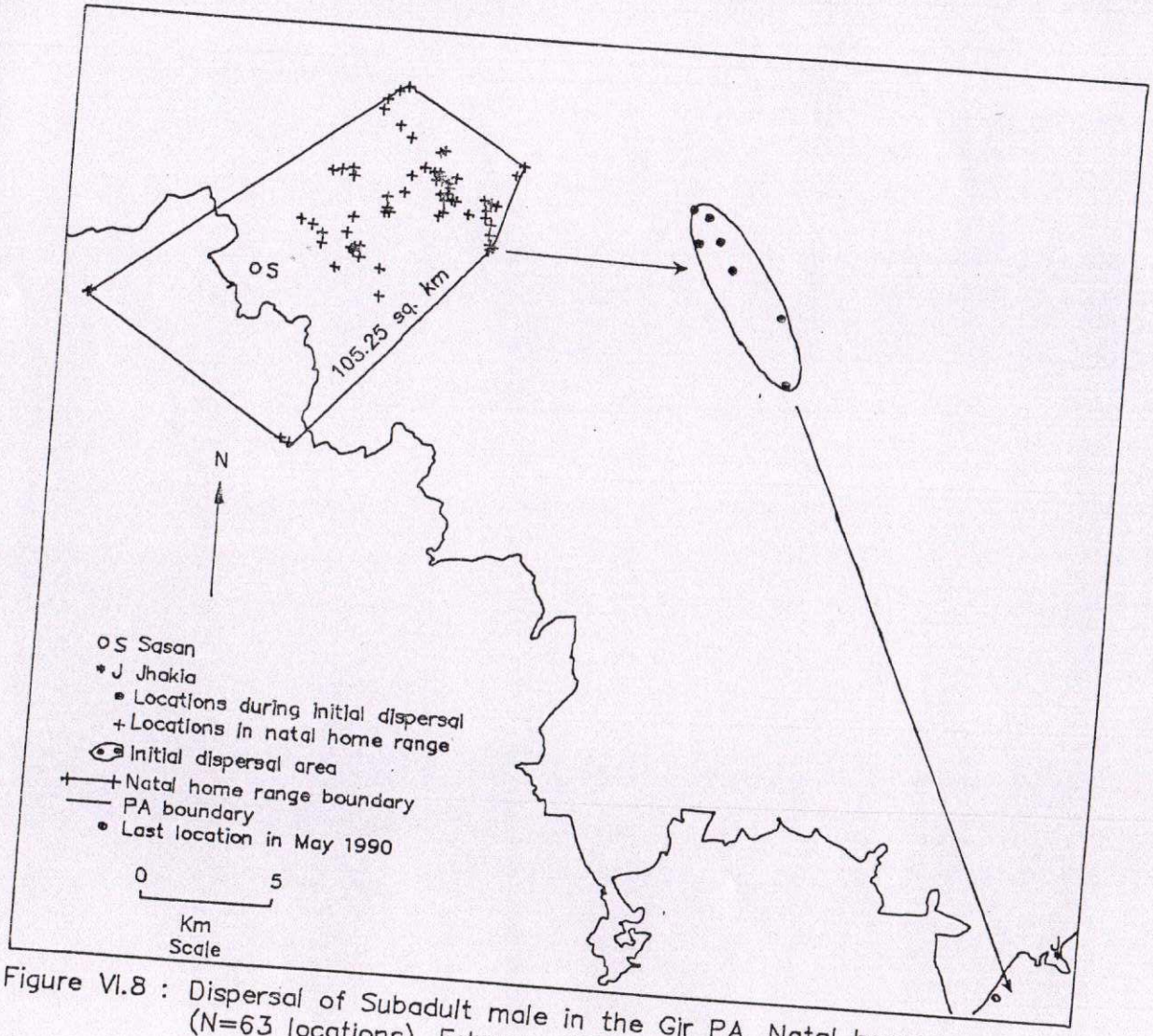


Figure VI.8 : Dispersal of Subadult male in the Gir PA. Natal home range (N=63 locations), February 1987 to February 1988.

Plate VI.1: Radio collared subadult male.

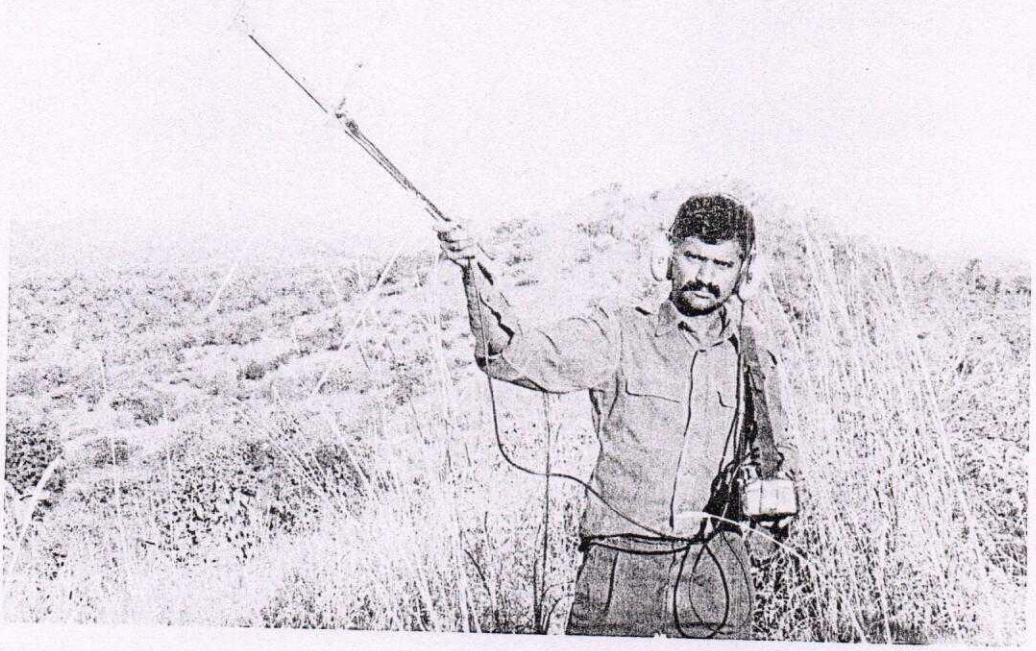


Plate VI.2: Radio tracking from a hillock.

CHAPTER VII

MANAGEMENT RECOMMENDATIONS

VII.1 Prevailing Management Practices and Problems:

Management of the Gir PA is under a Conservator of Forest of the Gujarat Forest Department (GFD), who has three Deputy Conservators of Forest (DCF) working under him. Two DCFs (Territorial) are incharge of Gir West and East divisions and the other (Wildlife) works from Sasan. The two territorial DCFs are responsible for protection work, fire and waterhole management, payment of compensation for livestock kills and attacks on people, management of maldharis and maintenance of roads and buildings. The DCF at Sasan is responsible for the management of tourism, conducting nature education camps, maintenance of the wireless network, and for the capture of problem-causing lions and leopards outside the PA. A field staff of about 300, including Range Forest Officers, Foresters and Guards are engaged in the protection and management of the PA.

Gir has lacked a management plan for more than five years, as the previous working plan (Joshi 1976) lapsed in 1986. Since then management has been on an *ad hoc* basis. Management has largely been guided by the recommendations of Joslin (1973, 1984) and Berwick (1974, 1976) and confined to maldhari translocation, stoppage of the seasonal influx of migratory livestock, creation of waterholes, attempts at habitat improvement by raising plantations of indigenous tree species, control of forest fires, maintenance of tourist facilities and conducting wildlife census once every five years (Government of Gujarat 1975 and B.J. Pathak & S. Tikadar pers. comm.).

In the last two decades, and especially in the 1980s, this concerted management effort has increased the conservation potential of the Gir and the Asiatic lions and disproved Talbot's (1960) prediction that within two decades the Gir forest would be gone and with it the lions.

Current conservation problems identified in the Gir are:

1. Problems resulting from human activities (temples, firewood and minor forest produce collection, and encroachment).
2. Maldharis and related issues (livestock grazing, degradation of riverine habitat, unrestricted lopping and cutting of trees, and livestock dung export).
3. Shortcomings in the present management system (lack of involvement of the local population in the management of the PA, waterhole management, proposed habitat modification, cumbersome system for payment of compensation for livestock killed by lions and leopards, lack of a proper tourism policy, and delay in locating an alternate habitat for the lions).
4. Lion attacks on people.

VII.1.1 Problems resulting from human activities: Temples, highways and the railway track cause disturbance to the forest. The four big temples attract an estimated 70,000 to 80,000 devotees annually and create several problems including firewood extraction, noise pollution, dumping of garbage and encroachment. In the prevailing social and religious milieu in India these problems are extremely sensitive and efforts to minimize them could be potentially explosive (B.J. Pathak pers. comm.). All four temples are large, permanent establishments. Kankai and Banej are situated on the banks of rivers,

crucial habitat for large mammals. These two and Patla Mahadev are on the boundary of the National Park. Tulshishyam has an area of 12.2 km^2 of forest land under its control. In 1985 the GFD raided and closed down a religious establishment within the PA at Bajaria. Court cases and an outcry of public indignation did not deter the GFD and fortunately this action also gained some political support. Such exemplary action is needed to curb this threat of expanding religious establishments within the Gir PA.

The three highways cutting across the PA carry a considerable volume of traffic and provide easy access to the PA. The GFD, despite facing much opposition, has closed the roads for night traffic and is under considerable public and political pressure to keep the roads open for 24 hours (S.C. Pant and B.J. Pathak, pers. comm.). At least six trains pass through the PA every day. These trains are powered by steam locomotives and the live coal embers that fall out are a proven fire hazard to the forest. Moreover animals, including lions, have been run over on the track.

Illegal firewood and minor forest produce collection are problems that need to be curbed. Villagers living along the boundaries of the PA depend almost exclusively on the Gir forest for their fuelwood needs. Moreover a certain section of the population has taken up cutting and selling firewood as their occupation. Fruits of *Zizyphus mauritiana*, *Syzygium rubicundum* and *Carissa opaca* are collected from the PA by hundreds of people. Apart from the disturbance caused by this uncontrolled entry of people, this fruit harvest deprives wildlife of nutritious food. Encroachment on the PA is largely in the form of insidious expansion of agriculture.

VII.1.2 Maldharis and related problems: All nesses are located close to the riverine tract and have caused considerable degradation of this vital wildlife habitat. Maldharis lop the larger trees and cut down medium sized trees for fodder, having a devastating impact on the vegetation. In a relatively arid habitat like the Gir, tree crop regeneration would be a slow process, with limited success.

The maldharis are allowed to graze their livestock within the PA. At present levels of grazing there does not seem to be too great an impact on the grass biomass. However, the illegal entry of large numbers of livestock on a daily basis from the adjoining villages is a matter of concern and needs to be stopped. In addition, the maldharis collect their livestock dung along with top soil. This is sold outside as bio-fertiliser. This loss of nutrients is deleterious to the ecosystem.

VII.1.3 Shortcomings in the present management system: Conservation strategies in tropical forest areas cannot be divorced from the overall patterns of land use (Roche 1979). This lucidly sums up the prevailing conservation scenario for the Gir ecosystem. Janzen (1988) highlights the problems of conserving national parks in tropical countries and emphasises the need for parks to earn their existence and suggests various ways to achieve it.

The GFD and its management policy for the Gir, are isolated from the aspirations of the local population. Harcourt, Pennington & Weber (1986) report from their studies in Brazil, Rwanda and Tanzania, that local people with less knowledge of wildlife and ecology show significantly less support for conservation. This was in situations of relatively less conflict than in the Gir, between the people and the PA

management, whereas in the Gir, the prevailing conflict levels are of a higher order (Saberwal *et al.* 1990). Maldharis who had remained tolerant of livestock predation by lions now seem to be retaliating. One lion was killed and buried close to a ness in 1991 (D. Sharma pers. comm.). The problems of the livestock compensation scheme will have to be resolved to make it realistic and acceptable to the Maldharis (Joslin 1984). The maldhari translocation programme has failed and the translocated maldharis have been reduced to a state of penury (pers. obs.). There is an overwhelming need for the GFD to involve the local population in the management of the PA. Strategies advocated by Mishra, Wemmer & Smith (1987) and Dobias (1991) would serve as appropriate models.

Chapter IV highlights the role of water in the lion's predation ecology. Hence, waterhole management should be in tune with this. During summers, and particularly in drought years, water is artificially provided throughout the PA. Often, water is provided in troughs placed by the road and barely a couple of kilometres apart. Widespread provision of water troughs, may disperse prey away from the riverine tracts, a preferred habitat for successful hunting by lions during summer. Providing water in a well planned manner would definitely benefit the wildlife in the Gir PA, especially the herbivores. Waterholes should be located after a thorough survey has determined the distribution of natural water sources and the man-made waterholes should be sensitive to the ecological needs of the various species.

There is a discussion amongst wildlife managers, on the need for habitat modification (e.g. thinning of trees) in the Gir. The rationale being that fairly dense

vegetation, especially in the National Park, may have an adverse impact on the hunting abilities of the lion (H.S. Panwar pers. comm.). The results presented in Chapter IV do not support this premise. Habitat manipulation could adversely affect species which prefer dense cover, such as sambar, the lion's preferred prey.

Thorne & Williams (1988) have stressed the problems of diseases affecting endangered species, which, when there is only one population left could lead to extinction. Clearly the establishment of a second population of the Asiatic lions in the wild is urgently required. There has been precious little planning and action in this regard, despite an attempt with limited success in 1957 (Negi 1969).

VII.1.4 Lion attacks on people: Between May 1988 and March 1991, lions have mauled 120 people resulting in 20 deaths (Saberwal *et al.* 1990). This level of aggression is unprecedented since early this century (Wynter-Blyth & Dharmakumarsinhji 1950). Saberwal *et al.* (1990) and Saberwal *et al.* (in prep.) report on the causes and possible solutions for resolving this conflict. The GFD needs to be more pragmatic and show greater urgency and compassion in dealing with this problem, otherwise the continued attacks could well lead to a backlash from the affected human population which could sound the death knell for lion conservation in the Gir.

VII.2 Management Recommendations and Conservation Strategies:

Wildlife management recommendations have to be tailored to specific situations and take into consideration field realities for them to be effective. A conservation strategy has to take a much broader and long-term view.

Most of the management problems listed are related to enforcing effective protection. Widespread conservation education to build up support for the Gir ecosystem is needed. Unless there is cooperation amongst various governmental agencies with sufficient political backing, effective conservation can never be achieved, given the socio-economic and political environment in India. Numerous inputs are required outside the PA (developing fuelwood plantations, conservation education, health care and family planning) without which nothing tangible can be achieved. "The threats to wildlife come predominantly from outside the wilderness areas, with the consequence that much of conservation biology is in fact largely irrelevant to conservation" (Harcourt *et al.* 1986). Punitive policing of the PAs, which are but islands in an ocean of humanity, can only succeed in the short-term.

VII.2.1 Management recommendations: An immediate and firm control needs to be placed on all problems resulting from human activities. If the translocation of the maldharis has to continue, it must be undertaken in a phased manner. Livestock is still an important prey for the lions, especially for the males. The rehabilitation scheme for the maldharis should be planned with greater sensitivity and the active participation of the maldharis themselves to ensure the success of the effort. While the maldharis continue to stay within the PA, curbs on livestock dung export and tree lopping and cutting should be strictly enforced. Further degradation of the riverine forest should be halted and attempts should be made at habitat restoration. A much greater involvement of the Maldharis and the local villagers in the management of the PA is essential. Recruitment to the GFD and involvement in tourism and related activities could be

immediately implemented. Mishra *et al.* (1987), Janzen (1988) and Dobias (1991) have given various models for integrating people and their interests in PA management. The Gir has an enormous tourism potential which remains untapped. Existing tourism is restricted to one small segment around the PA head-quarters at Sasan. Interpretation and guide facilities are inadequate and the majority of the tourists depart uneducated about the Gir and the need for conservation. Ill-conceived attempts at tourism development, like the fencing of an area to create a safari park within the PA (**Fig. II.1**) should have been avoided.

VII.2.2 Conservation strategy for the Asiatic lions: "Population management becomes particularly important for the so-called charismatic megavertebrates" (Foose 1987), which is a dire necessity in the case of small and isolated populations of endangered animals. The need for establishing a second population of lions in the wild cannot be over emphasised, a need which is reinforced by genetic studies (Lande & Barrowclough 1987), who report on the possibility of retaining greater genetic diversity of the species by the sub-division of a population.

VII.2.2.1 Translocation of the Asiatic lions: Sale (1986) has defined the principles for undertaking a translocation programme. The Gir lions qualify as prime candidates. This study has generated a data base which enables informed decisions to be made in this regard. The second habitat should be at least 500 km^2 in extent, with an adequate prey base and neither livestock nor people. Given the size of the lion's home range, smaller areas would result in the frequent straying out of lions and conflict with people. Since gaining independence in 1947, the human population of India has increased

tremendously, resulting in extensive loss of natural vegetation. Under these circumstances, the second home for the lions can only be found among the existing PAs. Based on discussions with forest department officials and wildlife ecologists, we have shortlisted the following areas as possible second homes for the lions; Desert National Park and Sanctuary, and Kumbalgarh Sanctuary in Rajasthan; and Palpur Kund (Kuno) Sanctuary in Madhya Pradesh (**Fig. VII.1**).

The Desert PA is attractive in that it is an extensive area (3,162 km^2) with relatively low density of people and livestock. Lack of surface water and large sized prey are major limitations. Chinkara is the most common wild ungulate, but it is too small to form the principal prey of the lions. Development of waterholes and introduction of nilgai, blackbuck and wild pig could make this area suitable for lions.

Kumbalgarh has a very rugged terrain and a low ungulate density. Currently this area is extensively exploited by people and livestock. The area is also limited (573 km^2), while the surrounding tracts have a high human density. Amongst the three, this seems to be the least suitable area for lion translocation.

Palpur Kund (445 km^2) is a suitable habitat with ample prey and low levels of disturbance. Stray tigers may visit this forest tract. Though limited in area like Kumbalgarh, there is ample forested land adjoining this PA. Therefore, if required the PA could be expanded. When compared with the Asiatic lions, tigers are widely distributed in India. Hence decision makers should take a holistic view of wildlife conservation in the country and designate this area as the second home for lions.

These recommendations are tentative at this stage. A comprehensive survey needs to be undertaken as high priority to assess the suitability of these areas for lion translocation.

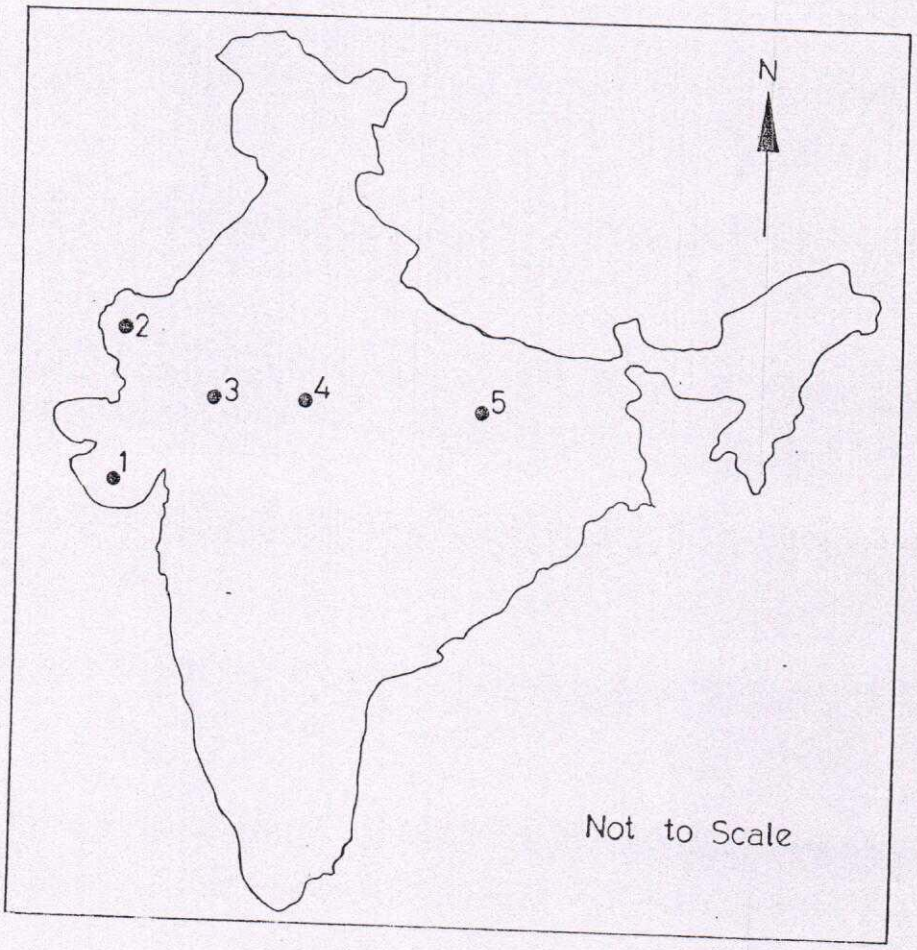
The previous lion translocation effort in Chandraprabha Sanctuary resulted in the increase of the lion population from three to 11. It is reported that the lions disappeared (Negi 1969), and were presumed shot or poisoned. This emphasises the need for continuous protection and monitoring of the translocated lions.

Population management should be an integral part of the lion translocation programme. To avoid the problems of inbreeding, male lions should be removed from the translocated population every third year or so and replaced by wild caught males from the Gir. With reference to tigers (Foose 1987) writes, "small populations must be managed genetically and demographically if they are to survive as evolutionarily viable entities over the long-term". This is equally applicable to the lion translocation effort.

VII.2.2.2 Need for long-term research in Gir: Long-term research and monitoring in Gir has enabled us to evaluate the impact of various management inputs and plan future conservation action. Joshi (1976) has recommended that research should be an integral part of the management in the Gir. Numerous research institutions have evinced a keen interest in conducting research in Gir and the GFD needs to develop a research programme and encourage and support continued research.

VII.2.2.3 Captive populations: O'Brien, Joslin, Smith, Wolfe, Schaffer, Heath, Ott-Joslin, Rawal, Bhattacharjee & Martenson (1987) have established that there are effectively no pure bred Asiatic lions in captivity outside Sakkarbaugh zoo, Junagadh, and also that this

population has only nine founders. Zoos play a vital role in conservation education, as repositories of genes for probable reintroduction and garnering support for *in situ* conservation (Mallinson 1988). Faced with the problem of lions attacking people outside the Gir PA, it is strongly recommended that these lions be captured and sent to zoos all over the world to re-establish an international captive breeding programme and to build up support for the conservation of the Asiatic lions. Many foreign zoos are prepared to pay considerable sums of money for the privilege of keeping the Asiatic lions as part of their collection and the revenue thus generated should be utilised to establish "The Gir Conservation Trust", which could work towards meeting the natural resource needs of the people around the Gir and in imparting conservation education. The resources of this Trust should be augmented by the revenue generated by an aggressive promotion of ecotourism. This would go a long way in ensuring the support of the local population for the conservation of the Gir ecosystem.



1 Gir PA
2 Desert PA
3 Kumbalgarh Sanctuary
4 Palpur Kund (Kuno) Sanctuary
5 Chandraprabha Sanctuary

Figure VII.1: Sites of present distribution or attempted reintroduction and possible future reintroduction of Asiatic lions in India.

SUMMARY

I carried out field research on the ecology of the Asiatic lions (*Panthera leo persica*) in the Gir forest between March 1986 and May 1990. The major objectives of my research were to assess the predation ecology, habitat use and the ranging patterns of the lions. The ultimate goal of this research effort was to examine the feasibility of a translocation effort in an attempt to establish a second free ranging population of lions.

The only remaining wild population of lions is today restricted to the Gir Protected Area in Gujarat. Historically this subspecies had a very extensive distribution, extending from Syria right across to most of north and central India but largely due to anthropogenic pressures the Asiatic lions suffered a drastic decline in their distribution and numbers. Lions in India have been restricted to the Gir forest since the late nineteenth century. It is reported that at one stage the lion population was as low as twenty. As a result the sole wild population of Asiatic lions has experienced a severe genetic bottleneck and lost most of its diversity.

The Gir Protected Area is about 1400 sq.km and of this about 260 sq. km has been constituted as a National Park. Most of Gir is dominated by stunted teak forest and various associations of species like *Acacia* and *Zizyphus*. The only evergreen tracts are the riverine forests. Based on vegetation composition and conservation status, the PA is classified into three areas, Sanctuary West, Sanctuary East and National Park. Maldharis a pastoral tribe reside in the Sanctuary and they graze livestock in the forest. Presently about 2,200 maldharis and 14,000 livestock are resident in the forest.

Gir has a diverse assemblage of prey species. Chital, sambar, nilgai, chinkara, chousingha, wild pig and common langur are the major mammalian prey species. Livestock is also preyed upon by the lions. Based on vehicle transects the prey population was estimated in the Gir PA. Chital dominates the community of wild ungulates, constituting

about 95% of the estimated 51,000 wild ungulates. The wild ungulate population has grown tremendously since the early 1970s when the estimated population was about 6,000 only. Chital densities are highest in Sanctuary East, while density of sambar is highest in National Park. The estimated ungulate biomass in Sanctuary East was 22,48,768 kg of which 73% is livestock. The ungulate biomass in Sanctuary West was 21,79,214 kg and 49.8% of this was livestock. The ungulate biomass in National Park was 5,04,672 kg and it comprised only of wild ungulates. The adult sex ratio of chital was 44.5 males:100 females and for sambar it was 48.5 males:100 females.

The predation ecology of the lions was assessed based on scat analysis and the collection of lion kills. Scats were collected in three distinct time periods;

i) 1986-June 1987 (Period I)

ii) July 1987-December 1987 (when there was a large scale influx of livestock into the PA) (Period II)

iii) 1989 (Period III)

and in the three areas of the PA and also from outside the PA. Data was also collected on the predation ecology of leopards to enable a comparison between lions and leopards.

Eight hundred lion scats and two hundred leopard scats were analyzed to identify the prey remains in them. Chital, sambar, nilgai, cattle and buffalo are the important prey species for the lions. The diet of the lions showed differences between the different areas and time periods, reflecting the availability of prey. Between Sanctuary West and Sanctuary East, there were significant differences in the choice of sambar and cattle in Period I. Similarly in Period II livestock dominated the lion's diet, reflecting the extremely high availability of livestock. The major differences between the diets of lion and leopard was the choice of langur and buffalo. Chital is the top ranking prey for both the large cats. The dietary overlap of lion and leopard was calculated to be 0.60 for Sanctuary West and 0.71

for National Park.

Two hundred and one lion kills were examined during the study. Of these wild ungulates constituted 52.2%. If the lion kills collected outside the PA and during Period II are excluded, wild prey forms 65% of the lion kills. Chital sambar, cattle and buffalo are the most frequently killed species. During Period II livestock formed 88.9% of the lion kills. Forty three leopard kills were examined and chital forms 72.1% of these kills. Leopard predation on livestock is very limited.

A distinct seasonal pattern was observed for lion predation of sambar. Bulk of the sambar kills were made during the drier parts of the year, 64% in summer and 20% in winter. Lions preferentially preyed upon chital and sambar stags. Male lions preyed preferentially on livestock.

Vegetation density does not seem to be affecting the predation ecology of lions. The kill sites for wild prey were more or less evenly distributed across the three density classes but 54% of the livestock were killed at sites with low vegetation density (0-400 stems/ha.) and only 8% of the sites had high vegetation density (>800 stems/ha.).

Seventy one per cent of the chital kills made by lions during summer were at sites <100 m from water. Seventy five per cent of the sambar kills were made at sites < 100 m from water, thereby highlighting the role of water in the predation ecology of the lions, especially during the dry summer. Riverine forests and reservoir beds are crucial hunting habitats for the lions, especially during the dry summer. Fifty five per cent of the chital kills and 44% of the sambar kills collected during summer were from these two habitats. Livestock are killed in a wide variety of habitats with no clear pattern emerging.

Based on kill data Preference Rating values were calculated for various prey species. Sambar, wild pig and cattle are the highly preferred prey. Even though chital is the prey most often eaten it is also numerically the most abundant prey and hence it has a low

Preference Rating.

Both the scat data and kill data indicate considerable overlap in the diets of lion and leopard in the Gir PA. The kills collected were assigned to various weight classes to determine whether there was any niche separation based on weight of prey between these two predators. For lions 51.4% of the kills weighed >100 kg and only 5.6% falls in the <25 kg class. For leopard no kill was recorded in the >100 kg class and the kills were more or less equally divided amongst the <25 kg, 26-50 kg and 51-100 kg weight classes.

The annual off take of biomass due to lion predation was calculated to be 4,10,625 kg which is 8.3% of the ungulate biomass. Sambar and nilgai are being subjected to extremely high rates of predation by lions.

The social organisation of lion is largely similar to the reported pattern from east Africa. Groups of related females and their young form the core of a pride and groups of males numbering between 1 and 7 (male coalitions) hold control over the females. The male coalition patrols and actively defends the territory. The male coalitions have a restricted tenure as resident animals.

The mean group size was calculated for four radio collared lions, based on a total of 292 radio locations. The mean group size for C female, an adult female was 4.5 and the group size varied from 1 to 11. The mean group size for two adult males, J male and L male was 2.2 and 2.1 respectively, with the group size ranging from 1 to 5 and 1 to 3 respectively. The subadult male, SA male had a mean group size of 4.5 when he was part of his natal pride but this dropped to 2 when he started showing signs of dispersing.

The social organisation of the lions in Gir varies from the reported patterns from east Africa in the very weak social bonds between resident pride females and resident territorial males. L male was observed on 14.6% of the locations with a lioness while J male was with a female only on 8.3% of its locations and that too largely while mating. C female was

located only once with an adult male. SA male was consistently located with his natal pride till he began showing signs of dispersing. Subsequently on 9 out of 11 locations he was located alone.

Using radio telemetry the annual and seasonal home ranges of lions were determined. C female had a wet season home range of 67 sq.km and a dry season home range of 84.75 sq.km. The annual home range for C female was 121.5 sq.km. J male had a wet season home range of 148.25 sq.km of which 50.4% was outside the PA and a dry season home range of 144 sq.km of which 29% was outside the PA. The annual home range of J male was 201.75 sq.km. L male had an annual home range of 231.75 sq.km. SA male's natal home range was 105.25 sq.km and it initially moved 16.5 km from the centre of its natal home range and was located with a male of similar age. Due to malfunctioning of the radio transmitter, the SA male was only tracked for a week after its dispersal. It was last located in May 1990 outside the PA together with another male. This was about 37 km from the centre of its natal home range. Local reports mentioned that SA male and its associated male had settled down outside the PA and frequently preyed on livestock.

The Gir PA presently lacks a management plan. The Asiatic lions have definitely increased in numbers but are still facing numerous conservation problems, problems which are common to all small and isolated populations. The urgent task is to translocate and establish a second free ranging lion population. Tentatively Palpur Kund (Kuno) Wildlife Sanctuary in Madhya Pradesh has been identified as the most suitable site for translocating the lions from Gir. Data generated by this study on the predation ecology and the home range size and habitat use by the lions will guide the choice of a suitable habitat for lion translocation. The conservation problems facing the Gir forest have been identified and management recommendations have been made to deal with them. Most of the problems result from human activity and hence a firm control needs to be placed on the activities endangering the Asiatic lion and its habitat.

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