Reproductive Strategy and Behaviour of Male Asiatic Lions

THESIS
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ABSTRACT

I studied the reproductive strategies of male Asiatic lions (*Panthera leo persica*) in relation to their social organization, ranging patterns, habitat use and activity patterns. The study was undertaken in the Gir Sanctuary and National Park, Gujarat, India from April 2002 to February 2007. Lions being social felids an understanding of their varied and habitat-specific social organization and dynamic social phases are crucial aspects of male life-history. This is owing to the fact that the effective reproductive period of male lions maybe limited due to incessant territorial strife between territorial males. I used a combination of conventional tracking and radio-telemetry to study behaviour and land tenure system of lions. I used scan sampling and continuous focal sampling to estimate activity and patrolling behaviour respectively. Using identification profiles of 112 individuals based on distinct individual marking, I intensively monitored survival of 20 adult lions and 32 cubs for a period of five years.

The intensive study area covering 1175 km² had a healthy growing population with a good proportion (60%) of individuals in the recruitment age-class. Group size of males was 1.4±0.50 (1-3, n=283) while female group size was 1.3± 0.53 (1-4, n =291). There seemed to be a synchrony of births in the population with a spurt in recruitment every two years. The average lion density was 10 (±0.14) but varied from across the study area based on the terrain, habitat and anthropogenic factors. Adult survival rates were high 0.92 (±0.07). Adult mortality (N = 71) was due to natural causes 66%, accidents 21% and un-identified 13%. However, much of mortality of adults occurred due to accidents outside the boundaries of the protected area. Cub mortality in intensive study area (n= 15) were due to infanticide (60%), abandonment (13%) and other natural causes (26%). Early mortality of cubs due to infanticide was the chief factor limiting their recruitment. The Moist forests along the riverine areas were the most preferred lion habitat within the home-range of adult lions ($\chi^2_{(7\ \mathrm{df})} = 22.5$, $P < 0.05$) while highly broken terrains and relatively arid areas of the protected areas were least preferred. In this regard, the National Park area though devoid of anthropogenic pressures was less suitable for lions compared to other areas of the protected area. In the present study, based on scat analysis, livestock contributed to only 14% of the lion diet within the protected area in terms of the relative number of individuals consumed but contributed 27% of the biomass consumed. Mean male ranges and core areas were larger 85 km^2 (±54 SD) and 10 km^2 (±3.9 SD) than females 35 km^2 (±7 SD) and 5 km^2 (±1.7 SD). Male home ranges showed maximum overlap (up to 67%) in core areas of female ranges. Thus, male home ranges seem to be determined by female core areas. Average dispersal distance was 23 km indicating that lion movement maybe restricted by the size of the protected area. Lions spent majority of their time resting or sleeping (78±7%) and territorial males spent majority (63%) of their active time in advertising their territory. Territory advertising included vocalization and patrolling and was done primarily in the early morning and late evening hours. Nomads showed erratic movements and scarcely advertised their presence.

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Summary

Lions are the only social felids and their social systems vary according to habitat, prey, inter and intra specific competition. Male lions form associations with related males and hold tenure over female prides for a definite period of their lifetime. This reproductive opportunity is therefore for a brief period of their life within which to optimize individual fitness.

I undertook a study of the social organization of the Asiatic lion (*Panthera leo persica*) with particular reference to the "Reproductive Strategies of Male Asiatic lions."

The field study was carried out from April 2002 to February 2007 and the intensive study area covered 1075 km^2 area of the Gir PA including Sanctuary West and National Park. My study addressed the following research questions relating to male reproductive strategies:

- What is the nature of social bonding in Gir lions and how does demography (population parameters) relate to male strategy?
- What is the nature of movement and space-use in lions and in terms of ranging, do males move with respect to female resources?
- What is the activity pattern of male lion and is it related to the diet or is it related territory defense?
- How much time does a male spend in vocalization and other ways of marking or declaring his territory?
- How are the mating opportunities shared among the coalition partners?
- How are coalition partners that share the reproductive opportunities related to each other?

The above hypotheses on male reproductive strategies were dealt under three topics: i) Demography and population structure ii) Home range and habitat-use iii) Movement, activity and diet.

i) Demographic changes in the Gir lion population were monitored using individual identification profiles for a period of four years. Lion population was estimated using mark-recapture models. Demographic profile was obtained by classifying lions under six age categories and sightings for each year were analyzed to obtain population structure, sex ratio and cub to female ratio. Group sizes, group composition and nature of male-female association were also obtained from lion location data. Twenty adults and 32 cubs in 15 litters of 12 females were monitored for five years. Adult as well as cub survival was assessed using program MICROMORT. Seasonality in reproductive activity was evaluated from direct sightings of cubs and mating events.

The data included 819 independent sightings. Seasonal encounter rates from 848 search hours were 0.15 (±0.14) for summer, 0.12 (±0.11) for monsoon and 0.20 (±0.17) for winter. The encounter rates for different park areas were 0.13 (±0.11) for national park area and 0.18 (±0.17). Encounter rates differed between monsoon and winter season (One way Anova, F = 4.65, df = 2, P = 0.011). The estimated population N (SE and 95% Cl) in the intensive study area was 121 (2.01, 117 – 125) and the density was 10(±0.14)/ 100 km². Prime adult females (Mean ± SD), (31.6 ± 1.6) and prime male (24.6 ± 4.4) consisted majority of the population. The adult sex ratio was 76.4:100 females. The ratio of cubs to adult female was 50:100 females. The average litter size was 2.13 ± 0.83 (N = 32). Males did not associate with females and tended to move and feed independently. Only 11.7 % of total sightings (n = 521) were male-female associations (N= 61) of these 67.2% were mating pairs, 16.4 % associations on kills and 16.4% were seen resting or moving together. The group sizes were low and largely consisted of like-sexed pairs. Average group size of males was 1.4 ± 0.50 (1– 3, n=283) while average female group size (excluding cubs) was 1.3 ± 0.53 (1– 4, n =291). Mating and cub birth did not show sharp seasonality. Mating occurred largely between January (late winter) and June (end summer). Cub birth showed two peaks in winter and monsoon. Cub survival up to recruitment or sub-adult stage was 56% (42 – 76). Infanticide by adult males was the chief cause of mortality during the first year of birth. The adult annual survival rate was 0.922 ± 0.07. However, causes of mortality varied within and outside the PA boundaries indicating higher occurrence of accidents outside the park.

ii) Movement patterns, spacing mechanisms and land tenure system of four females (one radio-collared female), five adult males (two radio-collared males) and one sub-adult male (radio-collared) were obtained. Of these, seven individuals were monitored from 2002–2007. It was possible to obtain day-night ranges for the radio-collared lions only. The 100% home range was calculated using minimum convex polygon estimate and the intensive area of use (core) was estimated using the 50% fixed kernel estimate. Habitat preference was tested using three analytical techniques. (i) A χ^2 test for habitat selection and Bonferroni's confidence intervals. (ii) Compositional analysis for obtaining second and third order habitat preference ranking. (iii) Relation of chosen ecogeographic factors of elevation, ruggedness of terrain, mean distance to artificial water sources, drainage, road and ness, wild ungulate abundance of three major species (chital, sambar, nilgai) and vegetation types with lion presence tested using ecological niche factor analysis.

Male ranges varied from 11 km² to 174 km² while intensive use area (± SD) was 10 km² (3.9). Male ranges overlapped considerably (21% – 65%) while female ranges overlapped less (3% – 20%) with each other. Female home ranges varied from 26 – 43 km² while the intensive use area (± SD) was 5 km² (1.7). The extent of sub adult male range was 182 km². The average dispersal distance of dispersing sub adults and adult males was 23 km. Out of the eight major available vegetation types, the moist mixed forest and the savanna habitats were the most preferred.

Ungulate pellet counts revealed that Chital showed more tolerance for human disturbance and avoidance of elevated areas and closeness to artificial water sources. Nilgai also showed avoidance for elevation and rugged terrain and preference of relatively more arid areas of the park. Sambar showed positive relationship with elevation and rugged terrain closeness to drainage sources and weak negative relationship with natural and artificial sources of water.

The results of the ENFA revealed that habitat use by lions was strongly associated with the prey species. The national park area and rugged areas were areas of low occupancy by lions. Lions largely preferred areas around nesses that were also close to riverine areas. The lions in Gir PA were fairly specialized (tolerance value: 0.36) in their choice of habitat.

iii) Lion diet was assessed both by intensive search across the study area and record of lion kills as well as analysis of scat. A questionnaire survey was conducted in twenty nesses that included seven nesses in central Gir and thirteen nesses in Gir-west to assess the livestock holding and causes of livestock mortality. Inter-kill intervals were obtained from direct observation of radio-collared lions.

A total of 258 kills were located of which domestic kills constituted 56% and wild kills 44% of the total. The uptake of wild and domestic prey varied between revenue areas around the PA, Gir-west and national park (χ^2=12.3, df = 2, $p< 0.001$). Livestock was part of the diet in all park areas. The consumption of wild and domestic prey also varied between seasons (χ^2=22.3, df = 2, $p< 0.0001$) showing a greater proportion of wild prey during summer months.

A total 310 scats were analyzed revealed twelve prey species in the diet. There was no significant difference in the diet between management zones and between seasons. Livestock contributed only 14% of the scats analyzed and wild prey contributed to 86%. In terms of biomass, livestock contribution was 33%, which was equivalent to the contribution of the principal wild prey, the chital. Continuous monitoring of lions revealed that male lions made kills at the rate of one kill per 3–4 days.

Predation accounted for 65% mortality of the Maldhari livestock. Maximum attacks on livestock occurred between 4:00–6:00 pm. Overall the data from both kills and scat revealed that proportion of domestic prey consumed within the park was less. However, lions still depend on livestock to a large extent outside the park boundaries.

Three radio-collared lions, namely K-male, Buathirth male and Patriyala males, were tracked continuously for periods ranging from 3 – 15 days and data on various aspects of lion behaviour were collected. Half-hour behaviour scans were recorded and proportion of time spent under each activity was used to derive time activity budget for the lions. Lion movement and patrolling behaviour were assessed from continuous monitoring of lions. Ten independent patrolling events of four male coalitions was analysed to obtain the rate and frequency of vocalization.

A total of 1356 scans totalling to about 700 hours of observation were done on the three collared males. Male lions in all age classes spent 73 – 85% of their time resting (sleeping and sitting). However, territorial males spent 63% of their active time in territory advertisement indicating that territory defense was most important activity for male coalitions during their tenure period.

Patrolling occurred during early morning and late evening. Both coalition partners participated equally in patrolling and advertising their territory. Males covered an average of 2.5 km (0.41 – 4.5 km) distance during a patrolling event. One patrolling event associated with scent marking on an average (±SD) lasted for 2.13 (±0.9) hours (0.8 – 3 hours, N = 6). One vocalization event lasted for 6.5 hours (N = 2) associated with roaring lasted for 2 hours and roaring at the rate of 2.7(±1.3) per hour. Sub-adults varied in their activity and movement and did not advertise their territory. Nomadic movement during dispersal was found to be erratic.

The reproductive strategy of Asiatic lion could be summarized from the study of the social structure, ranging patterns, land tenure system and activity patterns. Male lions formed coalitions of two males and rarely with three males. Coalitions tended to defend territories rather than prides and their range included 2–3 prides. Males had a much larger range than females and there was considerable overlap between male ranges. Males associated with pride females only at the time of mating. Infanticide was prevalent and contributed to cub mortality especially in the first year of birth. Neither the movement nor the activity of coalitions was related to their diet. Movement of males was related to the areas where females where concentrated and less related to habitat features. Males actively patrolled and defended their territories and spent most of their active time in territory advertisement. Mating opportunities were equal for the coalition partners. Males associated with coalition partners at all times and even during the mating period of the coalition partner.

Chapter 1

Introduction and Review of Literature

1.1 Evolution of Carnivora

Saber-toothed cats, belonging to the Upper Eocene, were the earliest known ancestor of modern cats. The extinction of the saber-tooth cats, evolution of modern ungulates, and the radiation of *Felinae* occurred during the Pleistocene (Eisenberg 1981). To begin with the members of *Felinae* were small-sized forest dwelling animals (Ewer 1973). Expansion of open woodlands, grasslands and deserts and many changes in the prey-predator evolution occurred during the late Cenozoic era. The evolving prey led the felids into open country and caused the radiation of modern felids with varied morphological characters showing an interesting variation in size and distribution (Eisenberg 1981). The earliest lion-like cat appeared in East Africa during the Late Pliocene (Turner and Anton 1997). By late Pleistocene large lion like felids were distributed across most of Africa, Europe, Asia, N. America and northern part of S. America (Turner and Anton 1997).

In the evolutionary tree, the genus *Panthera* species is considered the oldest while the genus *Felis* is considered the more recent. Genetic research puts members of the sub-family *Pantherinae*, namely *Panthera*, *Uncia* and *Neofelis* into one lineage (Eisenberg 1981). The subgenus *Tigris* (tiger branch) separated from the subgenus *Panthera* – jaguar (*P.onca*), lion (*P.leo*) and leopard (*P. pardus*) at the end of the Pliocene, followed by the separation of the Jaguar clade (Burger et al. 2004). Finally, approximately at the beginning of the lower Pleistocene, the lion and leopard clade split up (Burger et al. 2004). Large carnivores opened up niche for scavengers that included both the canids and the hyenas (Eisenberg 1981).

1.2 Classification of Carnivora

The family Felidae is classified under 14 genera. The sub-family *Pantherinae* includes the genus *Neofelis* (clouded leopard), *Uncia* (snow leopard), *Panthera* (*P. tigris, P. onca, P. leo*, and *P. pardus*) (Wilson and Reeder 2005).

Table 1.1: Classification of extant Carnivora - ***Class:*** *Mammalia;* ***Order:*** *Carnivora;* ***Family:*** *Felidae*

FAMILY	**SUB FAMILY**	**GENUS**	**NO. OF SPEICES**
Felidae	Felinae	*Felis*	7
		Prionailurus	5
		Puma	2
		Acinonyx	1
		Lynx	4
		Leopardus	9
		Leptailurus	1
		Caracal	1
		Profelis	1
		Catopuma	2
		Pardofelis	1
	Pantherinae	*Neofelis*	1
		Panthera	4
		Uncia	1

Recent mitochondrial and nuclear DNA studies have classified felids into three major sub families: Ocelot lineage (seven species), the domestic cat species (seven species) and the *Pantherinae* lineage (23 species) (Macdonad 2001). The ocelot and domestic cat lineage arose from two independent monophyletic groups while the *Pantherinae* group comprises of six monophyletic groups: *Panthera* genus, the *Lynx* genus, the Asian leopard cat group, the Caracal cat group, the Bay cat group, and the Puma group (including the cheetah). The serval and rusty spotted cat have doubtful lineage (MacDonald 2001).

1.3 Lions - Early Evolution

Two models have been proposed to explain the diversification of lions – multiregional origin model and single origin replacement model (Barnett et al. 2006). While the former supports long term evolution and diversification of present-day lion, the latter proposes that a single population of lions replaced the older populations in Africa and southwestern Eurasia (Yamaguchi et al. 2004), following a population bottleneck (Barnett et al. 2006). Recent investigations on phylogeographic history of modern lions, based on analysis of mtDNA sequences, indicates a single African origin model of modern lion evolution (Barnett et al. 2006).

Lions were the most widespread large terrestrial mammal during the late Pleistocene and had established in the entire Holarctic region (Barnett et al. 2006) including Africa, most of Eurasia and North America. Traditionally twelve and later eight sub species of *Panthera leo* have been classified based on location, mane appearance, size and distribution (Burger et al. 2004, Barnett et al. 2006, Table 1.2). Two distinct lineages are recognized to have existed at the end of Pleistocene, namely, the

Holarctic cave lion (*Panthera leo spelaea*) and the modern lion (*Panthera leo* spp.) (Burger et al. 2004). Recent studies have shown that mitochondrial variation is limited and does not merit taxonomic distinctions among extant African lions (Dubach et al. 2005). Hence, all sub-Saharan lions are classified into a single subspecies (Dubach et al. 2005, O' Brien et al. 1987). However, they may be divided into two main clades: to the west and east of the Great Rift Valley indicated by the fact that lions from Tsavo in Eastern Kenya are much closer genetically to lions in Transvaal (South Africa), than to those in the Aberdare Range in Western Kenya (Barnett et al. 2006). Recent evolutionary history of lions has resulted in three geographic populations on the basis of their recent evolutionary history, namely, North-African-Asian, southern African and middle African populations (Barnett et al. 2006).

Two distinct subspecies of extant lions, namely, *Panthera leo leo* and *Panthera leo persica* have been recognized that have diverged in recent times, about 55,000 and 200,000 years ago (O' Brien et al 1987). The free ranging lions today exist as two disjunct populations: *P. l. leo* in Africa and *P. l. persica* in India. The former are presently found in savannah habitats across sub- Saharan Africa while the only living representatives of the latter occur in the Gir Forest, in western India (Nowell and Jackson 1996).

Table: 1.2: Subspecies classification of lions (Burger et al. 2004):

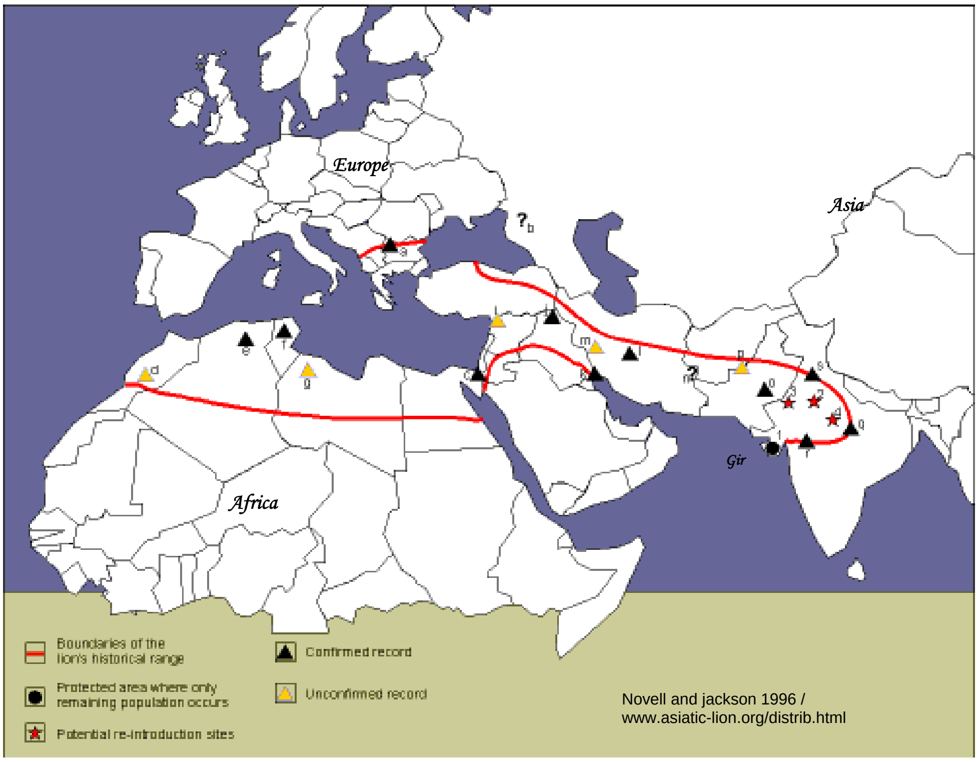
***Spelaea* Group**	
P. l. fossilis	Early Middle Pleistocene European cave lion
P. l. vereshchagini	East Siberian or Beringian cave lion
P. l. atrox	North American cave lion
P. l. spelaea	Upper Pleistocene European cave lion
***Leo* Group**	
P. l. persica	Asiatic, Persian or Indian lion
P. l. leo	(Barbary lion) All extant African lion species
***Senegalensis* Group**	
P. l. senegalensis	West African lion
P. l. azandica	North East Congo lion
P. l. nubica	East African- or Masai lion
P. l. bleyenberghi	Southwest African or Katanga lion
P. l. krugeri	Southeast African or Transvaal lion
P. l. melanochaita	Cape lion

1.4 Distribution of *Panthera leo*

1.4.1 Asiatic Lions: Distribution and Status

The only surviving free-ranging population of the Asiatic lion (*Panthera leo persica*) exists in the Gir forest, Gujarat, India. However, the Asiatic lion historically had a wide distribution (Fig. 1.1). The erstwhile range of the Asiatic lion once extended from Syria across the Middle East to Eastern India (Kinnear 1920, Joslin 1973). Lions inhabited extensive areas in North and Central India and were found in large numbers in the states of Punjab, Haryana, Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat and western Bihar (Fenton 1908, Dalvi 1969). Indiscriminate hunting wiped out lions from the rest of India 1880 (Pocock, 1936). Within the Saurashtra region, they were found in Dhrangadhra, parts of Jasdan, Chotila, Alech hills, Barda hills, Girnar and Gir. By the turn of the 19th century, large tracts of cultivation came to separate Gir, Girnar, Alech and Barda hills. As a result, the lion population got fragmented and ultimately limited to the Gir forest (Dalvi 1969). Lions were still known to move out of Gir in post monsoon and monsoon seasons (Singh 1997). In recent years, lions have taken permanent residence in the coastal forests of Kodinar, Girnar and Mitiyala forests (Singh 1997).

While the distribution of lions has consistently shrunk and has been limited to a single pocket in Gir, the population numbers within the area has also fluctuated widely over the years. The numbers of lions in the Gir was very small, believed to be as low as 12 animals in 1880 and very close to extinction (Wynter-Blyth and Dharmakumarsinhji 1950). Owing to the timely protection measures taken by the Nawab of Junagadh, the lion population got a brief respite from hunting and recovered to a number of 70. However, a famine that occurred between the years 1901 and 1904 brought the lions in direct conflict with people, thereby ending the earnest attempts of protection. As a result, yet again, the lion population declined to a mere 20 at the end of the famine in 1911. This brief period under the British and the following period under the new Nawab, the lion population was again resurrected from the brink of extinction. The 1936 census indicated a population of 287 (Dalvi 1969). Lion counts in the following years, in 1950, 1955 and in 1963 estimated the population to be 227, 290, and 285 respectively (Wynter-Blyth and Dharmakumarsinhji 1950**,** Wynter-Blyth 1956, Singh 1997). The population of lions has since shown a steady increase. In recent years, the increase in lion population has resulted in an increase in lion-density within Gir and consequently lions have dispersed and established themselves outside the protected area (PA). The present population estimate is 359 lions, including 291 within the PA and "satellite populations" of 68 (Gujarat Forest Department census report 2005).



Novell and jackson 1996 / www.asiatic-lion.org/distrib.html

Fig. 1.1: Historical range of *Panthera leo persica*

1.4.2 African lions: Distribution and status

The African lion population has been estimated to be between 16,500 – 30,000 (Bauer and van der Merwe 2004). They exist both as fragmented population in west and central Africa as well as continuous large population in East and Southern Africa (Bauer and van der Merwe 2004).

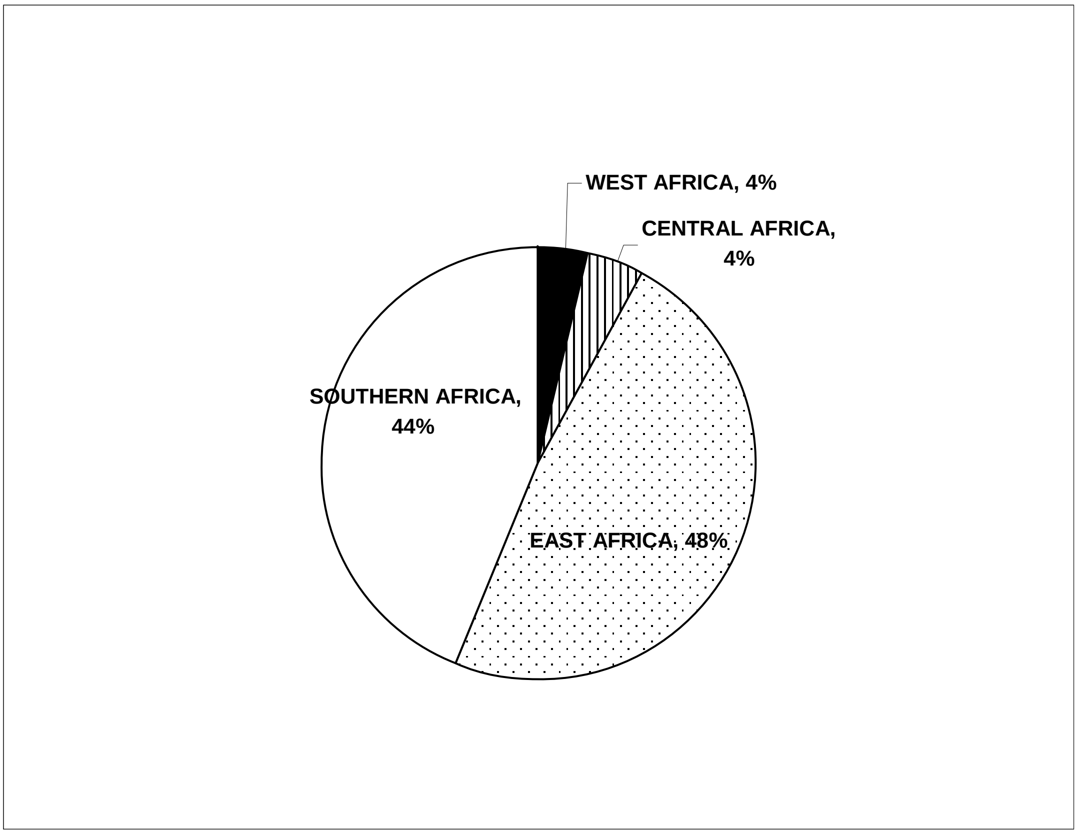


Fig. 1.3: Distribution of lions in Africa (Bauer and van der Merwe 2004)

1.5 Sociality in Competing Species

Carnivores are mostly solitary (Ewer 1973) but certain mongoose species, otters, wild dogs, hyenas and lions are social. Although, certain taxonomic groups among carnivores, such as canids and herpestids, have a tendency for social living, group living has evolved in each major taxonomic family across the order (Fig. 1.4, Gittleman 1989). It appears that grouping behaviour in carnivores evolved independently several times (Gittleman 1989).

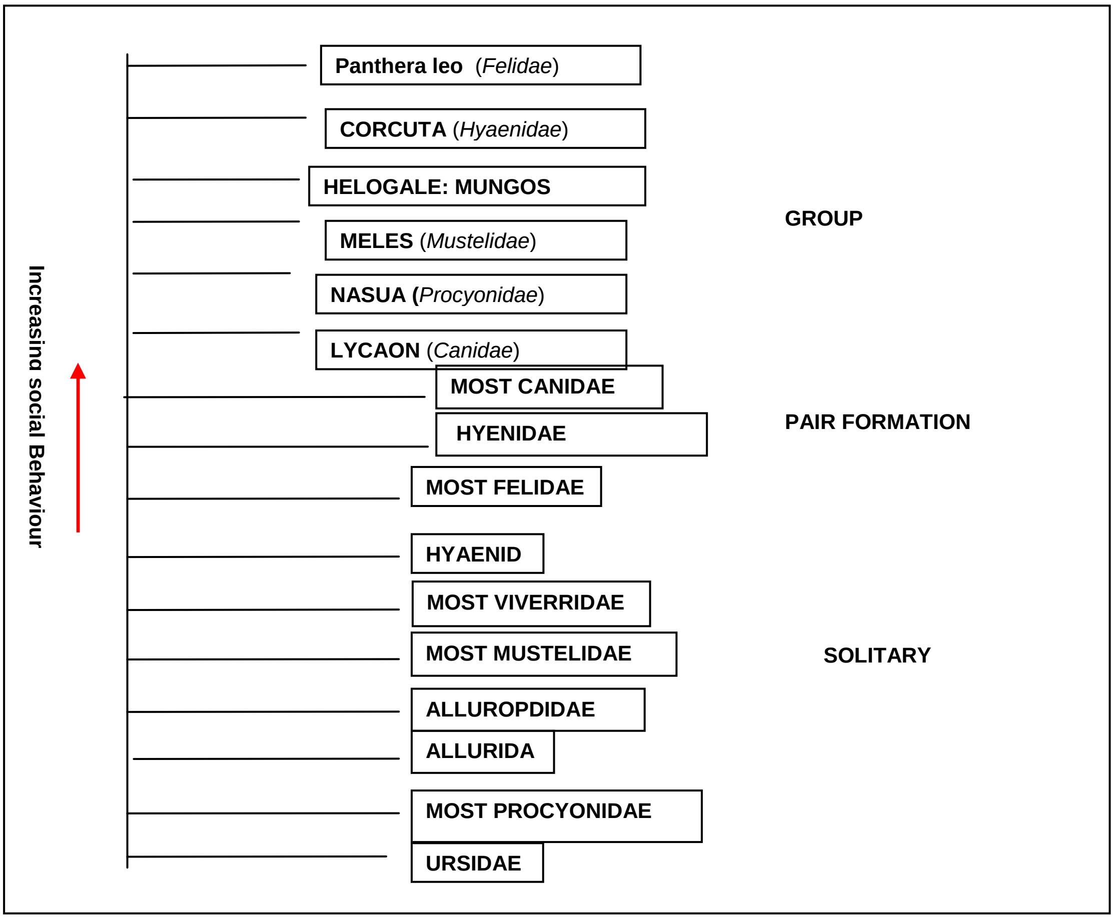


Fig. 1.3: Phylogenetic tree of social behaviour in Carnivora (reproduced from Gittleman 1989)

There are also several types of carnivore grouping that are functional responses to both the environment as well as to kinship and relatedness namely foraging group (related to hunting success), feeding group (related to sharing of food) population group (related to sharing a common home-range) and breeding group (related to mating) (Gittleman 1989). Behaviors such as guarding of foraging and breeding grounds, mutual regurgitation, reproductive tolerance and sharing of reproductive opportunities among group members and communal suckling or rearing of young ones have been attributed to kin selection (Bertram 1979).

Evolution of sociality is explained by the resource dispersion hypothesis (Macdonald 1983). Based on this theory, dispersion and abundance of resources cause variation in the social system of carnivores and are moulded both by ecological constraints and benefits. Thus, access to food acted as a catalyst to the evolution of sociality and resulted in expanding the niche for some carnivore groups (Macdonald 1983). In resource rich areas, recruitment of many individuals within a territory gave rise to other benefits resulting in selection of sociality in certain taxonomic groups (Macdonald 1983). Diverse selective pressures have contributed to the evolution of varied sociality with several advantages such as hunting and killing of large prey, anti-predator defence, social learning and information transfer, alloparental care and survival in hostile environment (Gittleman 1989, Macdonald 1983). Optimum resource exploitation, competition and reproduction are responsible for varied adaptations among carnivores.

- ***Resource utilization***

Predator-prey systems evolved in open areas and therefore abundant prey, open habitat, competitors and social living began in open habitats (Packer and Caro 1997). Direct competition for resources between species leads to evolution of social behaviour (Eaton 1979). Among carnivores, food acquisition and consequently reproductive success is the evolutionary cause of sociality (Caro 1994). Asocial carnivore species namely cheetah and leopard coexist successfully among other social carnivores – lions, wild dog and hyenas and exploit effectively, the same set of resources in these habitats by varying hunting strategies, prey and habitat preferences (Bertram 1979). Habitat preferences, activity patterns and their varying responses towards seasonal changes of prey availability separate carnivores into distinct niches (Kingdon 1997).

- ***Competition***

"Competition looms large in the lives and evolution of carnivores" (Kingdon 1997). Among social species there exist distinct patterns of hierarchy and established patterns of land tenure (Kingdon 1997, Eaton 1979). Some carnivore species may occur at low densities when sympatric with dominant species than would be predicted by prey density alone (Creel and Creel 1998, Table 1.3). Forces of competition and predation promote sociality in many carnivores (Creel and Creel 1998, Cooper 1991, Trinkel and Kastberger 2005, Mills and Gorman 1997).

- ***Reproduction***

The group living carnivores fall in two categories – one, where there is one breeding female in a group and several subordinate females and other, where all females breed simultaneously such as in the case of lions, some mongoose species and hyena (Gittleman 1989). In most carnivores, females defend food and denning sites while males defend the female resources. Mating systems are determined by the manner in which resources essential to female reproduction are dispersed in space and time (Caro 1994).

The period over which females are receptive, the degree to which females breed synchronously, their distribution in space, group size and female ranging patterns affect many aspects of male competition particularly spatial relation and ranging behaviour (Caro 1994, Gehrt and Fritzell 1999, Sandel and Liberg 1992). If female groups are unstable or solitary and their ranges too large to be defended, males defend dispersed or clumped mating territories within a portion of female’s home ranges (Schaller 1972).These principal factors would determine whether males defend: (a) feeding territories (b) Mating territories (c) roam in search of receptive females (d) defend females or (e) form temporary territories (Sandel and Liberg 1992). In terms of strategies these factors would determine if they would adopt monogamy, female defence polygyny or resource defence polygyny (Sandel and Liberg 1992).

Next, what are the factors that promote male grouping? High or localized female densities with overlapping ranges are found to drive male group living (Caro 1994). The advantages of male felid coalitions include procuring more matings and surviving serious challenges from other competitors (Hanby et al. 1995, Caro 1994, Macdonald 1983).

1.5.1 Leopard *(Panthera pardus)*

Social Organization: Leopards are solitary felids. They are social only when mating or rearing cubs (Bailey 1993, Kittle and Watson 2007). The leopard’s association with conspecifics is rarer when compared to other felid species (Bailey 1993). Existing at low densities, maintaining exclusive ranges and having access to available prey resource with high success rates predisposes leopards to asociality (Stander et al.1997).

Reproductive strategy: Leopards do not rely upon direct territorial defence but instead exhibit strong mutual avoidance by utilizing indirect signals such as scent-marking and vocal communication to ensure temporal separation of conspecifics (Marker and

Dickman 2005). Leopards utilize large areas and individual ranges have high degree of overlap in some areas (Marker and Dickman 2005) whereas in other areas, home-ranges of adult males have little overlap with each other but overlap with ranges of several adult females (Bailey 1993).

Hunting strategy: Leopards hunt alone by stalking close to prey and pouncing or sprinting from short range. The leopard requires considerable cover for ambush and is more successful by night (Bertram 1979). To stalk their prey they have to be alone and remain undetected to catch their prey before they flee (Bertram 1979). Their prey items cover a wide variety of species occurring in the woodland and have been found to contain as many as 30 species in Serengeti (Bertram 1979).

Competition: Leopards successfully avoid conflict with inter-specific competitors by dragging and hiding kills in thick vegetation (Stander et al. 1997) or caching on trees (Bailey 1993). The proportion of leopard kills cached in trees varies across habitats (Stander et al. 1997, Bailey 1993, Kittle and Watson 2007) and may be as much as 84% in areas of high levels of intra-guild competition (Bailey 1993). Thus, the costs of defending carcasses against larger and gregarious carnivores are avoided by solitary and secretive behaviour and conflict with competing males sharing their range is avoided by temporal separation (Stander et al. 1997).

Table:1.3 Various types of adaptation of sympatric carnivore to inter-specific competition: some examples from other studies

Adapting species and the dominant competitor	**Area**	**Activity**	**varied prey preference**	**Large group size**	**Low density**	**Suboptimal habitat**	**Aggression**	**Reference**
Hyena–lion	Etosha NP			+			+	*Trinkel & Kastberger 2005*
African wild dog–Hyena	Selous GR	+						*Creel & Creel 1998*
African wild dog–Lion	Kruger NP		+					*Mills & Gorman 1997*
Cheetah–Lion–Hyena	Serengeti NP		+	+				*Durant 1998*
Lion–Spotted hyena	Chobe NP			+				*Cooper 1991*
Dhole–Leopard–Tiger	Nagarhole NP		+					*Karanth & Sunquist 2000*
Leopard–Tiger	Chitwan NP	+						*Sunquist 1981*
Leopard–Tiger	Chitwan NP					+	+	*McDougal 1988*
Leopard–Tiger	Chitwan NP	+						*Seidensticker 1976*
Leopard–Tiger	Rajaji NP	+				+		*Harihar pers comm.*

1.5.2 Cheetah (*Acinonyx jubatus*)

Social Organization: Social organization of cheetahs is unique in that it is similar to social lions as well as the solitary big cats. Adult female cheetahs are solitary and associated with their dependent offspring. Adult male cheetahs may live alone or form coalitions of two or three individuals. These coalitions usually composed of littermates or in some cases consist of non-relatives (Caro and Collins 1986).

Reproductive strategy: Female cheetahs in the Serengeti are solitary, migratory and live at low densities. Males show varied strategies: some hold territory and others range over large areas. Male territories and grouping are therefore centered on where females temporarily aggregated during the extensive annual movements (Caro 1994).

Hunting strategy: Cheetahs have large ranges and are capable of following migratory prey (Caro 1994, Bertram 1979). They do not scavenge, are diurnal hunters and prefer open habitats (Bertram 1979). They have high hunting success and are very good at catching small size prey (Bertram 1979). Grouping in male cheetahs is a response to intraspecific competition for mates but do not improve hunting success or per capita food intake (Caro 1994).

Competition: Cheetah densities show an inverse relationship to hyena and lion density (Caro and Laurenson 1994) and therefore occupy refuge or sub-optimal habitats (Durant 1998). They avoid hunting in areas of high prey density where the risk of encountering more dominant competitors is high (Durant 1998).

1.5.3 Tiger *(Panthera tigris)*

Social Organization: Tigers have been successful in exploiting their niche by remaining solitary but are capable of socializing (Sunquist 1981). The tiger's habitat is relatively closed, sparse and has a scattered prey-base and competing predators are absent or occur at low densities (Sunquist 1981).

Reproductive strategy: Like-sex home-ranges are distinct. Exclusion of competing males within the home-range of a male is advantageous to both sexes in terms of access to resources, reproduction and care of young (Sunquist 1981). The distinct land tenure system thus reduces potential competition for resources and conflict among conspecifics (Sunquist 1981).

Hunting Strategy: Tigers use stalk-ambush technique to hunt down prey (Karanth and Sunquist 2000).

Competition: The tiger coexists with leopard and dhole that use the same areas and hunt in similar habitats (Karanth and Sunquist 2000). The three predators, partition their resources by selectively killing different prey types in terms of species, size and age-sex class and their activity is related to prey and thus coexist by means of ecological separation (Sunquist 1981, Karanth and Sunquist 2000).

1.5.4 ***Hyenas***

Social Organization: The social organization of the three hyena species are summarized (Table 1.4)

Striped hyaenas (*Hyaena hyaena)* are solitary that however frequently rest in pairs or occasionally in groups of up to four individuals. A number of individuals may feed on the same carcass but do so at varying times. Thus, foraging is strictly solitary. Both sexes appear to mate with multiple partners (IUCN Hyaena Specialist Group 2000).

Brown hyenas (*Hyaena brunnea)* associate in clans consisting of one dominant male, three to four subordinate males, four to six adult females and associated sub-adults and young. Clans typically number about 13 hyenas including young and defend a common territory (Owens and Owens 1979).

Spotted hyenas (*Crocuta crocuta)* live in complex stable social groups called clans (Kruuk 1972). Each clan contains multiple adult females, their offspring and one to several resident immigrant adult males. Female hyenas generally spend their entire life in the natal clans while all sub-adult males disperse (Kruuk 1972). Females are the dominant members, followed in rank by cubs, while adult males rank lowest. The society is highly structured, with dominance relationship between the matrilines that endure for generations (Kruuk 1972). Although spotted hyenas are better adapted to a scavenging lifestyle than any other predators in their range, they obtain the majority of their nourishment through hunting (Kruuk 1972).

Hunting strategy: Hyenas are nocturnal hunters and tend to run down their prey to exhaustion (Bertram 1979). They therefore most often take slower individuals – small young, very old, sick or injured animals (Kruuk 1972). The hyena’s shape and gait enable it to travel long distances and exploit food resources by feeding on dead carcass and scavenging (Bertram 1979). There is an increase in hunting success in bringing down large prey with increase in group size (Kruuk 1972).

Competition: Competition between lions, hyenas and wild dogs depend on a number of ecological factors including habitat fragmentation, density of prey, size of prey, opportunities for scavenging and habitat where the species occur together (Creel 2001). Competition does not limit the relative number of lions but has a marginal positive influence on hyena numbers (Purchase 2004). The type and abundance of prey is the most significant determinant of population size and therefore only in extreme environments lions and hyenas should adversely affect each other (Purchase 2004).

Table 1.4: Comparative social system of the striped, brown and spotted hyena

	Striped hyena	**Brown hyena**	**Spotted hyena**
	Data deficient	Family clan -male, female, subadult and cubs	Gregarious, polgynous, female dominated
Size of clans	Data deficient	Small (< 15)	Large
Hunting	Solitary	Solitary	Solitary and in packs
Food sharing	Rare	Rare	Shared along order of hierarchy
Territorial	Data deficient	In high density areas	Group defence
Communal denning	Data deficient	Yes	Yes
Communal feeding	Data deficient	Yes	No

1.5.5 **Lions** (*Panthera leo)*

Social Organization: Lions are the only social felids that live together in social units called prides. Group formation in lions has been described as fission-fusion interactions (Schaller 1972). In open habitats, female pride consist of 2–18 females and a coalition of males that has entered the pride from elsewhere and associate with the pride during their tenure with the pride (Schaller 1972, Bertram 1975, Bygott et al. 1979, Packer and Pusey 1982). The interesting feature of lion sociality is that they do not form dominance hierarchies within prides (Schaller 1972, Bertram 1975, Bygott et al. 1979, Packer and Pusey 1982**)**. Female companions of a pride are always closely related, male companions are either closely related or unrelated and mating partners are usually unrelated (Packer et al.1991).

Group territoriality, group hunting and communal cub-rearing form the basis of this cooperation (Grinnell et al. 1995, Heinsohn and Packer 1995). The social structure defines the way in which these resources are used or shared. This aspect of lion sociality has been well documented in the Serengeti lions of Africa (Schaller 1972, Bertram 1975, Packer and Pusey 1982, Grinnell et al. 1995, Packer and Pusey 1983, Packer and Pusey 1987, Packer et al. 1988).

Pride females: At the age of three, a sub-adult female is either recruited into the pride or driven out of it depending upon the existing adults in the population (Bertram 1975). Females have a life span of about18 years; start breeding at 3 to 4 years of age and breeding declines from 11 years of age (Packer et. al. 1988). Females resume sexual activity when cubs are about 18 months old (Bertram 1975, Heinsohn and

Packer 1995). However, females that lose their cubs generally resume sexual activity within days or weeks of the loss (Schaller 1972, Packer and Pusey 1983).

Coalition males: At three years of age male lions are either expelled or leave their natal prides voluntarily. At this stage they have scanty mane but are sexually active (Bertram 1975). Male lions form coalitions of 2–9 individuals during the nomadic phase of their lives with brothers and cousins from the same pride or with non-related males (Packer and Pusey 1997). Successful male coalitions become resident in the first pride when they are about four years old (Packer and Pusey 1987) and are resident in a pride for about 26 months. The average reproductive lifespan of males is 33 months (range 5–130 months) (Packer et. al. 1988). Aggressive encounters during pride defence and takeovers cause injuries limiting the effective lifespan of males to 12 years (Packer et. al. 1988).

Nomads: Nomadic lions are not necessarily of a different population but are “surplus” from the resident breeding populations (Schaller 1972, Bertram 1975). Most nomads are males looking to establish and wrest control of prides from other coalitions (Schaller 1972) and include both sub-adult males, as well as old males expelled from their territories by other males (Schaller 1972). Nomadic females are those expelled from their natal territories. Nomads that do not establish territories, have shorter lifespan, do not reproduce effectively, and have small litters that are less likely to survive (Schaller 1972, Bertram 1975).

Reproductive strategy: Reproductive success of individuals of each sex depends on the number of like-sex companions they have (Packer and Pusey 1987).

Male Strategies: A male takeover is defined as the complete replacement of one male coalition by another (Bertram 1975). A successful coalition gains temporary but exclusive access to a group of females, till ousted by another coalition (Bygott et al. 1979). Larger coalitions are likely to gain residence in a pride, remain in residence longer, and gain access to more females than do small coalitions (Bygott et al. 1979). Group formation thus results in greater reproductive success (Bygott et al. 1979, Packer et. al. 1988). Infanticide in lions is a male reproductive strategy whereby males terminate a female's investment in the offspring of other males in order to stimulate female sexual receptivity (Hrdy 1974, Bertram 1975). Incoming males that takeover a pride kill small cubs and oust sub-adult females below breeding age and resident sub-adult males (Pusey and Packer 1983).

Males generally remain in the same pride for 2–3 years and typically father only one cohort per pride (Pusey and Packer 1993). The association of adult male coalitions and female prides may be occasional or throughout the tenure of territorial males and may vary in different areas. In open areas, males associate with the prides throughout their tenure and thus show direct parental investment by providing protection to dependent cubs from infanticidal nomadic males (Kleiman and Malcolm 1981).

On the other hand, in closed areas, males operate alone and maintain territory by patrolling, scent marking and roaring. This strategy is effective not only in discouraging rivals from entering the pride range but also ensures greater reproductive success for the males (Funston et al. 1998). This strategy ensures more effective territory defence against elusive intruders in thick cover and is more effective because (1) It discourages rivals from entering the pride range, (2) Resources of the pride range are defended better and (3) Pride males can gain access to neighboring prides and sire more cubs. Since, pride females in big groups are able to protect their offspring without the help of pride males (Funston et al. 1998).

Female Strategies: Females cooperate to defend their hunting grounds, denning sites and water holes from other prides and at the same time also communally suckle and raise their cubs and jointly protect them from infanticidal males (Packer and Pusey 1997).

Sub-adult Strategies: Births are synchronous within a pride following a male takeover (Bertram 1975). The resident male coalitions are able to successfully raise one cohort during their tenure period (Bygott et al. 1979). Large male cohorts have the advantage of entering new prides intact whereas cohorts of only one or two males would have to team up with males from other prides (Packer et al. 1988). Although the overall reproductive success increases with increase in group size, the individual reproductive success becomes low (Packer et. al. 1988). Therefore kinship is essential for the maintenance of larger coalitions where reproductive success of each individual is highly skewed (Packer et al. 1991).

Hunting Strategy: Availability of denning sites, water and a stable, high-density resident prey-base supports a high density and stable lion population with smaller home-range with much less spatial overlap between prides (Scheel and Packer 1995, Ogutu and Dublin 2002, Spong 2002). For instance, lion density was 3.3 times higher/ km (Yamaguchi et al. 2004) in Ngorongoro Crater compared to Serengeti plains where the availability of prey varied (Scheel and Packer 1995). Hunting success has been shown to increase with increase in group size, especially in hunting down large prey (Stander 1992, Funston et al. 2001). In open areas, hunting success of males is reduced owing to the fact that they are much slower and more conspicuous to the prey and they therefore optimize their feeding requirement by associating with pride females throughout their tenure and appropriating prey from them (Bertram 1979). In closed areas however, males obtain more meat by hunting alone rather than if they were to scavenge from females (Funston et al. 1998).

Competition: Pride size and lion associations in some areas are determined by presence of competing species, the spotted hyenas (Cooper 1991). Several nomadic lions form aggregates of up to 17 and associate with prides to form stable associations in order to defend against spotted hyenas (Cooper 1991).

Thus, the life-history strategies of sympatric carnivores and patterns of their social systems depend on available resources, reproductive strategy and competition. Felids are able to sustain at the top of the food chain by various adaptations that includes, most importantly, their social structure. While leopards are always solitary (Bailey 1993), tigers are capable of social living (Sunquist 1981) and male cheetahs adopt group living to improve their reproductive success (Caro 1994).

1.6 Lion Sociality: *Not As 'Plain' As It Seems*

Since lions attained a wide distribution in evolutionary history, they are thought to have influenced evolution of many sympatric carnivores through direct and indirect competition (Eisenberg 1981). It appears that the members of *Panthera* share a common lineage up to Pliocene and later lions alone developed certain other characteristic features such as group living and mane that distinguish them from rest of the group (Yamaguchi et al. 2004). Thus, lion evolution has important implications for palaeocecological reconstruction and evolutionary study of other carnivores (Yamaguchi et al. 2004). Although lions are the only social felids, their social systems show remarkable plasticity. However, the popular concept of lion social behaviour is of the patterns observed in the well-studied lions of the Serengeti plains. Whenever the context of sociality or the lack of it is discussed in carnivores there is always a comparison with lions (Sunquist 1981, Stander et al. 1997, Caro 1994). Yet lions do not form a standard reference pattern to compare with. For instance, some studies have shown that lions form larger groups than predicted by maximum foraging efficiencies (Coraco and Wolf 1975). Reviews on the evolution of social behaviour in carnivores have been done by several authors (Eaton 1979, Gittleman 1989, and Macdonald 1983). There have been reviews on optimum foraging groups that maximize hunting success (Clark 1987, Giraldeau and Gillis 1988) associations that benefit from fighting other competing species (Cooper 1991, Coraco and Wolf 1975) and associations that optimize reproductive success (Packer and Pusey 1982).

I undertook the following review of lion social organization compiling information relating to prey, habitat and competition in order to provide a framework around which the social system gets patterned. I took into account pride and coalition composition, male-female interaction, pride size, home-range, habitat, prey availability and competition. I obtained data from literature as well as from personal communication with experts in the field (Appendix 1).

The ecological parameters that potentially affect lion social organization, namely habitat and prey are listed (Tables 1.5 & 1.6) and the lion social organization are summarized (Table 1.7). Adequate information was not available on all parameters for a particular habitat. Prey biomass is a very important determinant of group sizes. However, the data on prey biomass with respect to the lion data-base was unavailable. Therefore, detailed analysis and further interpretation was not possible.

Few studies (Purchase 2004, Funston 2007, and Hemson 2003) have reviewed the social organization of lions with all factors taken together. Two studies of lions have reviewed the population, density and status of lions across Africa (Bauer and van der Merwe 2004, Chardonnet 2002). If a detailed data-base taking into account prey and diet parameters (including livestock uptake), habitat and climate, social structure, density, home range becomes available, it would be possible to ascertain the drivers of the observed patterns of lion social organization. However, it is clear that the social system of lions is very dynamic and varies with respect to habitat, anthropogenic pressures and dependency on livestock, prey availability and competition (Cooper 1991, Funston 2007, Hemson 2003, Schaller 1972, Hanby et al.1995).

1.7 Male Strategies and Social Organization

Coalition formation and its establishment is the most important determinant of male reproductive success. Mating success depends on temporal patterning of females in oestrus and the reproductive fitness depends on the nature and size of the coalition. A male lion’s reproductive success is largely restricted to a particular phase of his life when he holds control over a pride.

1.8 Justification of study

It is evident that the social organization of lions is influenced by habitat, variation in density and group sizes, prey availability and by existing management and anthropogenic pressures. The Gir PA, characterized by high lion density with low genetic variability confined within limited extent of the Gir, should have an unique social organization and interesting topic of study. Very little is known about the details of coalition tenure, the nature of coalitions and interaction between and within coalition, and interaction of males with resident pride females.

Table:1.5 Description of location and habitat of twelve well documented lion habitats of Africa

Study area	**Region**	**Country**	**Park area (km²)**	**Vegetation**	**Cover**	**Author & Source**
Kruger NP	Southern Africa	S.Africa	23, 700	Open woodland savanna	mixed	P.J. Funston (Pers comm.)
Greater Tsavo Ecosystem	East Africa	Kenya	20, 000	Acacia – Commiphora woodland	Medium	Bruce Patterson (Pers comm.)
Selous Game Reserve	East Africa	Tanzania	92, 000	Wooded savanna, *Miomom Combretum* thickets	Medium	Spong 2002
Etosha NP	Southern Africa	Namibia	22, 270	Short grass plains	Open	Stander 1992
Serengeti	East Africa	Tanzania	40, 000	Acacia woodlands /plains	Open	Hanby et al. 1995
Luangwa valley	Southern Africa	Zambia	355	Mixed	Medium	Yamazaki 1996
Mid - zambezi	Southern Africa	Zimbabwe	2196	Alluvial/ Colophospermum/ dry	closed	Norman Monks (Pers comm.)
Masai mara NP	East Africa	Kenya	1530	Open wooded grassland		Ogutu &Dublin 2002
Ngorongoro Crater	East Africa	Tanzania	250	Savanna	Open	Hanby et al. 1995
Chobe NP			11, 700	Savanna	mixed	Cooper 1991
Hwange NP	Southern Africa	Zimbabwe	14,600	North-west area: *Coleospermum* mopane woodland and scrub. Kalahari sand: *Baikiaea plurijuga* woodland	mixed	Loveridge 2005
Gir Sanctuary and NP	Gujarat State	India	1883	Dry teak forest	mixed	Meena et al. 2007

Table:1.6 Details on prey related parameters and competition for the twelve lion habitats of Africa

Study Area	**Prey Diversity**	**Prey Availability**	**Prey biomass (kg/km²)**	**Livestock availability**	**Livestock intake**	**Competing predators**	**Reference**
Kruger NP	5	High	246	None	Low	Low	East 1989
Greater Tsavo Ecosystem		Seasonal	Data deficient	High	Low	Medium	East 1984
Selous Game Reserve	14	High	1874	None	No	Low	Caro et al. 1998
Etosha NP	11	Seasonal	283			Low	Coe et al. and East 1984
Serengeti	13	Seasonal	970	None	None	Low	Hanby et al. 1995
Luangwa valley	Data deficient	Data deficient	10003	Data deficient	Data deficient		Ndhlovu & Balakrishnan 1991 in Hemson 2003
Mid - zambezi	high	High	Data deficient	None	None	Medium	Norman Monks *pers comm*
Masai mara NP	8	High	10335	Medium	Medium	Medium	Ogutu &Dublin 2002
Ngorongoro Crater	8	High	15660	None	None		Hanby et al. 1995
Chobe NP	low	High	11, 693	Data deficient	Data deficient	Low	Cooper 1991
Hwange NP			30	No	No	High	East 1984
Gir Sanctuary and NP	7	High	2,764	High	High	Low	Khan 1994

Table:1.7 Details on lion social organization for the twelve lion habitats of Africa

Study Area	**Population estimate**	**Home range *(km²)***	**Density */ 100 km²***	**Average group size**	**Male group size**	**Female group size**	**M–F interaction *(during tenure)***	**Source**
Kruger NP	2200	150	10.5	11.8	2.1	4.5	Throughout	P.J. Funston (Pers comm.)
Greater Tsavo Ecosystem	675		Low	8	1	7.4	Throughout	Bruce Patterson (Pers comm.)
Selous Game Reserve	3750	52.4	16	5.3	2.4	3.4	Throughout	Spong 2002
Etosha NP	230	600	2	4.2	1.5	4.8	Throughout	Stander 1992, Oxford &Perrin 1998
Serengeti	2500	200	10	11.5	3.1	5.4	Throughout	Hanby et al. 1995
Luangwa valley	49	58	12.7	9.7	2	3.8	Occasional	Yamazaki 1996
Mid - zambezi	120*		5.2	7.7	2	8	Throughout	Norman Monks (Pers comm.)
Masai mara NP	547	71	30	22	2.4	9.2	Throughout	Ogutu &Dublin 2002
Ngorongoro Crater	53	45	40	16.25	3.25	3.5	Throughout	Hanby et al. 1995
Chobe NP	213	1000	5	7	2	7	Occasional	Cooper 1991
Hwange NP	250	Male: 700 Female: 345	3.6		1.9	2.77	Occasional	Loveridge 2005
Gir Sanctuary and NP	360	Male: 85 Female: 35	11		1.4	1.3	Occasional	This study

* only for Mana pools National Park

1.9 Scientific Studies in Gir

Several aspects of ecology and movement patterns of the Asiatic lions have been documented (Joslin 1973, Chellam 1993). Gir has a long history of research and the studies conducted so far include both the animal and plant component of Gir. Berwick (1971, 1976) studied the conflict between wild ungulate and livestock population and the role of predators. Joslin (1973) studied the reasons responsible for decline in the population of the Asiatic lions and suggested appropriate management recommendations. Sinha (1987) studied the ecology of wildlife with special reference to lions in the Gir and looked in detail at ranging patterns and diet of lions and also interactions with local graziers. Khan (1993) studied the ungulate-habitat governing the distribution of major ungulate species in the Gir Sanctuary and its management implication. Chellam (1993) studied the ecology and predation range of the Gir Lions. Sharma and Johnsingh (1995) studied the vegetation composition and investigated the impact of *maldharis* on vegetation and the habitat utilization by ungulates. Jhala et al. (1999) validated the use and applicability of the vibrissae spot method for individual identification and population estimation of Asiatic lions. Jhala et al. (2002) developed monitoring protocols for long term monitoring of lions and their prey population. However, there is a paucity of information on social organization of the Asiatic lions as compared to studies on African lions.

I undertook a study of the Social Organization of the Asiatic lions from April 2002 to February 2007, with special reference to the “Reproductive strategy and behaviour of male Asiatic lions”. The above aspects were addressed through conventional tracking, radio telemetry and behavioural observation.

1.10 Objectives of the study

1. To determine the population structure and social organization of Asiatic lions in the Gir Protected Area.

2. To study the home range and habitat use of Asiatic lions.

3. To assess the diet of Asiatic lions and its influence on daily activity of male lions.

4. To assess the time activity budget for male lions to get an idea on time spent on advertising territory, hunting, feeding, resting and mating.

5. To study the movement patterns of coalitions of male lions.

Chapter 2

Study Area

2.1 Location and Size

The Gir wildlife sanctuary and national park is located in the southern part of the Kathiawar peninsula, in the state of Gujarat in western India, extending across districts of Amreli and Junagadh, at 20º 57´ and 21º 20´ N latitude and 70 º 27´to 71 º 13´ longitude (Fig. 2.1). It covers an area of 1412.13 km² of which 258.17 km² comprises the National Park and 1153.42 km² comprises the Sanctuary. The forest extends about 70 km along the west to east axis and about 20 km on an average along the north to south axis. Recently the Chachai-Pania wildlife sanctuary (39.64 km^2) at the northern boundary of Gir PA has also been included as part of the Gir Conservation Unit (GCU). Additionally, there is a buffer area of Reserved forest (245.90 km^2), Protected forest (107.51 km^2) and Unclassed forest (77.19 km^2) comprising of valuable grassland and forests.

2.2 Climate

The Gir PA (hereafter referred to as 'the Gir') has a semi-arid climate with minimum and maximum temperature ranging from 5º to 47º C. The average rainfall is 900 mm but there is a precipitation gradient along the east-west axis, with eastern and western regions having an average of 633mm and 1013 mm, respectively (Fig. 2.2). The climate is semi-arid with three distinct seasons: Summer (March to mid-June), Monsoon (mid-June to mid-October) and Winter (late October to February).

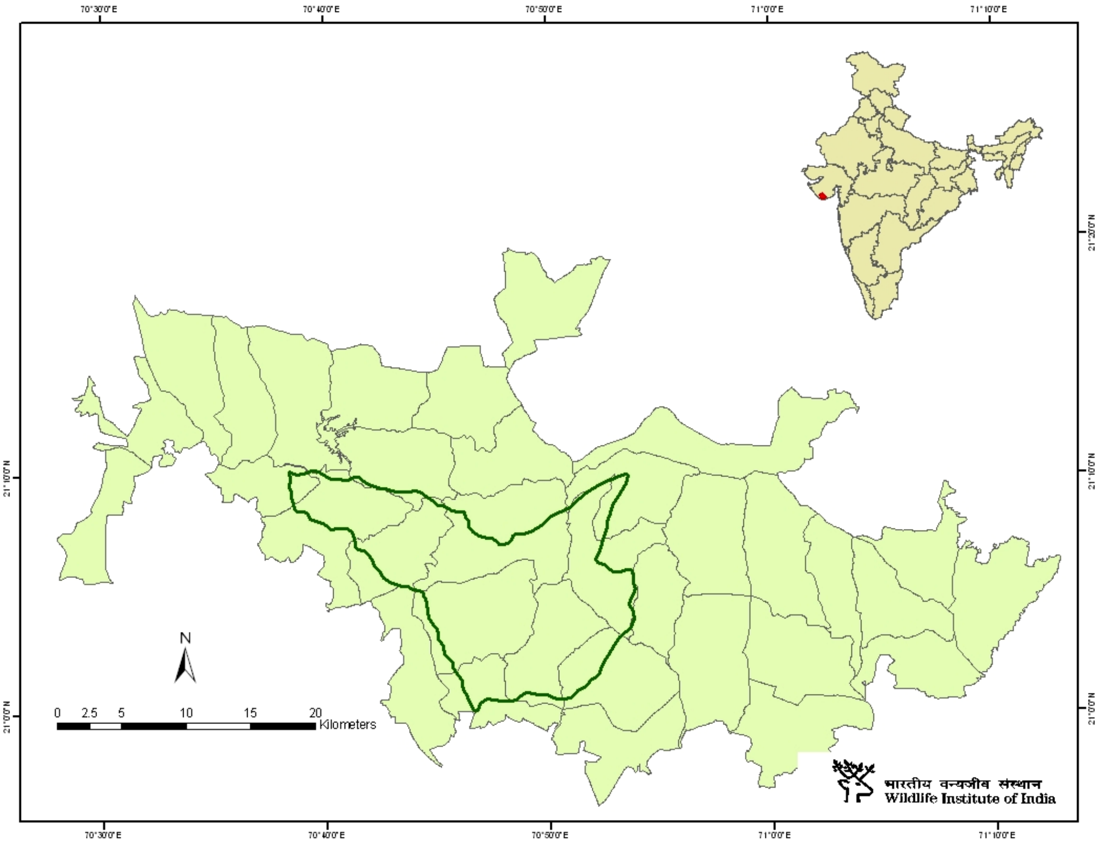


Fig. 2.1 Location of the Gir Sanctuary and National Park in north western India

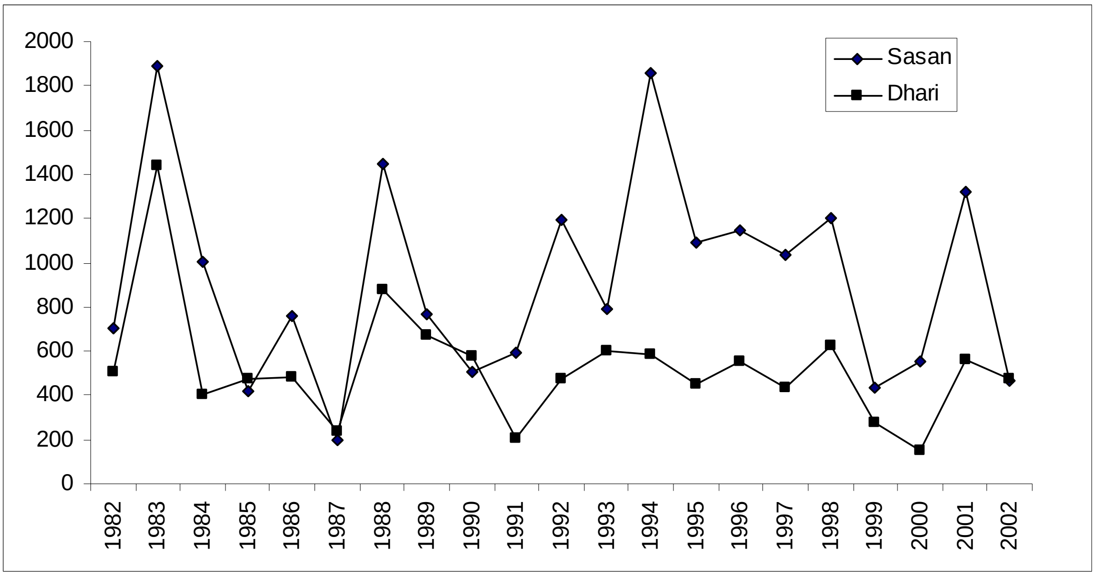


Fig. 2.2 Rainfall between the period 1982 -2002 recorded in Gir-west (Sasan-Gir) and Gir – East (Dhari) within the Gir Sanctuary and National Park

(**Source:** Pathak et al. 2002)

2.3 Topography and geology

The Gir is a series of low hills of volcanic origin with an altitudinal range of 83 -524 msl (Fig. 2.3). The protected area is surrounded by flat, arid and extensively irrigated agricultural land. The Gir has undulating terrain, varying across the park. Central part of Gir has a more hilly terrain when compared to the rest of the park. The terrain has been classified into the following categories (Chellam 1993):

Flat plain; Gentle slope ; Steep slope; Hill top; River bed; and Reservoir bed

The chief geological formation of the Gir is deccan trap occurring as acidic and basic dyke formations. While the prevailing rock is dolomite or basalt, limestone is also of common occurrence. Gneiss, quartzite, quartz and feldspar are other rocks found scattered across Gir. Soil is varying across the park and ranges from lateritic soil in much of the north and east of Gir, to black cotton soil in the southwest and along valley floors.

2.4 Drainage

The Gir is drained by seven rivers namely Hiran, Datardi, Singhoda, Machundhry, Ghodavadi, Raval and Shetrunji (Fig. 2.4). Four major reservoirs are there in Gir – Kamleswar, Shingoda, Machundri and Raval. All rivers, except Shetrunji, flow southwards and drain into the reservoirs. Numerous small seasonal streams flow through the forest. During the dry season, water is a limited resource and restricted to perennial rivers, reservoirs and deep rock pools of small streams. These natural water sources and about 250 artificial waterholes maintained by the Gujarat forest department are sources of water within the park during summer.

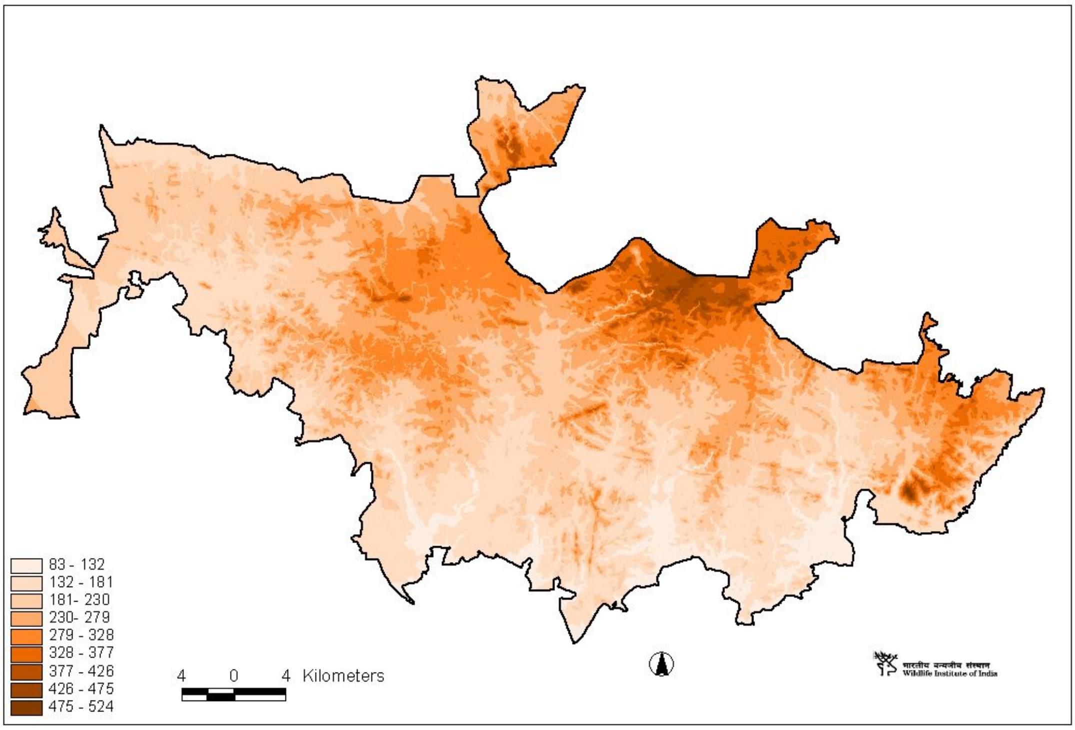


Fig. 2.3 Topography and altitudinal ranges within the Gir Protected Area

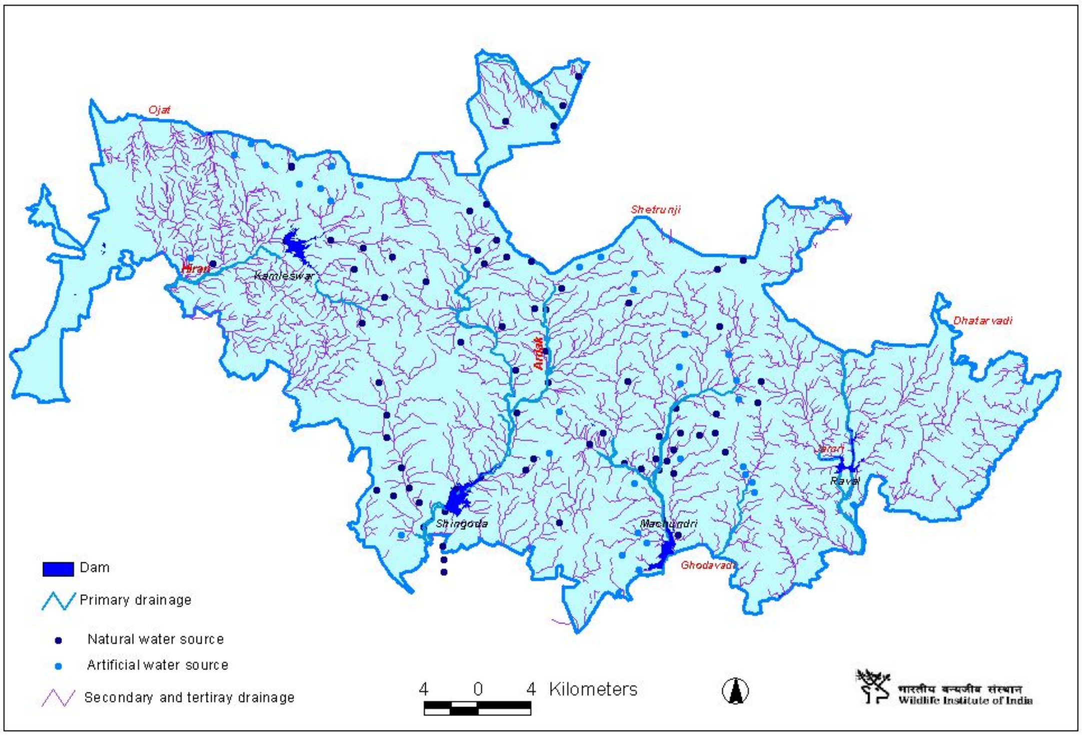


Fig. 2.4 Distribution of perennial rivers, Dams, natural and artificial water-sources within the Gir Protected Area

2.5 Fauna

The Gir forest has a diverse assemblage of wildlife. Apart from the lion, other carnivore species are leopard (*Panthera pardus*), jungle cat (*Felis chaus*), rusty spotted cat (*Felis rubiginosa*), ratel (*Mellivora capensis*), striped hyena (*Hyaena hyaena*), jackal (*Canis aureus*), Indian fox (*Vulpes bengalensis*), common mongoose (*Herpestes edwardsii*), ruddy mongoose (*Herpestes smithii*) and small Indian civet (*Viverricula indica*)

The wild prey-base for the larger carnivores comprises chital (*Axis axis*), sambar (*Cervus unicolor*), nilgai (*Boselaphus tragocamelus*), chousingha (*Tetracerus quadricornis*), chinkara (*Gazella gazelle*), wild pig (*Sus scrofa*), porcupine (*Hystrix indica*), common langur (*Semnopithecus entellus),* rufous tailed hare (*Lepus nigricollis ruficaudata*) and peafowl (*Pavo cristatus*)

2.6 Flora

The forests of the Gir fall under 5A/C1a i.e. very dry teak forests (Champion and Seth 1968). Teak occurs mixed with dry deciduous forests. Canopy is more closed in western Gir compared to eastern Gir with teak and mixed deciduous forest. The forests are classified into the following types (Singh and Kamboj 1996):

Teak Forests (Type 5A/ Cla): Nearly half of the area in Gir forests is occupied by this type. The typical overwood trees of this forest type include *Tectona grandis, Acacia catechu, Terminalia crenulata, Diospyros melanoxylon, Acacia nilotica, Phyllanthus emblica etc.* The underwood trees include *Zizyphus mauritiana, Acacia Senegal, Acacia leucophloea, Butea monosperma* etc.

Non-Teak forests (types 5/DS1 and 5/DS2): The remaining half of Gir consists of these forest types, namely very dry teak forest and dry savannah forests respectively. Teak forms less than 10% of the growing stock in these areas. The typical overwood trees include *Acacia catechu, Anogeissus latifolia, Terminalia crenulata, Diospyros melanoxylon, Acacia nilotica, Phyllanthus emblica, Lannea coromandelica, Sterculia urens* etc. The underwood trees include *Zizyphus mauritiana, Butea monosperma, Bauhinia racemosa, Barleria priontis* etc.

Riverine Forest: A distinct belt of vegetation is found along the principal rivers and streams. The typical overwood trees include of this forest type include *Syzigium cumini, Pongamia pinnata, Ficus racemosa, Ficus bengalensis, Tamirinndus indicus* etc. The typical underwood tree of this forest type is *Carissa congesta*.

Coastal Border Forest: this forest type consists of plantations of *Prosopis juliflorra* and *Casuarina equisetifolia* along the coastal belts of Una and Kodinar talukas.

The vegetation of Gir has been further classified into broad classes by various authors:

1. Eleven classes (Chellam 1993):

(i) Riverine forest
(ii) Teak forest
(iii) Acacia - Zizyphus woodland
(iv) Mixed forest
(v) Acacia woodland
(vi) Scrubland
(vii) Teak - Acacia – Zizyphus
(viii) Teak mixed forest

(ix) Teak-Acacia woodland
(x) Open land
(xi) Agricultural land

2. Three broad classes (Qureshi and Shah 2004, Fig. 2.5). This recent classification has been used in this thesis

(i) Moist mixed vegetation
(ii) Mixed forest
(iii) Thorn forest

Class	Characteristic species
Moist mixed vegetation	
Moist mixed forest	Dominant species: *Tectona grandis replaced by Anogeissus latifolia. in Gir (east)* Associates: Acacia *spp., Wrightia tinctoria, syzigium spp., Mitrragyna parviflora, Bauhinia racemosa, Diospyros melanoxylon and Emblica officionalis.* Understorey: *Acaciaspp., Zizyphus spp.,Grewia tiliaefolia, Helecteres isora, Carissa carandas, Manilkara hexandra and ixora arborea.*
Mixed forest	Dominant species: *Tectona grandis replaced by Anogeissus latifolia. in Gir (east)* Associates: *Diospyros melanoxylon, garuga pinnata, Gmelina arborea and Mallotus phillipensis.* Understorey: *Acacia spp., Zizyphus spp.,Wrighia tinctora, Grewia tiliaefolia, Helecteres isora, Carissa carandas, Manilkara hexandra and Capparis sepiaria..*
Thorn forest	
Teak –Acacia-Zizyphus	Dominant species: *Tectona grandis replaced by*

	Anogeissus latifolia. in Gir (east), Acacia catechu, Zizyphus mauritiana Associates: *Acacia spp., Zizyphus spp.,Terminalia spp.,* Understorey: *Zizyphus spp., Carissa carandas and Capparis sepiaria*
Acacia - Zizyphus	Dominant species: *Acacia spp.,Zizyphus spp.,* Understorey: *Carissa carandas and Capparis sepiaria*
Scrubland	Dominant species: *Acacia catechu, Acacia leucohloea,Zizuphus numularia* Associates: *Zizyphus spp., Capparis sepiaria and Balanites aegyptica*
Savanna	Dominant species: *Acacia spp.,Zizyphus spp.,Terminalia crenulata, Bauhinia racemosa, Tectona grandis, Anogeissus spp, Boswelia serrata and Balanites aegyptica.* Understorey grasses: *appluda mutica, Heteropogon contotus, Themeda quadrivalvis and Sehima nervosum*
Hill forest	
Acacia - Anogeissus	Dominant species: *Tectona grandis replaced by Anogeissus latifolia. in Gir (east),* Associates: *Acacia spp., Terminalia spp., Wrightia tinctora, Grewia tiliaefolia, Boswellia serrata, Flacourtia indica, Bauhinia racemosa and Zizyphus spp.,*
Acacia - Lannea - Boswellia	*Acacia spp., Lannea coromandelica, Boswellia serrata, Tectona grandis, Terminalia crenulata, Wrightia tinctora, Soyamida febrifuga and Sterculia urens*

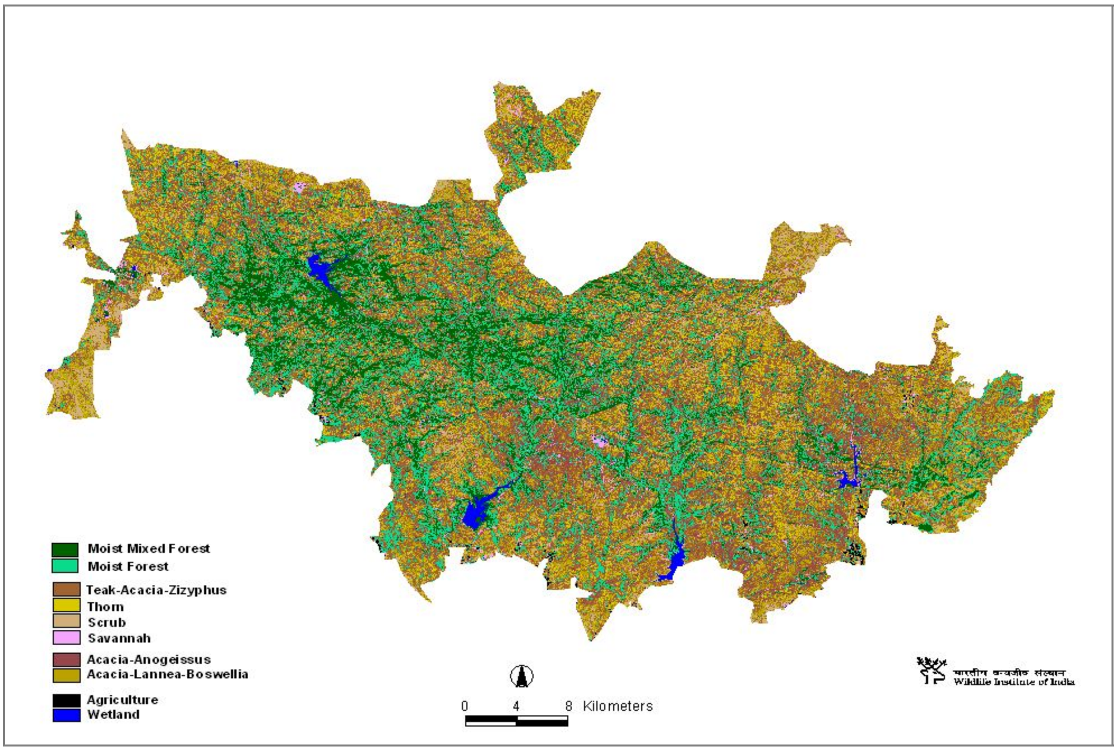


Fig. 2.5 Vegetation types of Gir Protected Area (**Source:** Qureshi and Shah 2004)

2.7 History of management:

1965	Declaration of Gir sanctuary covering an area of 1265 km^2 under Gujarat Wild Animals and Wild Birds Protection Act 1963
1972	Gir lion Sanctuary project
1975	National park area constituted
1972 - 87	Relocation of 592 *Maldhari* families

2.8 Administration

The Gir national park and sanctuary is divided into 16 ranges and 38 blocks (Fig. 2.6) managed by three deputy conservator of forests (DCF), namely two territorial divisions DCF (west), DCF (east) and the DCF (wildlife) reporting under the conservator of forest (CF), Wildlife division.

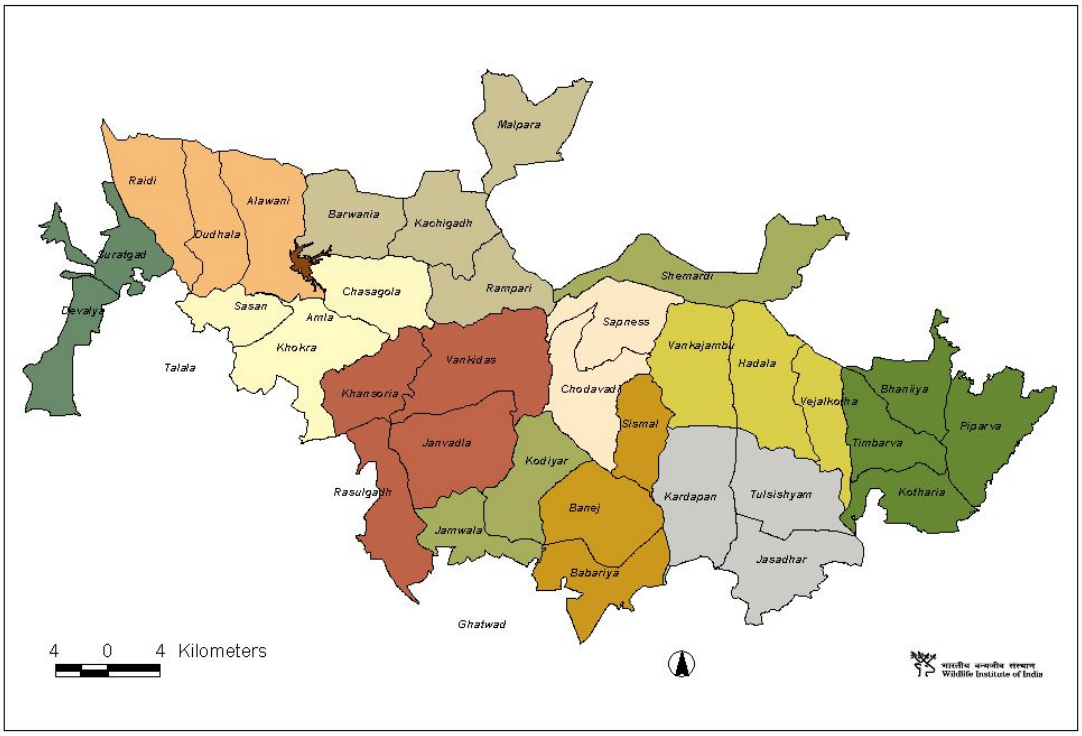


Fig. 2.6 Management Units of Gir Protected Area: Blocks are shown with boundaries and ranges in different colours

2.9 People

The economy of Gir is farm based agriculture, horticulture and animal husbandry. In recent years, in the western and southern boundary of Gir, the crop pattern has shifted from agriculture to horticulture with the introduction of kesar mangos as an important cash crop. With the replacement of intensive irrigation drought resistant traditional crops such as maize and bajra have been replaced by groundnut and sugarcane. There are 97 peripheral villages with over a lakh human population and over 90,000 livestock

The *Maldharis* are resident cattle graziers belonging to ancient tribes such as the *Charan, Bharwad, Rabari, Ahir* and *Kathi*.; over 2000 *Maldharis* with 10,000 livestock in 54 nesses across the Gir PA and about 4000 people in 14 forest settlements with a livestock of nearly 5000 are resident in the sanctuary (Fig. 2.7).

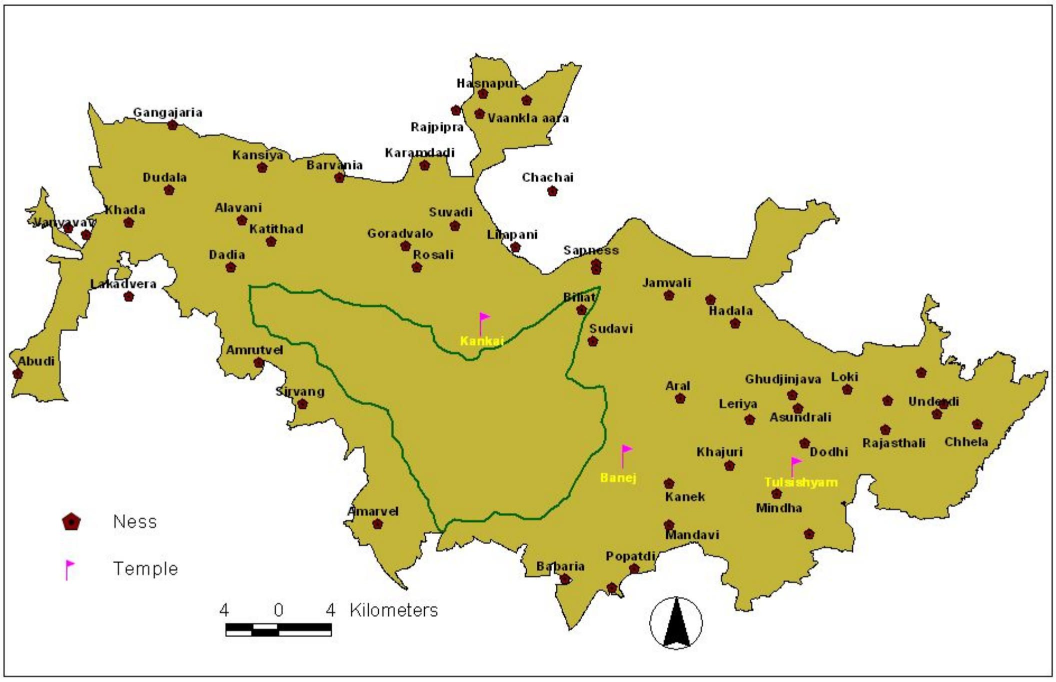


Fig. 2.7 Locations of *Ness*-sites and forest settlements within the Gir Protected Area, the boundary of the National Park within the protected area is shown

2.10 Current use of the forest

The following threats and pressures on the forest are recognized by the management:

(i) Encroachment into forest land

(ii) Grazing

(iii) Fuel wood extraction

(iv) Poaching

(v) Tourism / Pilgrimage

(vi) Collection of NTFP

(vii) Forest Fire

(viii) Natural Calamities

Fuelwood and minor forest collection and resource needs of surrounding villages and resident grazier communities exert considerable pressure on the forest. Unregulated grazing, lopping and felling of fodder trees, compaction of soil caused by livestock, unsustainable removal of topsoil along with dung for preparation and sale of manure are some of the negative impacts of Maldharis on the Gir (Berwick 1983). Temples, highways, tourism are some of the disturbances caused to the forest. An average of 95,000 tourists visit the Gir every year. There are three temples – Kankai, Banej, and Tulsishyam attracting about 2,50,000 devotees annually. The Gir is well connected and traversed by about 700 km of roads. Three highways cut across the PA and carry a heavy volume of traffic causing immense disturbance and threat to wildlife in the area.

Seasonal Changes in Gir PA

Chapter 3

Demography and Population Structure

3.1 Introduction

Monitoring wildlife populations, especially those of critically endangered species that are vulnerable to stochastic events, diseases and inbreeding depression, is crucial for the effective management and long term conservation of these species (Ogutu et al. 2006, Loveridge et al. 2001). Inbreeding can impair reproductive capacity and fitness (Smith and Mcdougal 1991). For example, the cheetah *Acinonyx jubatus*, lions *Panthera leo leo* of the Ngorongoro crater and the Asiatic lions *Panthera leo persica* of the Gir have been shown to have poor quality of sperm (O’Brien *et al*., 1986, 1987 a, 1987b, Menotti-Raymond and O’Brien 1993). They may also be vulnerable to diseases (Packer et al. 1991, Thorne and Williams 1988). Inbreeding depression is also reflected in other aspects of fitness such as effect on litter size, birth weight and early survival (Smith and Mcdougal 1991). Demographic vigour of a population is defined as its level of well-being in terms of fecundity and survival and is a measure of rate of increase of a population (Caughley 1977). The overall rate of increase of a population would have to be balanced by the rates of birth and death and which in turn would be influenced by environmental fluctuations (Caughley 1977). A healthy demographic structure would thus be defined by stable survival rates and population numbers, sex ratios that are not disparate or skewed, and with a substantial proportion of the population in the category of breeding adults in younger age groups. Genetic variability of the population is another pre-requisite for long-term survival of species. It is therefore important to assess population numbers on a regular basis, to record and monitor population fluctuations and survival rates based on rates of natality, mortality, immigration and emigration.

Abundance can be expressed as absolute density, relative density and also as total number of animals in a population (Caughley 1977). Several alternate methods of scaling and predicting carnivore densities have been used in recent works (Loveridge et al. 2001, Carbone and Gittleman 2002, Karanth et al. 2004). Traditional methods of population estimation using prescribed sampling strategies incorporating transects or quadrats are impractical for large carnivores because they usually exist in low densities, are widely dispersed, hard to detect, and exist in inaccessible areas (Ogutu et al. 2006, Stander 1998, Loveridge et al. 2001).

Total counts depend on the recognition of individuals and groups and is the tally of all known animals. Total counts are possible for small areas, conspicuous animals or when survey is conducted over a short period so as to preclude significant movement (Caughley 1977). The lion census in Gir, conducted every five years since 1968 uses this technique (Singh 1997, Singh and Kamboj 1996, Pathak et al. 2002) and involves intensive searches across all areas in which lions are located both within as well as outside the protected area. The use of baits has been abolished since 1995 and the present day census involves intensive search and location in different forest beats simultaneously during the three-day census period.

Techniques such as mark-recapture using vibrissae spot patterns (Pennycuick and Rudnai, 1970, Jhala et al. 1999, Jhala et al. 2004) and marked individuals (Smuts et al. 1977) are found to be the most reliable methods of accurately censusing lions (Loveridge et al. 2001). Indirect methods such as spoor count (pugmark) and calling stations are less intensive (Loveridge et al. 2001) but yet good alternatives. Spoor counts provide repeatable and inexpensive measures of some population parameters (Stander 1998). However, this method requires great expertise in spoor identification, meticulous and detailed measurement, and intensive sampling for greater accuracy and precision (Loveridge et al. 2001, Stander 1998). The other indirect method is the call-up method or use of calling station as a survey and monitoring technique (Ogutu and Dublin 1998). The potential variability between individuals in their response to call-up sounds and other factors however need careful consideration for this method (Loveridge et al. 2001). I have used the vibrissae spot pattern method on a sight-re-sight framework in this study for population estimation.

Lions are the only true social felids and therefore social living is expected to influence aspects of lion ecology such as population regulation, population structure, home range size and dispersal patterns. The social organization in turn, is likely to be influenced by habitat, prey abundance and to some extent also by existing management policies and anthropogenic pressures. In the case of lions, a stable social system is also a very important determinant of cub recruitment (Packer and Pusey 1983). Stable and sustained male coalition tenure of greater than three years would be required to ensure survival of litters up to dispersal age (Packer and Pusey 1983).

3.2 Asiatic lion: Conservation Status and Conflict Issues

The Asiatic lions have the classic qualities of a critically endangered species being a single population existing in low numbers with a low founding population. Today the only living representatives of the lions once found throughout much of South-West Asia occur in India's Gir Forest (Nowell and Jackson 1996). This population of the Asiatic lion, *Panthera leo persica*, is classified as Critically Endangered (CR C2a(ii)) (IUCN 2000) and is also categorized as endangered under Schedule I of the Wild Life Protection Act (1972) of India. In the past, Asiatic lions experienced a genetic bottleneck but were resurrected from the brink of extinction by timely conservation practices. In recent years, they have shown a steady increase in population numbers. However, the Gir lions have markedly less allozyme, mitochondrial and nuclear DNA heterozygosity compared to the African lions (O'Brien *et al.* 1987b). They were found to be monomorphic and the males were observed to have low sperm viability and testosterone levels (O'Brien *et al.* 1987 b). Later studies have shown that Asiatic lions exhibit higher degrees of polymorphism than previously reported (Shankaranarayan et al. 1997). However, since they exist as a single, isolated population they maybe are yet susceptible to inbreeding depression (Shankaranarayan et al. 1997)

Management interventions in the last 20-25 years such as relocation of the local graziers, the *Maldharis*, reduction in livestock grazing and control of fire have led to vegetation recovery and increase in wild ungulate population (Berwick and Jordan 1971, Khan et al. 1995). Consequently, there has been a change in the proportion of uptake of domestic livestock in the lions' diet (Joslin 1972, Chellam 1993).

The lion population has shown a steady increase in the past two decades (Wynter Blyth and Dharmakumarsinhji 1950, Wynter Blyth 1956, Singh 1997, Gujarat Forest department census reports, Fig. 3.1). The Gir today has a very high-density carnivore (lion and leopard) population. In recent years, lions have started dispersing out of the Gir PA and taken permanent residence in certain areas outside the PA (Protected Area) boundaries. These peripheral populations have been recorded in Girnar, coastal areas, and the hill ranges extending from Mitiyala to Savarkundala along Shetrunji river (Singh 1997). The 2005 census has estimated a population of 68 in these areas (Gujarat Forest department census report 2005).

The Gir is also impacted by a growing human population: There are 97 peripheral villages with over 1,00,000 human population and over 90,000 livestock. There are over 2000 *Maldharis* with 10,000 livestock in 54 nesses are resident within the Gir PA and an additional 14 forest settlements of over 4000 people with nearly 5000 livestock are also resident within the PA (Pathak et al. 2002).

The increase in wild prey and predators in Gir PA and the impacts of a growing human population have resulted in increasing incidences of human-animal conflict. On the one hand, changes in cropping pattern and the substantial increase in sugarcane, groundnut and mango cultivation around Gir has resulted in an increase in crop damage incidences by wild ungulates (Vijayan and Pati 2000) and on the other, there has been an increase in human-carnivore encounters. During the period 1978-1991 there was an average of 14.8 lion attacks and 2.2 lion-caused human deaths annually with 82% incidents occurring outside the PA (Saberwal et al. 1994). Lion attacks on people had escalated during a severe drought in 1987 and 1988 (Saberwal et al. 1994). During the period 1995 – 2003, numerous attacks on people by lions and leopards have been reported around the Gir PA (Pathak et al 2002). During this period, 265 cases of attacks on humans by carnivores (Fig. 3.1-3.2) have been recorded, amounting to an average of 34 cases per year. Of these incidents, 79.6% of these attacks have been in the peripheral areas of the park (Pathak et al 2002). In this time period, the number of rescued animals (disease, injury and rescue and relocations from open wells and habitations) by the Gujarat forest department has also been high (Fig. 3.3) - averaging 24 and 30 per year for lions and leopards, respectively (Pathak et al 2002). Thus, although the Gir is a compact and continuous stretch of forest, it is subject to severe anthropogenic pressures and in turn the growing wild animal populations impact on the surrounding human habitations.

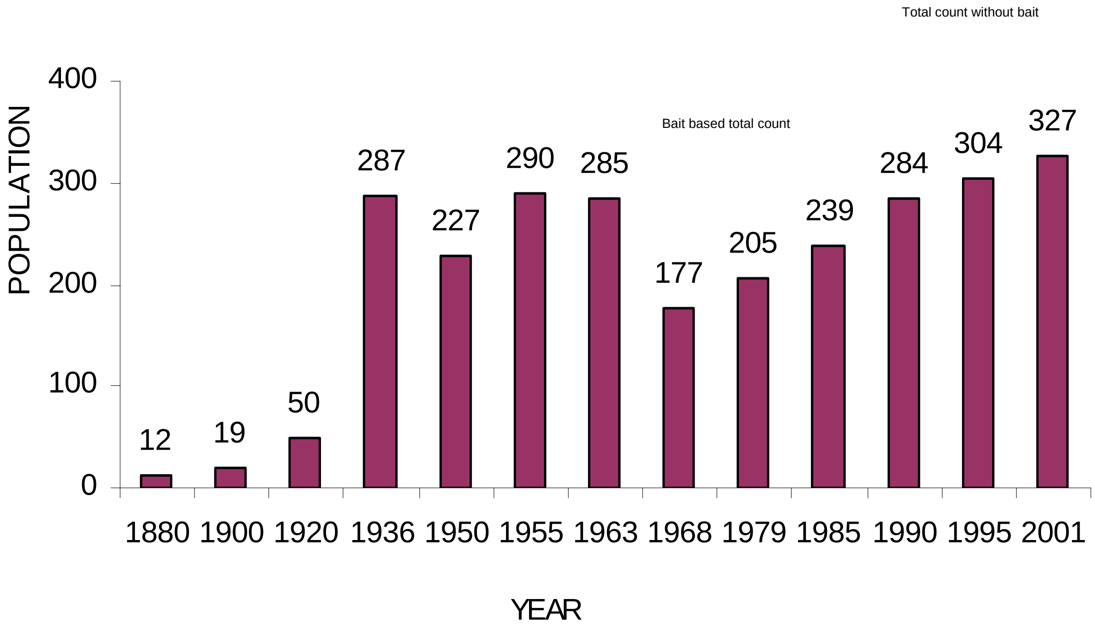


Fig. 3.1 Past population estimates of Asiatic lion (Singh and Kamboj 1996)

Table 3.1 Lion Population Estimate based on 2005 lion census(Gujarat Forest Department data 2005*)*

Region	**Area[*] (km^2)**	**Adult Male**	**Adult Female**	**Sub-Adult**	**Cub**	**Total**
Gir PA & adjoining areas	1800	68	100	61	62	291
Girnar Forest	179.5	05	05	05	02	17
Una, Kodinar, Sutrapada, Coastal area	110	07	05	0	0	12
Mitiyala Sanctuary, Savarkundla, Liliya Taluka, adjoining area of Bhavnagar District	19.4	09	14	06	10	39
Total		**89**	**124**	**72**	**74**	**359**
Devaliya Interpretation Zone	14	01	04	03	03	11

*Source: Pathak et al 2002

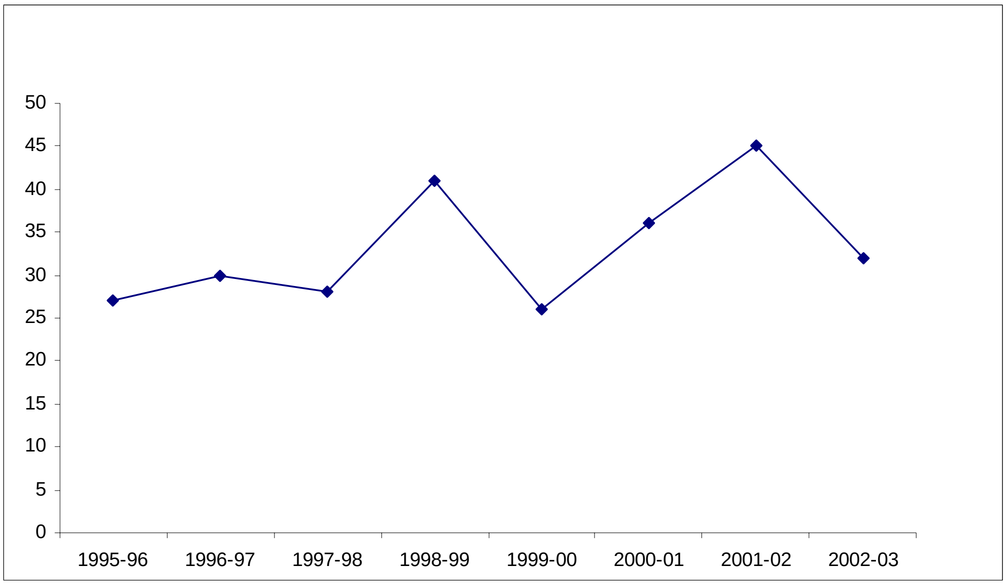


Fig. 3.2 Incidence of human injury by lion and leopard in Gir

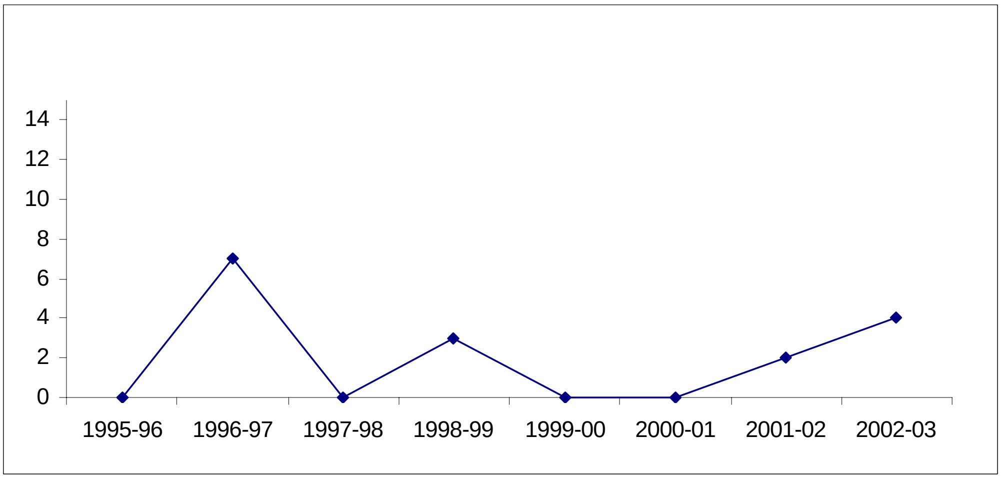


Fig. 3.3 Incidence of human mortality caused by lion and leopard in Gir

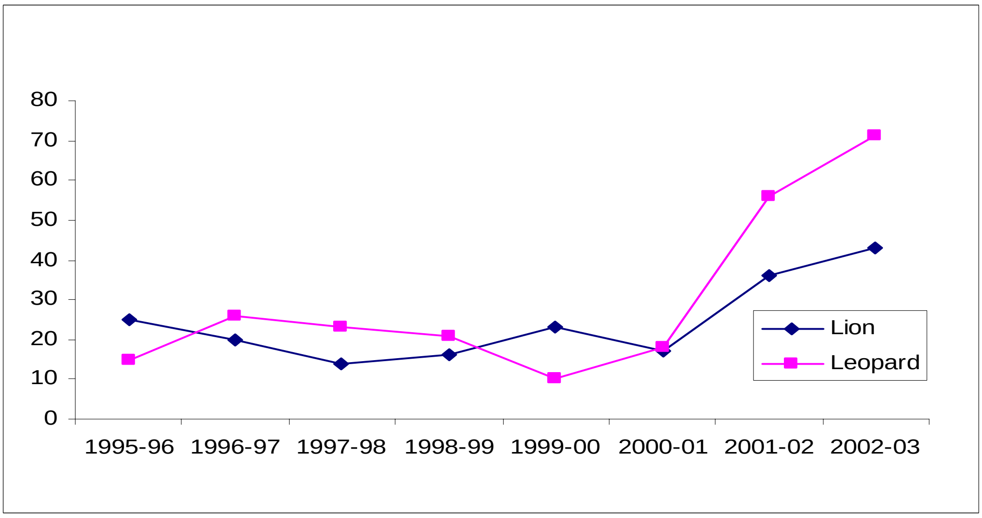


Fig. 3.4 Carnivore rescue operation undertaken by management in Gir

3.3 Objectives

High carnivore density, low genetic variability of lions, limited size of the Gir PA, fluctuating prey base, increased anthropogenic pressures should be the determinants of lion demography and demographic changes (birth, population sex ratio, survival and mortality) of lions in Gir PA. This chapter looks at the population estimate and density of Asiatic lions in the Gir PA. It also covers aspects of social organization, population structure and demographic information on survival, seasonality of reproduction and mortality factors.

The main objectives of this study were:

- To estimate the population size and density of Asiatic lions in the Sanctuary West and National Park areas of the Gir PA
- To record demographic changes in the lion population during the study period from April 2002 to February 2007.

3.4 Methods

Most data has been collected from intensive search and location of lions in west and central Gir from April 2002 to January 2007. Vocalization, prey alarm calls, lion-kills, pugmarks and other cues were used to track lions.

All sightings include the record of location, sex, age-category and activity of the lions. A Garmin® eTrex hand-held GPS (Garmin International Inc, Kansas, USA) was used to record the coordinates of lion sightings. Lions were classified under six age-categories based on condition of canines, body condition and colour. The categories were - small cubs (<1 year), large cubs (1 to 2 years), sub adults (2 to 4 years), prime-young (4 to 7 years), prime-old (7 to 9 years), old (>9 years) (Schaller 1972, Jhala et al. 2004).

Detailed description and identification of animals based on distinct body markings and vibrissae spot pattern method (Pennycuick and Rudnai 1970) were maintained for lions located in the intensive study area. A Bushnell® 20-60× spotting scope was used for making detailed observations.

Incomplete data due to limited visibility, skittish or aggressive nature of lions, were not used for analysis. Profiles of individual animals (Appendix II) based on repeated sightings have been maintained for the record of movement, survival, demographic events and activity and behaviour of the lions in the study area. All births and mortality events were recorded as far as possible due to a rigorous field monitoring schedule combined with good exchange of information with the park authorities and their lion-rescue and monitoring crew within the intensive study area.

3.5 Data Analysis

3.5.1 Encounter rate

Encounter rates (search index), for locations between the years, 2002 – 2004, were calculated as sighting per search effort. The search hours have been considered from the time of entering the forest and include both time spent driving the forest roads and also the tracking on foot for each sighting. Group sighting were considered as a single sighting. The question was: what was the required (random) search effort to locate a lion in different seasons?

3.5.2 Population and density

The density of the lions in the study area was estimated as the population size divided by effective sampled area. Appropriate statistical models using sight–resight population estimation method were used (Jhala et al. 2004) in order to overcome the confounding effects of season, time of day, inter-observer variation, weather and habitat in estimation of population by the estimation of detection probability (Efford et al. 2004). Two different models, namely POPAN for population estimation of the entire area and a more refined model, Pollock robust design was chosen for comparing the two management units of the PA. For the latter analysis, the data was more conducive to consider immigration, emigration, birth and death.

Effective sampled area: Effective sampled area was estimated by area of the polygon connecting the outermost lion locations and a buffer width ($\hat{W}$) estimated as half the mean distance moved (1/2 MMDM) by recaptured lions (Karanth and Nichols 1998). The Estimated density ($\check{D}$) was calculated using the relation $\check{D} = N / (A (\hat{W}))$ (Karanth and Nichols 1998).

Population estimate: Population estimate for the intensive study area was analysed using Jolly-Seber models with POPAN formulation using computer software program MARK (2002). The POPAN formulation considers estimates of p (probability of detection), phi (probability of survival), b (birth) and N (total number of lions in the study population) and derives the N-hat value which is the estimated population. Thus, this model considers the abundance, net birth and population growth. The model selection procedure of MARK selected the model which assumes time varying p and constant phi, pent (probability of entering the population), and N parameters.

Unique individuals were identified from all lion sightings based on individual identification profiles. Re-sightings were obtained for two seasons, summer and winter, surveyed across the years from 2002 to 2005. The capture histories of individual lions, for a total of eight sessions were then put in the standard X-matrix format (Otis et al. 1978). These data were subjected to further analysis using POPAN formulation of Program MARK.

A comparison of lion densities for two park areas (Fig. 3.5) was also estimated using the Pollock's robust estimate model. Unique individuals were identified from all lion sightings based on individual identification profiles. Re-sightings were obtained for each month surveyed across the years from 2002 to 2005. Accumulation of new sightings for each month in a year were plotted to obtain the saturation of total individuals sighted. The capture histories of individual lions, for a total of eight sessions were then put in the standard X-matrix format. Pollock's robust design with Huggins heterogeneity design was run on Program MARK 4.3 (White 2002) to obtain population estimates. Four primary occasions were chosen for the four-year study period. Based on the preliminary analysis, all individual sightings from January to June were considered as secondary occasions and a presence-absence matrix was obtained. The best model fit for the above analysis was M_0 that considers constant probability of capture. The results were scrutinized for further interpretation.

3.5.3 Population structure, sex ratio, group composition and group size

Lion sightings for each year were scrutinized for recaptures from the lion reference sheets (Appendix II). The recaptures were excluded and proportion of individuals in each age-class was calculated. The data was similarly analyzed to arrive at sex ratio, cub to female ratio, male-female associations. Group sizes were calculated as the average number of adult in prides and coalitions including sub-adults. Dependent cubs in prides were not considered for group size calculation (Joslin 1973). Male-female groups were classified as mating pairs, associations sharing kills and those moving or resting together. Litter size was calculated from the time when became visible (approximately two weeks).

3.5.4 Seasonality of mating and birth

Seasonality in reproductive activity was evaluated from records of incidences of mating events made during intensive searches and opportunistic observations. The proportion of mating episodes occurring in different parts of the year was calculated and represented graphically. Based on age of cubs at time of sighting, the month of birth was estimated. The proportion of cubs born in different time of year was then calculated.

3.5.5 Mortality and Survival

All lion mortality incidents encountered were recorded and corroborated with data obtained from the Gujarat Forest Department records. The records were also used for analysis of magnitude and causes of mortality for the entire park. A total of thirty-two cubs in fifteen litters of twelve regularly monitored females in the intensive study area were used to calculate litter sizes and cub survival. Of the females monitored, three were radio-collared. Annual survival and cause specific mortality was calculated using the program MICROMORT (Heisey and Fuller 1985).

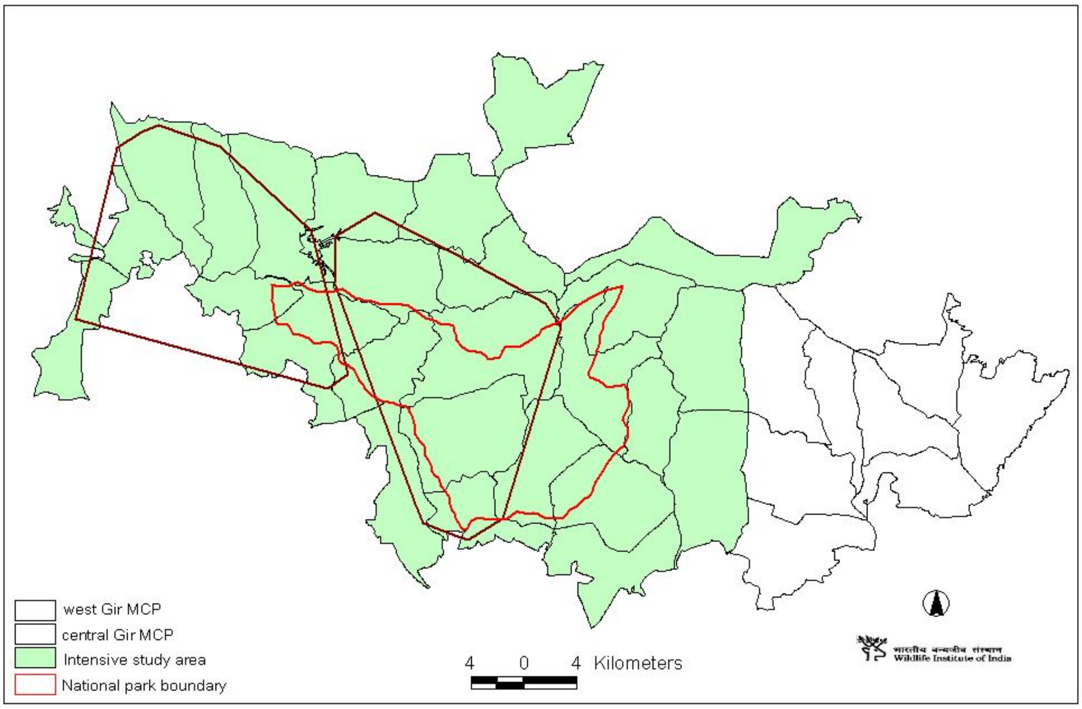


Fig. 3.5: The intensive study area within the Gir Protected Area is highlighted along with the National Park and administrative block boundaries. The minimum convex polygons (MCP) obtained by joining the outermost locations of lions for population estimation are shown

3.6 Results

A total of 819 independent sightings during the period between 2002 and 2005, covering a total area of 1075 km^2 were considered for analysis. Surveys conducted in Gir-East, data of 2006 and data based on radio-telemetry were excluded for this analysis. Identification profiles for 112 individuals were prepared during the study period.

3.6.1 Encounter rate

Encounter rates were calculated based on data collected over 848 search hours from May 2002 to June 2004. Encounter rates differed between monsoon and winter season (One way ANOVA, F = 4.65, df = 2, P = 0.011). Mean encounter rates were much lower for the monsoon season and significantly lower than winter encounter rates. Summer encounter rates were comparable with both winter and monsoon sightings (Table 3).

Table 3.2: Multiple Comparison test of mean encounter rates of lions for summer, monsoon and winter seasons (Duncan's multiple–comparison test, α = 0.05, df = 146, Mean Standard Error = 0.02)

Monsoon	Summer	Winter
0.115*	0.147	0.203*

Note: * denotes that pairwise comparison of means between monsoon and winter showed them to be significantly different.

3.6.2 Population number and density

Population estimate for intensive study area:

Effective sampled area: 872 km^2

N-hat (S.E. and 95% Cl): 121 (2.01, 117 – 125, N = 112)

MMDM & variance (d): 8.66 (1.2 E-16)
Buffer width& variance (W): 4.33 (2.9E-17)

Density (SE) of lions in intensive study area: 10 (0.14) / 100 km^2

Table 3.3: Population Estimate for Gir-west and central Gir based on Pollock's robust design with Huggins heterogeneity (Program MARK)

Park area	Session (2002 -2004)	Effective sample size (N)	M(t +1)	Abundance	SE	CI (95%)
Gir (west)		216				
	1		31	36	4.61	31.9 – 54.5
	2		32	32	0.40	32.0 – 34.6
	3		24	26	2.00	24.3 – 34.3
	4		19	20	1.59	19.1 – 27.7

Park area	Session (2002 -2004)	Effective sample size (N)	M(t +1)	Abundance	SE	CI (95%)
		Average Estimate		**29**		
Central Gir		107				
	1		19	27	10.5	20.0 – 76.0
	2		22	23	1.5	22.2 – 30.4
	3		13	14	1.8	13.1 – 22.9
	4		11	13	2.4	11.1 – 24.8
		Average Estimate		**20**		

Effective sampled area in Gir (west) = 264 km²

Effective sampled area in central Gir = 399 km²

3.6.3 Age-Sex Composition

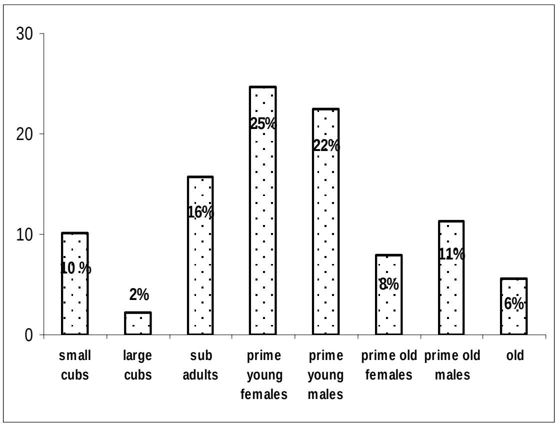


Fig.3.6a: 2002

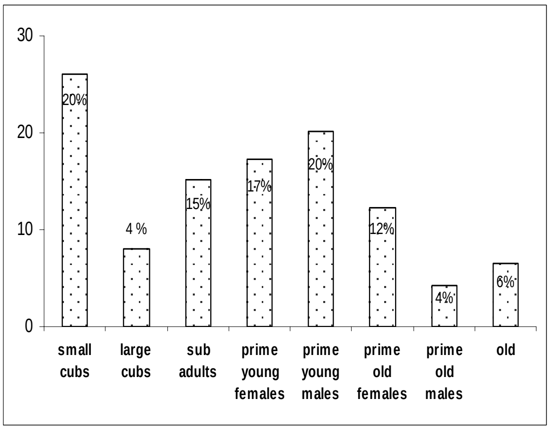


Fig.3.6b: 2003

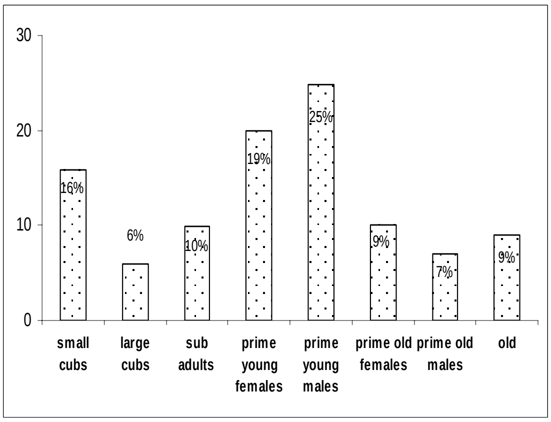


Fig. 3.6c: 2004

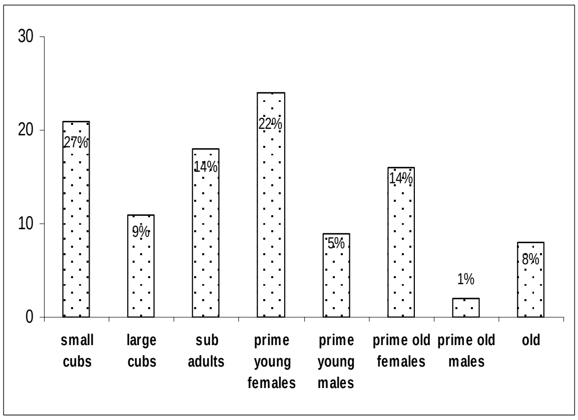


Fig.3.6d: 2005

Fig. 3.6 Age and sex composition of the lion population in Gir- west and National park based on ad libitum sighting and visual estimation of age categories for four year period between 2002 to 2005.

AGE-CLASS	2002	2003	2004	2005
N (Number of uniquely identified individual lions and their associated young)	**89**	**139**	**102**	**109**
Total Sightings	**117**	**246**	**314**	**142**

3.6.4 Social Organization

The adult sex ratio was 76.4:100 females. The ratio of cubs to adult female ratio was 50:100 females. The average litter size was 2.13 ± 0.83 (N = 32). Males did not associate with females and tended to move and feed independently. Only 11.7 % of total sightings (n = 521) were male-female associations (N= 61) of these 67.2% were mating pairs, 16.4 % associations on kills and 16.4% were seen resting or moving together. The group sizes were low and largely consisted of like-sexed pairs. Average group size of males was 1.4 ± 0.50 (1-3, n=283) while average female group size (excluding cubs) was 1.3 ± 0.53 (1-4, n =291). Mating and cub birth did not show sharp seasonality. Mating occurred largely between January (late winter) and June (end summer) (Fig. 3.7). Cub birth showed a winter and monsoon peak (Fig. 3.8).

3.6.5 Seasonality of Mating and Birth

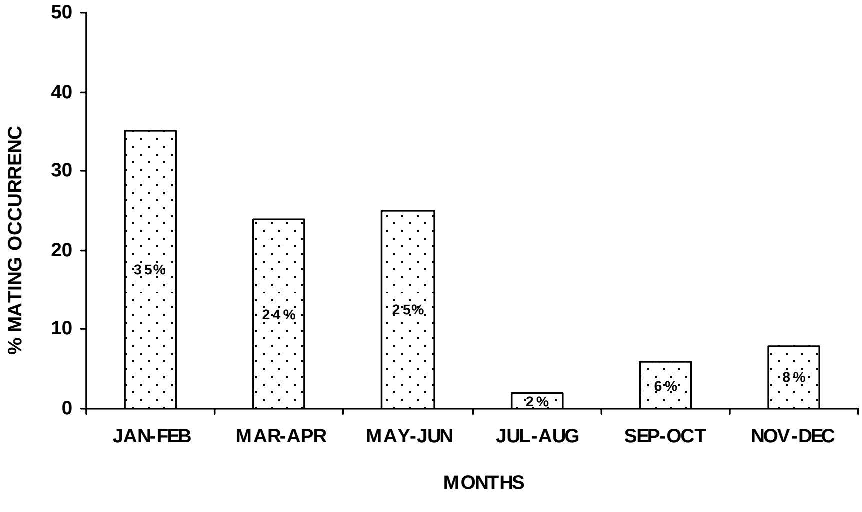


Fig. 3.7: Seasonality and record of mating events (N=51) of lions in Gir- west and National park between 2002 to 2006.

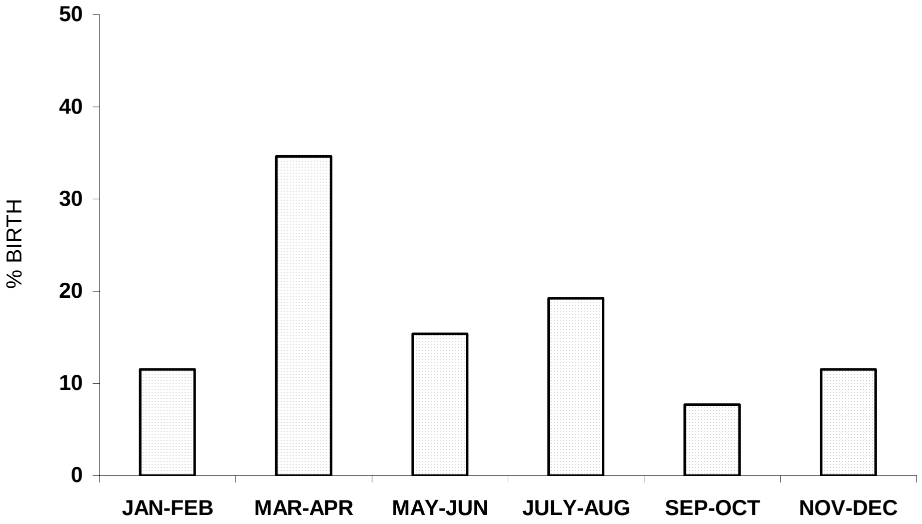


Fig. 3.8: Seasonality and record of lion cub birth corrected to time of birth from the day of sighting in Gir- west and National park between 2002 to 2006. (N=26)

3.6.6 Cub Survival and recruitment

Mortality of cubs immediately after birth (till about two months) could not be ascertained with certainty because observations were difficult to make. Hence survival rates have been calculated from two months of age when cubs became visible for monitoring purposes. Cub survival was monitored for 32 cubs in 15 litters of 12 females. Cubs did not die due to accidents. Causes of mortality within the intensive study area were classified into two categories: (i) infanticide by adult males and (ii) Other factors such as rejection by mother, diseases and injury. The results revealed that there was 69% cub survival in the first year. Cub survival from small-cub to large-cub stage (one to two years) and from large cub to sub-adult stage was 87% and 93% respectively. However, the overall survival up to recruitment or sub adult stage i.e. 3 years was 56% (Table 3.4).

Table 3.4: Estimates of survival and mortality of lion cubs from two month to sub adult (three years) stage in Gir PA.

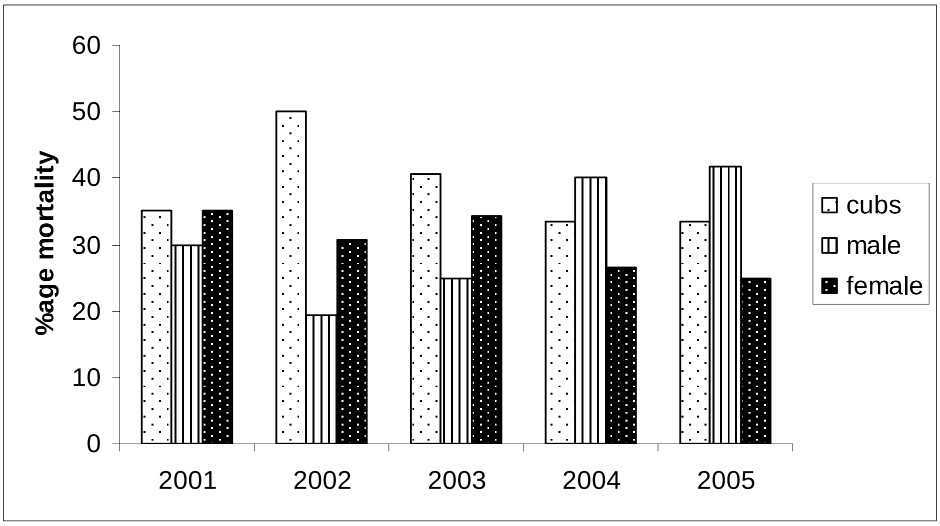
Survival Parameter	**Rate**	**95 % Cl**	
		Lower	**Upper**
Survival from two months to 1 year	0.69	0.556	0.871
Survival from Year 1 to Year 2	0.872	0.748	1.000
Survival Year 2 to Year 3	0.931	0.811	1.0
Overall survival from cub up to recruitment age	0.56	0.417	0.768
Mortality rates (*Cub to 1 Year*)			
1. Infanticide	0.24	0.097	0.389
2. Other causes	0.60	0	0.14
Mortality rates *(Year 1 to Year 2)*			
1. Infanticide	0.0423	0	0.13
2. Other causes	0.0847	0	0.197
Mortality rates *(Year 2 to Year 3)*			
1. Infanticide	0		
2. Other causes	0.681	0	0.19

3.6.7 Mortality and adult survival

Adult survival and cause-specific mortality, excluding cubs, was analysed for five years for twenty known individuals in the intensive study area. Overall survival for adults was nearly 92% because specific mortality (natural and accidents) for adults was negligible in the 2002 and 2006 year. The survival rate (CI) for the 2003, 2004 and 2005 year was 89% (76 -100), 87% (72 -100) and 85% (70-100) respectively. The adult annual survival rate was 0.922 ± 0.07.

According to Gujarat Forest Department records, a total of 71 deaths of adults and cubs occurred in the five year period (2001 – 2005) in the entire Gir PA (Fig. 3.9).

The data showed that the causes of mortality varied within and outside the PA boundaries indicating higher incidences of accidents outside the park (Fig. 3.10).



YEAR	Cubs (N)	Male (N)	Female (N)
2001	**7**	**6**	**7**
2002	**13**	**5**	**8**
2003	**13**	**8**	**11**
2004	**5**	**6**	**4**
2005	**8**	**10**	**6**

Fig. 3.9: Cub and adult (male and female) mortality records in Gir PA for five year period between 2001 to 2005

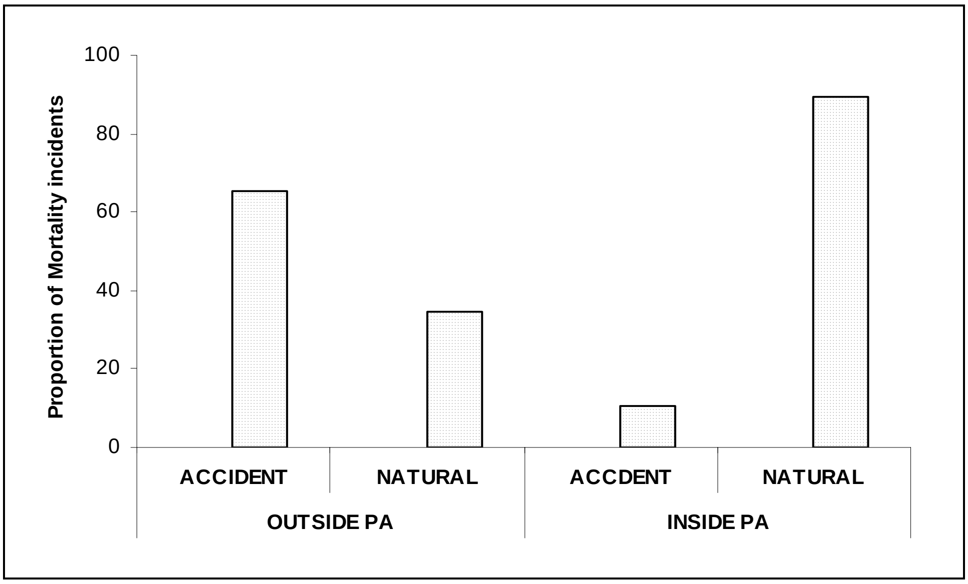


Fig. 3.10: Comparison of causes of mortality of adult lions within and outside Gir PA for five year period between 2001 to 2005 (N=71)

3.7 Discussion

The intensive study area had covered over 75% of the Gir sanctuary and National Park and included the study of about 67% of the adult population of the Gir PA (Table 3.1).The population estimate of adult lions in the intensive study area falling in west and central Gir was about 120 individuals.

Seasonal changes in Gir are marked and therefore lion encounter rates showed significant variation between monsoon and winter season (Table 3.2). During summer, the forest is open following shedding of teak leaves, water sources are localized and therefore lion movement is limited around water sources. During monsoon the grass cover is high, visibility is low and encounter of lions in the *riverine* and forest areas are rarer and greater in the relatively open hillocks. During the winter season there is fairly good visibility but water sources are widespread and lion movement is also extensive.

Density of lions was high (10 lions per 100 km^2) and varied between park areas owing to differences in habitat, terrain and prey availability. Lion densities are highly varied across different lion populations of Africa (Chardonnet 2002). High density areas have between 20 – 40 lions per 100 km^2; medium density areas have 5.0 to 9.4 lions per 100 km^2; while low density areas have 0.2 to 0.8 lions per 100 km^2(Chardonnet 2002). In comparison, the Gir lions fit in between high and medium density areas.

The demographic data revealed a greater proportion of the population in the prime reproductive age class (Fig. 3.6 a–d). As expected the age-sex composition did not vary drastically between years. However, a noticeable spurt of births has occurred in alternate years, namely in 2003 and 2005. The cub to female ratio was 50:100 with an average litter size of two cubs.

The relative proportions of male coalitions and female prides are very important aspects determining social structuring and cub survival in lions (Loveridge and Macdonald 2002, Cooper 1991). Fewer male coalitions in relation to prides, would result in extensive, unrestrained movement of male lions between prides (Loveridge and Macdonald 2002) and also in making the prides more vulnerable to infanticide males (Cooper 1991). The sex ratios showed a marginally higher proportion of females to males. Almost all lion populations show a slight bias towards females and have an adult population sex ratio of 1:2 (Schaller 1972; Mills et al. 1978; Packer et al. 1988; Stander 1991; Creel and Creel 1997). However, in area where selective hunting of male lions occur, the sex ratios are skewed in favour of females and varies from 1 male: 4 females in Zambia (Yamazaki 1996), 1male: 5.7 females in Botswana (Cooper 1991) or 1:6 in Zimbabwe (Loveridge 2007).

Group sizes are highly varied in different African lion populations. The average group size varies from 4.2 in Etosha National Park (Stander 1991) to 22.0 in Masai Mara National park (Ogutu and Dublin 2002). The average female group size varied from 3.4 in Selous Game Reserve (Spong 2002) to 9.4 in Masai Mara National Park (Ogutu and Dublin 2002). In Gir, the average group sizes were low – female group size was 1.3 (n=291, range 1 – 4) and male group size was 1.4 (n=283, range 1–3).

Group size indicates prey abundance and determines the size of prey consumed (Eloff 1973, Stander 1991, Chellam 1993). Prey density is a key determinant of large felid abundance (Karanth et al. 2004). Lion density has a positive linear correlation with prey abundance (van Orsdol et al. 1985, Carbone and Gittleman 2002). Groups of two to three gain highest rates of food intake per day (Coraco and Wolf 1975). However, contradicting results from the Serengeti suggests that lions do not forage in groups that optimize foraging success (Packer et al. 1990) implying that cooperative hunting is a consequence rather than a cause of sociality (Packer and Ruttan 1988). Yet, in majority of areas it has been observed that hunting success of lions increases linearly with group size and group hunting is necessary for capturing large prey (Stander 1991, Caraco and Wolf 1975, Schaller 1972). Group hunting has been implied for hunting success and capturing large prey and increasing linearly with group size (Stander 1991, Caraco and Wolf 1975, Schaller 1972).

In areas where small to medium sized prey are consumed, such as in the Kalahari, lions exist in small group sizes or are solitary (Eloff 1973). In Etosha, lion group sizes fluctuate seasonally with respect to changes in prey availability (Stander 1991). The optimum foraging group size is a pair of lions for prey <50 kg available during dry season whereas, in wet season higher density of wild prey resulted in larger hunting groups (Stander 1991). In the case of open areas with seasonal migratory prey, lions adapt to fluctuations in prey biomass as well as absence of preferred prey during some periods of the year (Hanby et al. 1995). Prey selection varies between sexes where the male-female social bonding is weak, with females preferring medium sized prey and males going for larger sized prey (Funston 1992, Scheel and Packer 1995). The small group size of the Asiatic lion has also been ascertained to the small size of the most abundant prey (chital) however they do form larger groups in areas where livestock forms a major part of the diet.

The lions in the relatively open Gir (east) area, where there are greater number of nesses and a greater dependency of lions on livestock, lions are known to form bigger groups. I did surveys in the area and located 91 individuals in 9 groups. A mixed group consisted of 2 adult males and 4 adult females. Female groups ranged from 2–6 while two male coalitions were seen on two occasions. It is also true that two or three groups that are concentrated around nesses in Gir (east) are in bigger groups and as one moves away from the cluster of nesses big (>4) lion groups are rarer. Thus, where large-size prey, such as livestock forms the staple diet, larger lion groups can be sustained.

Based on the above observation, it is further possible that in the undulating areas of Girnar, Mitiyala and hills north-west of Gir extending towards Shihor and Bhavnagar areas, lion social structure will be different from the Gir PA and also to that of the coastal lions that live very close to human habitation and under the sparse cover of *Prosopis* forests.

In Gir, group sizes have been reported by two studies and interestingly there appears to be a change in the social system of lions over the years. A comparison of group sizes of lions in the past three decades reveals a trend towards formation of smaller groups. Joslin (1973) reported average female group sizes to be 2.1 (n=58, range 1–11) and average male group size to be 1.6 (n=58, range 1–4). Ravi Chellam (1993) reported average female group-size to be 4.5 (n=109, range 1–11) and the average male group size to be 2.2 (n=72, range 1–5).

Male-female associations are found to be very weak and the sexes largely interacted for the purpose of mating. Fitness and reproductive rate and cub survival are known to be related to pride size (Packer et al.1988, Grinnell and Mckomb 1996). In Gir, females form small associations of 2–3 individuals that are, most often than not, mother–daughter pairs (Pers. obs). During mating, the female dissociates from the pride, consorts with the male during entire mating period and then rejoins the pride. Several mating incidences were recorded when there were new incoming males. However, the actual mating episodes that translated to cub birth could not be identified and the spurt of mating following the establishment of new territorial males maybe considered acts of subordination on the part of the females. There does not appear to be sharp seasonal mating peaks. Most mating episodes seem to occur between January and May as the season turns from winter to summer.

Cub birth also showed a pre-summer and a monsoon peak that did not actually synchronize with the mating episodes. Infanticide was high during the first year of birth and responsible for 27% of overall cub mortality. Other factors such as nutrition, disease and accidents were responsible for 16% overall mortality.

Following cub birth, the sub adults or young female daughters (N = 3) of previous litters have been observed on several occasions to stay back and protect the cubs while the adult female goes out to hunt (Pers. obs). The older female cubs have also been observed on three occasions to actively resist attacks by male lions (Pers. obs).

Females in the study area resumed mating when the cubs reached two years of age and became independent (N = 4) and female cubs started mating after they reached two years of age (N = 3). In Kruger in comparison, the age of first reproduction varied from 3–5 years of age (Funston et al. 2003). After the loss of a cub due to infanticide one of the radio-collared females came into oestrous and resumed mating two months following the loss (infanticide occurred on 26 April 2002 and mating recorded on 29 June 2002). The average inter-birth interval of 24 months was comparable to that of Serengeti lions (Packer and Pusey 1987) where cub mortality in the first year was high due to infanticide by males and starvation resulting in only 33% of cub survival (Schaller 1972, Bertram 1975) and corresponded with food availability in seasonal areas (van Orsdol 1981). In Kruger, the annual survival rate of cubs up to 12 months of age was 84%; of large cubs was 89% and survival up to sub-adult stage was 91% (Funston et al. 2003). Due to low levels of mortality in the juvenile-age class, the inter-birth interval was much longer and was about 40 months in this case (Funston et al. 2003). Adult mortality within the park was low and was largely due to natural causes. However, outside the PA boundaries lions were prone to accidents.

3.8 Conclusion

The Asiatic lions within the Gir PA consist of a growing population of lions, existing in high densities but however restricted and limited by the size of the PA. This study also shows that causes of mortality vary within and outside the PA boundaries. A minimum of 15 adult lion deaths per year occurs and this loss has to be compensated by the annual recruitment. Incidences of accidents are much higher in zones around the protected area boundaries (Fig. 3.10). Group sizes have reduced in the past four decades and perhaps been influenced by changes in the prey and habitat during this period (Khan 1996). Results from the data on lion demography show that while birth is aseasonal and asynchronous among breeding females, recruitment is limited by infanticide and accidents.

3.9 Conservation implication

Large carnivores require large tracts of suitable habitat with sizeable prey-base (Loveridge 2002). The other challenge for conservation of carnivores is the issues of genetic isolation and susceptibility of small populations to diseases (O'Brien et al. 1986, Packer et al. 1991). Sub-adult lions are forced to disperse from superior habitats in areas where competition for space is intense (Hanby et al. 1995). However, protected areas in the present day are "islands in a landscape of human modified land-use areas" (Loveridge 2002). Dispersing animals are therefore forced to use sub optimal areas, such as agriculture areas and human habitation surrounding protected areas or reserves (Hanby et al. 1995). The increasing human population around protected area boundaries results in destruction of natural habitats and also causes modification of the habitat by activities such as livestock grazing (Loveridge 2002). Livestock predation and threat to human lives are the other crucial consequences of human-carnivore conflict in the boundaries of protected areas (Loveridge 2002). Conservation measures should therefore be aimed at amelioration of conflict between lions and human communities both on park boundaries and other areas where lions occur outside the protected areas (Loveridge 2002). It may also be necessary to create corridors to enable free movement of excess lions between reserves or isolated forest patches (Hanby et al. 1995).

In the case of Gir, the protected area has high lion densities resulting in increased dispersal of lions into “satellite areas” (Table 3.1). These sub-populations (Girnar population, coastal population and Dhari-Una population) are however separated by human habitations. The movement of animals in the peripheral areas of the park causes conflict with people, in terms of attacks on humans and livestock depredation (Figs. 3.2 & 3.3). This apart, the study shows that lions are vulnerable to accidents and poaching when they move outside the PA boundaries (Fig. 3.10). In the year 2007, seven lions were killed in a single month due to poaching. Apart from poaching, poisoning by livestock owners, accidental electrocution in the farm areas, accidental deaths due to open wells are some of the other threats faced by lions. Hence, facilitating the movement of lions to the areas where sub populations have established, acting as population sinks, seems to be one of the short-term solutions. It has already been proposed to expand the Gir Protected Area and develop safety- net area (Gir management plan) and unify the forest areas extending across three districts, namely Junagadh, Amreli and Bhavnagar districts under a single administrative control (Gir management plan) and to initiate landscape level management. Survival of lions in these “satellite areas” would require that the size of the reserves and prey-base are adequate with minimal conflict with the people living in the surrounding areas.

Translocation has been recommended as a suitable long-term solution for the conservation of Gir lions. Following surveys across northwest India, Kuno Wildlife Sanctuary in Madhya Pradesh has been chosen as a suitable second home for the Asiatic lion (Chellam et al. 1995). However, there are yet several hurdles and criticisms impeding the implementation of this program (Kabra 2003, 2006). Proactive management policies would be required to protect the Asiatic lions and also finding specific solutions to universal problems of carnivore conservation: space requirement, conflict mitigation and vigilance against outbreak of diseases.

In this context, the maintenance of accurate records and continued monitoring of demographic changes with scientific protocols, records of level of conflict and survival of lions in the inter-phase areas (areas in the periphery of the park), accounts of changes in the lion social structure and composition within the park as also in the established populations in peripheral areas is of immense importance for the long-term conservation of the Asiatic lions.

Chapter 4

Home Range and Habitat Use

4.1 Introduction

Simplistic definitions describe home-range as areas where animals “enact their day to day activity” (Burt 1943, Powell 2000) and territories as core areas of exclusive use (Powell 2000) that overlap less than expected by chance (Caro 1994). Occasional sallies or exploratory forays are also not considered as part of the range (Burt 1943). However, it is realized that home ranges should be defined only for a specific time interval in the milieu of a dynamic environment and varying resource availability (Powell 2000). Many factors influence habitat-use and home-range size including prey distribution and density, reproductive requirements and intra and inter-specific requirements and competition (Sunquist 1981). Members of many species of Carnivora exhibit intra-sexual territoriality and maintain territories only with regard to members of the same sex (Powell 2000, Sunquist 1981). In most carnivores, females defend food and denning sites while males defend the female resources (Bailey 1993, Sunquist 1981, Trivers 1972). It has also been observed in carnivores that female range overlap and grouping is primarily affected by the distribution and predictability of food (Sunquist 1981). Lions are social carnivores that exhibit group territorial behaviour comprising of related females that defend a permanent home range that persists for many generations (McComb et al. 1994, Schaller 1972) and males that defend access to pride females (Schaller 1972, Grinnell et al. 1995). In lions, space use mechanism between the sexes can vary in different areas based on whether male-female interactions are weak (Funston et al. 1998, 2001, 2003, Chellam 1993) or throughout tenure (Schaller 1972, Bertram 1975, Packer and Pusey 1988). Seasonality in prey and water availability and vegetation cover can influence the stability of lion territories and group sizes they support (Macdonald 1983, Hanby et al. 1995). Overcrowding and competition for resources is avoided by either ousting or recruiting sub-adult females within the pride based on resource availability (Schaller 1972).

Habitat quality influence home range size while conspecific competition over space determines the distribution of individuals within the population (Spong 2002). Thus, it is important to test for selection of habitat within the range (Aebischer et al. 1993). Habitat selection involves a resource being used more or less than its availability (Alldredge and Ratti 1986). Habitat selection for a species can be considered as a hierarchical process occurring at three levels: First, selection of a home range (second order) within the geographical range (first order) and habitat-use within the home range (third order) (Johnson 1980). Assessing habitat availability accurately from the point of view of the animal is a very complex process with many limitations and can often be misleading (White and Garrott 1990). This is because mere comparison of habitat use and availability alone may not be indicative of how critical the selected habitats are to the animal’s fitness (White and Garrott 1990). Several statistical techniques are available for analysis of resource selection and have to be selected with caution (White and Garrott, 1990, Alldredge and Ratti 1986, Millspaugh and Marzluff 2001, Aebischer et al. 1993). These should be based on number of animals, number of observations per animal, number of habitats and magnitude of the differences to be detected (Alldredge and Ratti 1986).

Spacing mechanisms, territorial behaviour, social organization, relatedness, dispersal strategies and coalition turnovers would be very important determinants of the Asiatic lions' survival within the confines of the protected area. This chapter looks at home-range estimation of four females, seven adult males and one sub-adult male. The tenure, changes in social status, dispersal and spacing mechanisms of the lions are discussed. Habitat use is looked at three levels: first, a comparison of use (location data points) and availability (habitats in intensive study area), second, home-range selection and habitat use within the range and lastly, a relationship between lion distribution and several covariates such as habitat types, prey availability and disturbance regimes.

4.2 Objectives

- To study the home range of coalitions of lions.
- To understand the spacing mechanisms and extent of overlap between male coalitions and female prides (Land tenure system)
- To study habitat use in relation to the available habitats of the Gir PA

4.3 Methods

4.3.1 Home range and space use mechanisms

A total of seven adult males were monitored during the study period of which two were radio-collared. These males were located by intensive search – I would set out to specifically locate one of the males and search in all prior known locations, based on vocalization cues, indirect signs and secondary information sources. It was possible to locate male lions in the early morning when they tended to vocalize. Once located, the identity of the lion was confirmed from its vibrissae patterns (Pennycuick and Rudnai

1970) and other permanent marks on its body. Following this, I attempted to follow the animal as far as possible. In the absence of radio-collar, it was not possible to always know of the sudden occasional forays typical of male lion movement pattern and also difficult to locate lions at night but otherwise a fairly accurate representation of the range area was obtained.

Thus, the overall ranging patterns obtained for the males in the four-year period can be considered to cover majority of the animal's range. In the case of the Kokra male, its venturing into the adjacent revenue area was known but could never be confirmed using its identification profile. Hence, its range is calculated for its movement within the park and the data of this male has only been used for calculating Minimum Convex Polygon (MCP).

One GPS-satellite VHF radiocollars and one GPS VHF were deployed on a sub-adult (**Patriyala male**) and an adult male lion (**Buathirth male**) respectively in December 2005. Both males were part of two male coalitions. Darts were fired through a gas-powered projectile (Teleinject) and the lions were tranquilized using drug combination of ketamine and meditomedine (Jalanka and Roeken 1990, Kreeger 1996) and revived using the drug atipamezole hydrochride. Following tranquilization, lions were aged based on indicators such as weight, tooth-wear, body colour and condition. Standard morphometric measurements were also taken and the animal was weighed before revival.

The collar of the adult male stopped functioning within two days and the male was re-collared with a VHF collar in May 2006. In January 2006 another prime (young) male, part of a two male coalition (**K-male**), was deployed with a normal VHF collar that was active till monsoon 2006. The maximum life of the collars was for a year and once the collars failed the animals were tracked by conventional tracking. I homed in on the lions and following that, recorded data on the location fixes, habitat features and presence of associate animals particularly the coalition partner. Once located, I would try and make a minimum of one hour's observation on the activity and behaviour of the lion. The home range of the non-radiocollared animals are the day-ranges of these animals. Continuous behaviour data was also collected and the monitoring schedules ranged from 1–10 days. The summary and results of this data will be discussed in the subsequent chapter.

In the case of females it was possible to track and locate the prides on a regular basis since they had more predictable and localized movement patterns. Day ranges of four females, out of which two were fitted with Telonics VHF collars during an earlier study, were monitored during the current study.

Lion location data were plotted and analysed using ArcView (version 3.1, ESRI, Redlands, CA) and the Animal Movement extension (Hooge et al. 1999). Latitude and longitudinal fixes were used to calculate 100% minimum convex polygon (MCP) home ranges (Mohr 1947) for lions with > 20 data points and 50% fixed kernel range (Worton 1989,1995) for those with >40 data points were also computed.

4.3.2 Habitat Analysis

4.3.2.1 Use and availability

Habitat analysis consists of comparisons of availability and use to determine preference-avoidance of particular habitat (White and Garrott 1990). The habitat preference of lions was derived using data on four females and seven males intensively monitored for their ranging patterns. Lion locations were accompanied by data on activity, micro-habitat features and distances to water and human habitation. Each lion location was projected on the map of Gir and assigned to the nine vegetation types (see Chapter 2: Study Area) on GIS domain and this information was extracted to get the "used" habitat for the lions. A 100% MCP was obtained by pooling all the location fixes of lions, including both male and female locations, for delimiting the intensive study area. Habitats falling within this polygon were considered as "available" habitats for the lions. The proportion of each habitat category within the intensive study area, 550 km^2 in extent, was determined. A χ^2 test for habitat selection and Bonferroni's confidence intervals ($P< 0.05$) was used to test for habitat preference (Neu et al. 1974, Byers et al 1984). The data was analysed at two levels, first, for all lions and then separately for the sexes.

4.3.2.2 Ranking of habitat preference

Habitat preference ranking was done at two levels. First, the proportion of points falling within the various habitat types within the home range (100% MCP) of an individual animal was compared to the proportion of available habitat types within the study-area. At the second level, the proportion of habitat types within the core area (50% kernel) was compared with the proportion of habitats within the home range. At both scales of selection, compositional analysis was used to develop a ranking of habitat preference (Aebischer et al. 1993). Since six animals are the minimum required sample sizes for compositional analysis location data for both males and females were pooled (Aebischer et al. 1993).

4.3.2.3 Lion habitat use in relation to chosen habitat covariates

Use and availability with respect to available habitat seems a very simplistic way of looking at habitat preferences especially for a large carnivore such as the lion. The choice of habitat itself could be due to availability of resources such as prey, vegetation cover, water and safe refuges from anthropogenic pressures. Further, modelling spatial distribution of lions would also help to extrapolate and identify potential habitats and thus help in future conservation initiatives. Therefore, the third level of habitat analysis looked at the determinants of lion spatial dynamics by relating the spatial distribution of lions to ungulate abundance, topography, vegetation, drainage, water availability, road network and presence of human settlements.

Habitat suitability (HS) maps were developed using the Ecological Niche Factor Analysis (ENFA) (Hirzel 2001, 2002, 2006a). ENFA uses “presence” data of the species of interest thereby overcoming the problem building models based on false “absence” – in cases where species are present but not detected or habitats that are suitable and yet not utilized by the species (Hirzel 2002). The distribution of ecogeographical variables (EGV) for the species distribution (presence data set) is compared to that of the whole area (global distribution).The EGVs include environmental, topographical and anthropogenic parameters of the study area.

Step 1: ENFA and HS map: The model primarily summarises all EGVs into a few uncorrelated factors. This first factor describes marginality (species niche versus global area) while the subsequent factors describe the species specialisation (the ratio of the variance of the global distribution to that of the species distribution). The first factor maximizes the marginality of the focal species and is the ecological distance between the species optimum and the mean habitat within the reference area (Hirzel 2002). The other factor maximizes the specialization of this focal species and is the ratio of the ecological variance in mean habitat to that observed in focal species. The species distribution on the factors allows to compute a HS index for any set of EGV values and thus to draw the HS map (Hirzel 2002).

The EGVs chosen in the present study are described in the following section. The distribution of drainage, settlements and roads (Figs 2.4, 2.7) are self-explanatory and already described in Chapter 2. However, a more detailed description of vegetation classes, topography and ungulates are discussed.

Step 2: Re-classification of HS map output: The primary output HS map is often misleading and does not provide scope for ecological interpretation. Hence, HS maps are re-classified using the F curves derived from cross validation.

Step 3: Cross Validation: A cross validation is done to assess the consistency and stability of the model using three different indices. The Boyce index (Boyce 2002, Hirzel 2002, 2006b) indicates how to evaluate the presence-only model by relating predicted to expected presence ratio for several classes or bins. The index measures the correlation between habitat suitability values and the area adjusted frequency of presence points in the habitat map. Two other indices validate the prediction accuracy of the HS model (Hirzel 2006b). AVI measures proportional accuracy in classifying habitat and ranges from 0 to 1. Higher values of AVI denote a more accurate model. CVI measures the difference between the model and a random model, with values ranging from 0 to AVI. High values of CVI indicate a model that is very different from random (Hirzel 2006b).

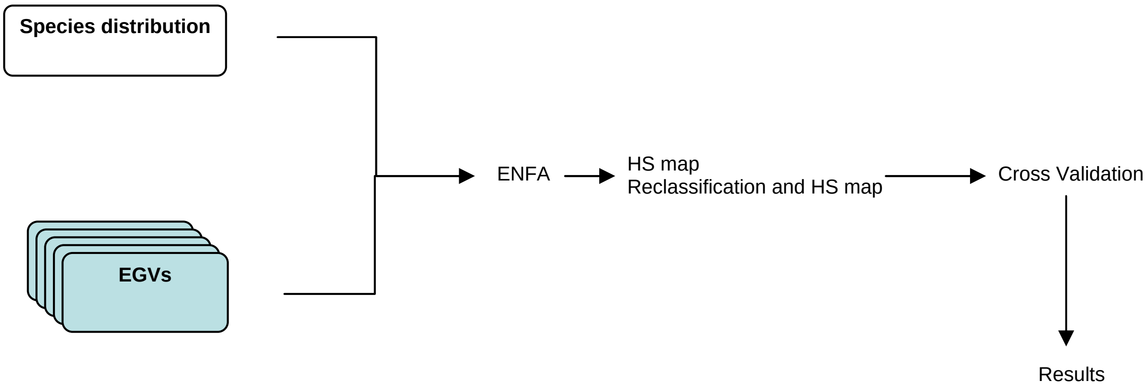


Fig. 4.1: Brief overview of ENFA (Hirzel, 2002) model

i) **Lion distribution**

- Intensive and exhaustive search for lions was conducted across the intensive study area in Gir-west and National Park from 2002-2005
- GPS coordinates of 768 individual lions locations were converted to degree decimals and further converted into point locations and projected in 1:50,000 map of Gir.
- Average values of lion presence were calculated for each grid and later re-classified into presence-absence (1 or 0) for each grid. The relationship between the lion distribution values were related to EGVs using ENFA (Hirzel 2002)

ii) **EGVs: Data collection, source and data processing (Fig 4.2)**:

- An IRS ID LISS III image of 1995 was used to landuse/landcover map. Gir PA maps, which were procured from Survey of India (SOI) and Gir Management Plan (Singh and Kamboj 1996), were digitized at 1:50000 scale. Remotely sensed digital data was geo-rectified with toposheets (SOI, 1974). Total positional error was estimated to be 15 meters. The images were re-sampled to achieve 23.5 m pixel size (Qureshi and Shah 2004, Sharma et al. 1999).
- Satellite imagery was visually interpreted to classify forest type. Hybrid classification technique was used to classify remote sensing data into different vegetation classes. Final vegetation map (Chapter 2: Study Area) was prepared on the basis of unsupervised and supervised classification (Qureshi and Shah 2004).
- Grid-wise area occupied by each vegetation type was extracted from vegetation maps. A separate layer was prepared for each vegetation type.
- Digital elevation model of 25m × 25m was generated from the contour file. Slope maps were also prepared simultaneously. Elevation was classified into 9 classes namely 83-131m, 132-180m, 181-229m, 230-278m, 279-327m, 328-376m, 377-425m, 426-474m and 475-523m. Slope was classified into 10 classes namely 0°, 1-8°, 9-16°, 17-24°, 25-33°, 34-41°, 42-49°, 50-58°, 59-66°, and 67-74°. However, slope was not used as EGV instead coefficient of variation of DEM was chosen as an indicator of terrain ruggedness.
- Toposheets were digitized to create layers for the eco-geographic variables of road network, drainage and contour (Fig. 2.4).

- The locations of forest settlements and nesses within the park were obtained from field surveys.
- GPS coordinates of the settlements (Fig. 2.7) and lion locations were converted to degree-decimal and further converted to point locations. The base map of lion location and settlement was prepared in 1:50000 map of Gir using Arcview GIS 3.2
- Ungulate abundance index was calculated from pellet count data from 53 transects across the intensive study area walked during both summer and winter seasons. Six plots, each of size 2m × 20m were placed at every 250m in opposite directions in each transect line. Totally, 312 plots in 52 transects were covered. Pellet groups of different species were identified on the basis of their shape and size and the pellet groups of the important ungulate species, chital, sambar and nilgai were counted. The GPS coordinates of the plots and pellet abundance attributes were projected on GIS domain. Following that distribution of the three ungulate species based on abundance index was obtained by interpolation using Arc GIS 9.x to represent ungulate distribution within the intensive study area (Fig 4.6 a-c).
- For the model, the pellet abundances were classified into 5 categories based on equal percentiles (25th, 50th, 75th and 100th). ENFA models were run for each of the ungulate models and later the model was incorporated as an EGV for the lion model.
- Data including point locations of lion locations, settlements, ungulate abundance indices, road, primary, secondary, tertiary drainage attributes were converted to raster grids of 1 km × 1 km using Arc GIS 9.x

- Grid-wise Euclidean distances were calculated for road (10 km), drainage (10km) and settlement (5 km) to a distance within the boundaries of the study area were calculated using Arc GIS 9.x
- Information on mean and standard deviation on all the eco-geographic variables were extracted in grids of size1 km² using Arc GIS 9.x software.
- IDRSI Andes Edition and Arc View 3.2 were used for data processing. Biomapper (Hirzel et al. 2004) version 3.2 was used for ENFA analysis.
- All EGV layers were clipped to equal size and normalised using Box-Cox transformation. We used polyconic projection for all spatial layers.

Table 4.1 Summary of preparation of EGV layers for ENFA analysis

EGV	**Treatment**	**Source**
DEM mean	Mean of DEM	SRTM Data
DEM CV	coefficient of variation of DEM	SRTM Data
Settlement	Euclidean distance from settlement up to 5km	Field data
Drainage	Grid-wise euclidean distance from drainage up to 10 km	Vector map from toposheets
Road	Grid-wise euclidean distance from road up to 5km	Vector map from toposheets
Chital	Pellet abundance index for 52 plots in intensive study area	Field data
Sambar	Pellet abundance index for 52 plots in intensive study area	Field data
Nilgai	Pellet abundance index for 52 plots in intensive study area	Field data

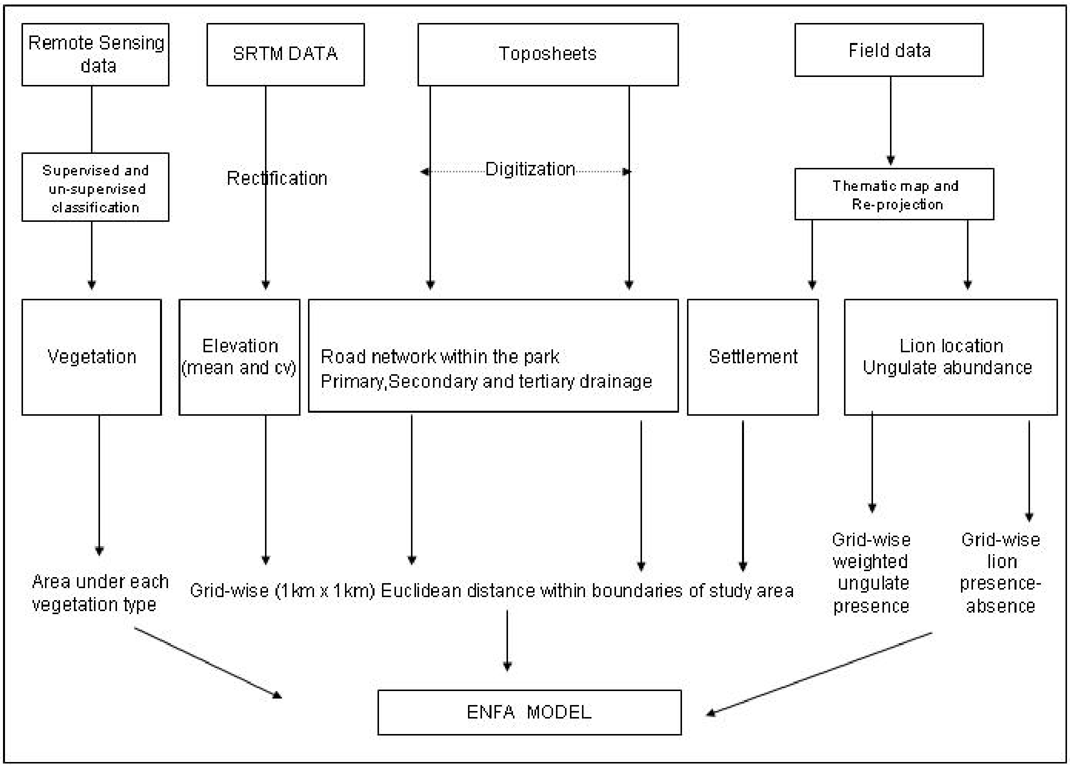


Fig. 4.2 Flowchart showing the Ecological Niche factor analysis procedure

iii) EGVs: Description of vegetation, topography and ungulate distribution in Gir

Vegetation

Table 4.2: Area under different vegetation classes within Gir PA (Qureshi and Shah 2004)

Vegetation Type	Area (km²)
Wetland	9.94
Moist Mixed Forest	183.70
Mixed Forest	244.0
Teak-Acacia-Zizyphus	427.9
Acacia-Anogeissus	194.2
Acacia-Lannea-Boswelia	180.6
Thorn Forest	111.3
Scrublands	64.5
Savanna	19.8
Agriculture	4.2

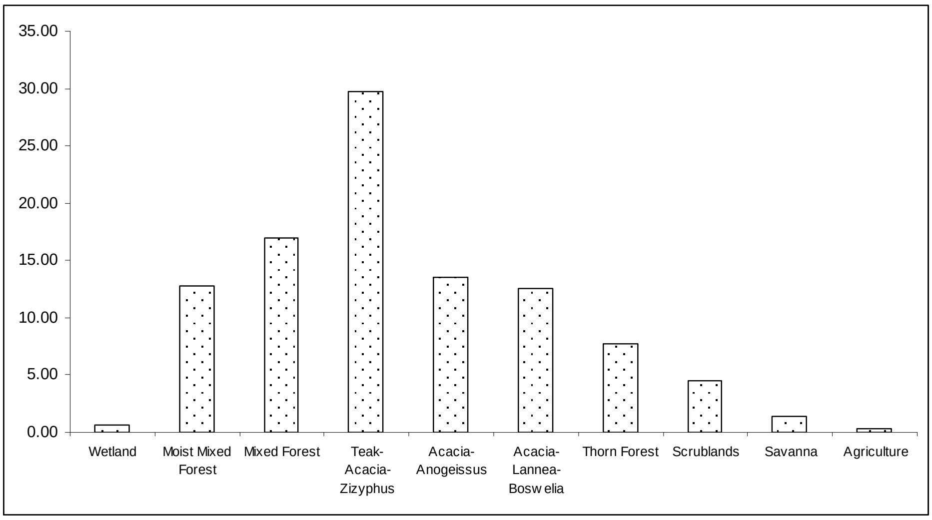


Fig 4.3: Percent area under different vegetation classes within Gir PA

Elevation

Table 4.3: Area under different elevation classes within Gir PA

Elevation classes (m)	Area (km²)
83-131	79.2
132-180	333.3
181-229	435.7
230-278	299.0
279-327	196.8
328-376	66.4
377-425	28.8
426-474	5.5
475-523	0.61

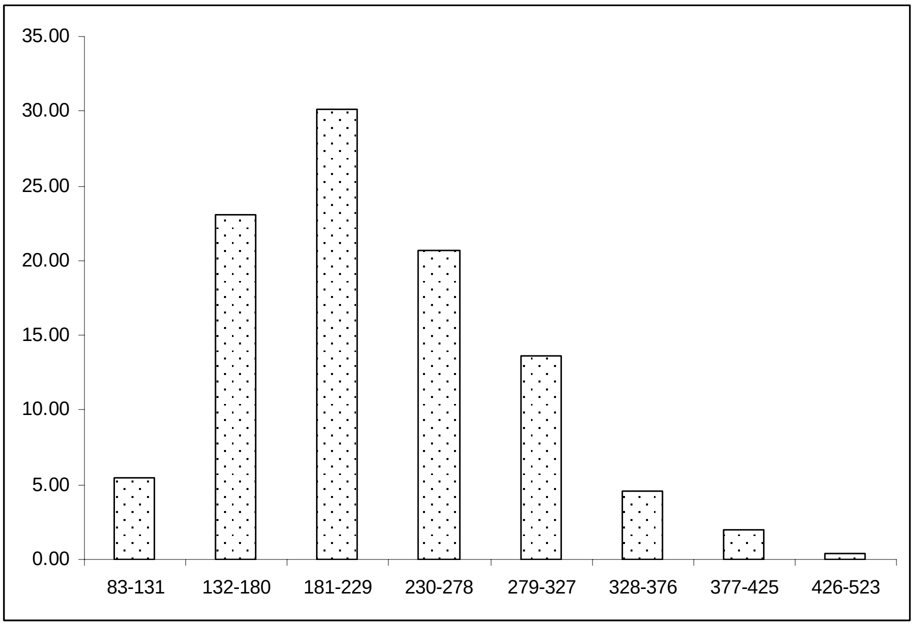


Fig. 4.4: Percent area under different elevation classes within Gir PA

Slope

Table 4.4: Area under different slope classes within Gir PA

Slope (degrees)	Area (km²)
0	230
1-8	779
9-16	258
17-24	93
25-33	34
34-41	11
42-49	5
50-58	2
59-66	1
67-74	0

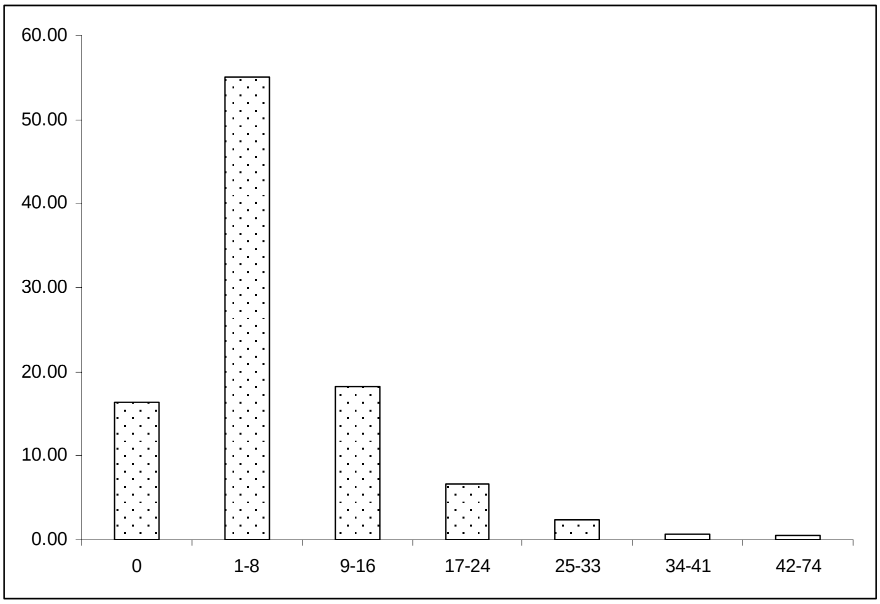


Fig. 4.5: Percent area under different elevation classes within Gir PA

Ungulates

From an earlier study it is known that chital concentrate in flat, productive valleys with high diversity of palatable shrub species. *Teak-Acacia-Zizyphus*, thorn and riverine forest in particular are the preferred habitat of chital (Khan 1996a-b). Inspite of being grazers themselves, chital tend to avoid pastoral settlements and heavily grazed areas (Khan 1996a). Sambar deer are solitary browsers and prefer hilly terrain with high tree and shrub cover. Sambar are even less tolerant of biotic disturbance when compared to chital (Khan 1996a). Nilgai prefer open and undulating areas and do not inhabit areas with high tree and shrub density as is common in Gir East area. Nilgai habitat is thus characterized by low tree and shrub densities with a dominance of thorny species and undulating terrain (Khan et al. 1996b). Based on this study, the following summary for the three major ungulate species of the Gir is given as:

Table 4.5: Biomass, average weights, density and group size of the three major ungulate species of the Gir PA

	Biomass (kg/km²) *Khan et al. 1996b*	Average weight (kg) *Schaller 1967*	Density ± C.L. (indiv/km²) *Khan et al.1996b*	Typical Group Size *Khan et al.1995*
overall	2,764			
Chital		45	50.8±3.2	11.4 ± 5.7 (N = 14553)
Sambar		125	2.09±0.28	2.4 ± 1.8 (N = 832)
Nilgai		180	0.58±0.15	3.5 ± 2.2 (N = 549)

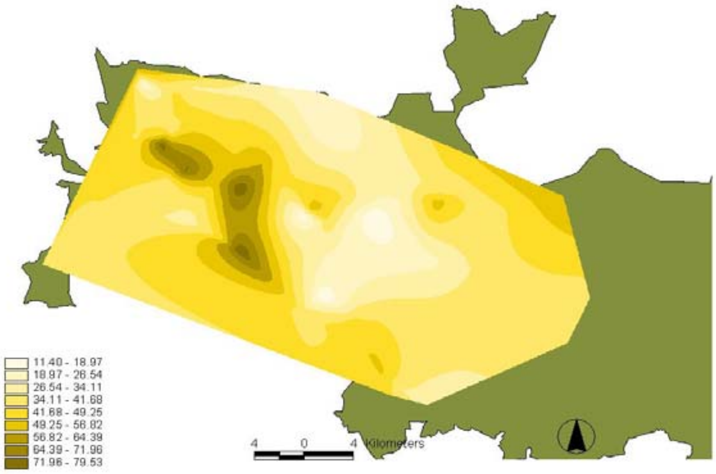
The results of the ungulate habitat-use study showed the three major ungulates to have distinct distribution within the study area (Fig 4.6a-c). Eological interpretation of the ungulate-habitat relationship has been done with caution. For instance, several artificial water sources are present in the western Gir, which is in the tourism zone is also an important place for wildlife sighting in summer season. In the National Park areas these water points are present but few are filled and maintained in the dry season. Towards the edges of the park, water sources in agricultural areas may be sources that would not show up in the relationship considered. Since, the ruggedness of the terrain would be a greater influence than the actual elevation or slope of an area, the standard deviation of the mean Euclidean distance was also considered.

The ungulates did not show very strong relationships with the chosen habitat factors. Interestingly however, the analysis did indicate the nature of preference of a habitat variable (positive or negative) and also the distinct and variable preference of the ungulate species.

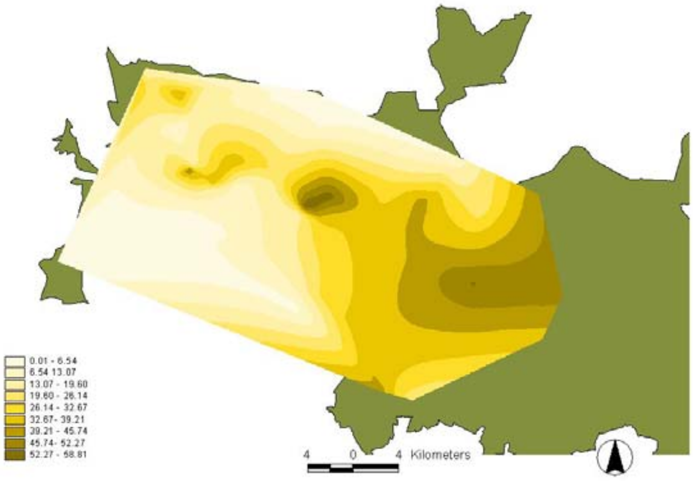
The ungulate habitat-use data revealed that chital density to be higher in Gir-west, Sambar density greater in the undulating areas of central Gir and Nilgai concentration to be greater in open areas closer to the park boundaries (Fig 4.6 b-c). Chital showed more tolerance for human disturbance and avoidance of elevated areas and closeness to artificial water sources. Chital was more abundant in the western part of Gir that has relatively less undulating terrain but has greater biotic pressure and presence of nesses. Nilgai showed avoidance for elevation and rugged terrain. It showed “avoidance” to drainage sources and closer to artificial water sources. This shows that it was in relatively arid areas of the park and thus more towards the edges of the park boundaries (Fig 4.6c). Sambar showed positive relationship with elevation and rugged terrain closeness to drainage sources and weak negative relationship with natural and artificial sources of water.

Table 4.6 Relationship between three major ungulate species with terrain and water availability (Pearson Correlation significant at 0.01)

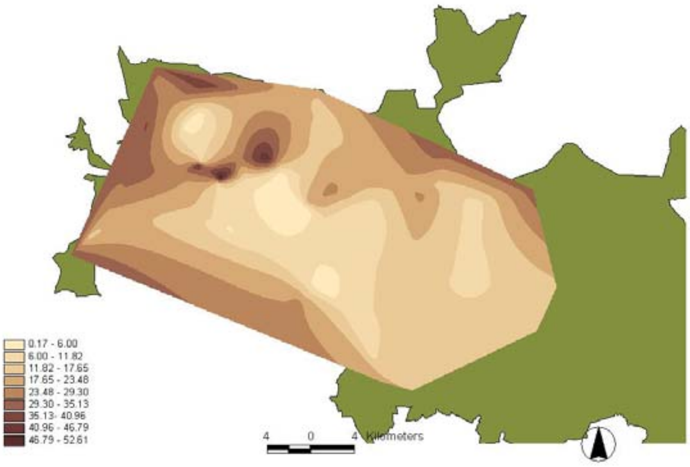
	Mean DEM	Mean Slope	SD DEM	Primary drainage	Secondary drainage	Natural water-point	Artificial water-point	Mean ness distance
Sambar		0.29	0.33	-0.55	-0.39	-0.57	-	0.53
Chital	-0.23					0.23	-0.16	-0.32
Nilgai		-0.23	-0.25	0.37	0.35	0.39	-0.20	-0.46



4.6-a Chital habitat in intensive study area



4.6-b Sambar habitat in intensive study area



4.6-c Nilgai habitat in intensive study area

Fig. 4.6 Ungulate distribution based on interpolation of pellet abundance in intensive study area

4.4 Results

4.4.1 Land tenure system and ranging patterns

Adult male lion coalitions

Kamleswar males*:* The natal area of Kamleswar males was in Chodavadi (Mukherjee, pers. comm.) in the year 2001. In summer 2002, the males became resident in Kankai area about 10 km from their natal territory. In December 2002, they ousted the resident male (Pilipat male) and gained control over Kamleswar area 23 km from Chodavadi. During this period they were known to foray into the range of the adjoining male coalition in Khuthni and Jamutala areas.

In May 2004, one of the partners was captured and had to be retained in captivity due to an injury. In the following two months, the associate male stayed on in the same area and later moved on closer to establish a new territory 8 km from *Kamleswar*. In 2006-07, this male has a new coalition partner and has a new range (Tenure III) in the *Padapani* area (Fig. 4.7).

Kheramba males: According to available records, the *Kheramba* males had established in their natal territory itself. Since the study commenced in 2002, these males have been monitored and have been observed to operate within a defined area for over three years without much deviation. During this time they are also known to have sired many cubs. In June 2005, one of the males died and till last observed the associate was still resident in the peripheral parts of the same range (Fig. 4.8).

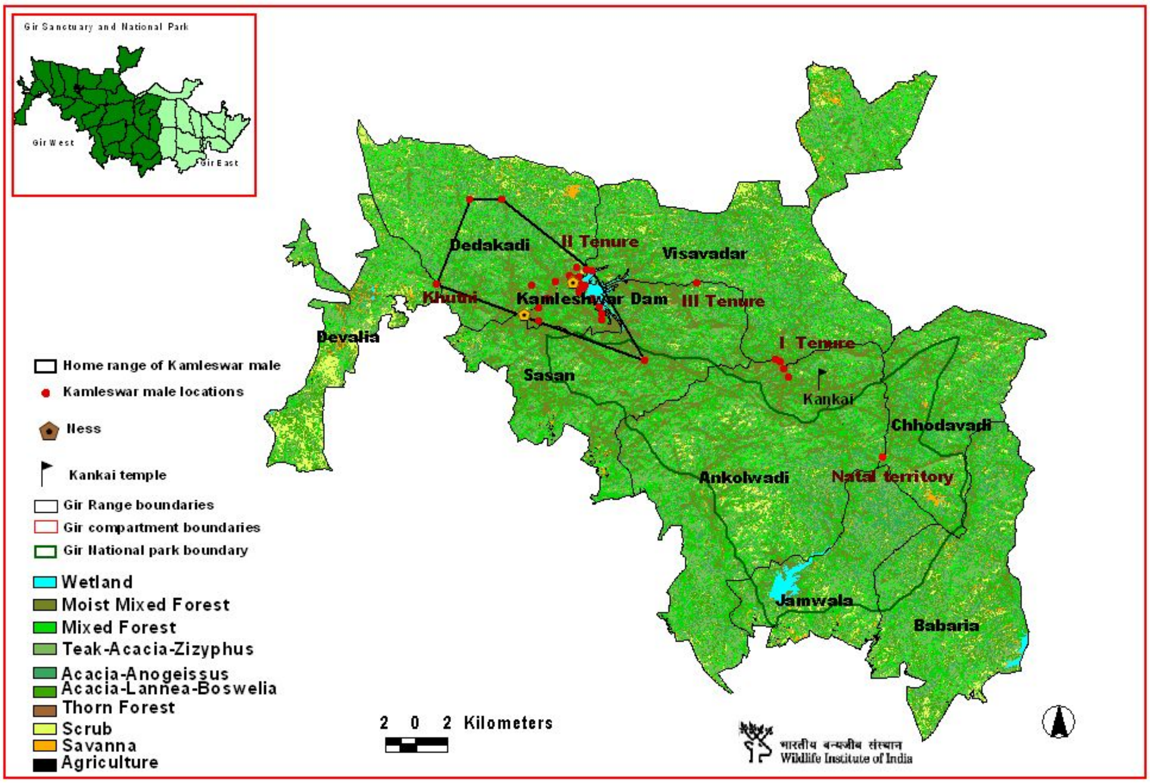


Fig 4.7: Kamleswar male: Home range and three range shifts from 2001 -2007

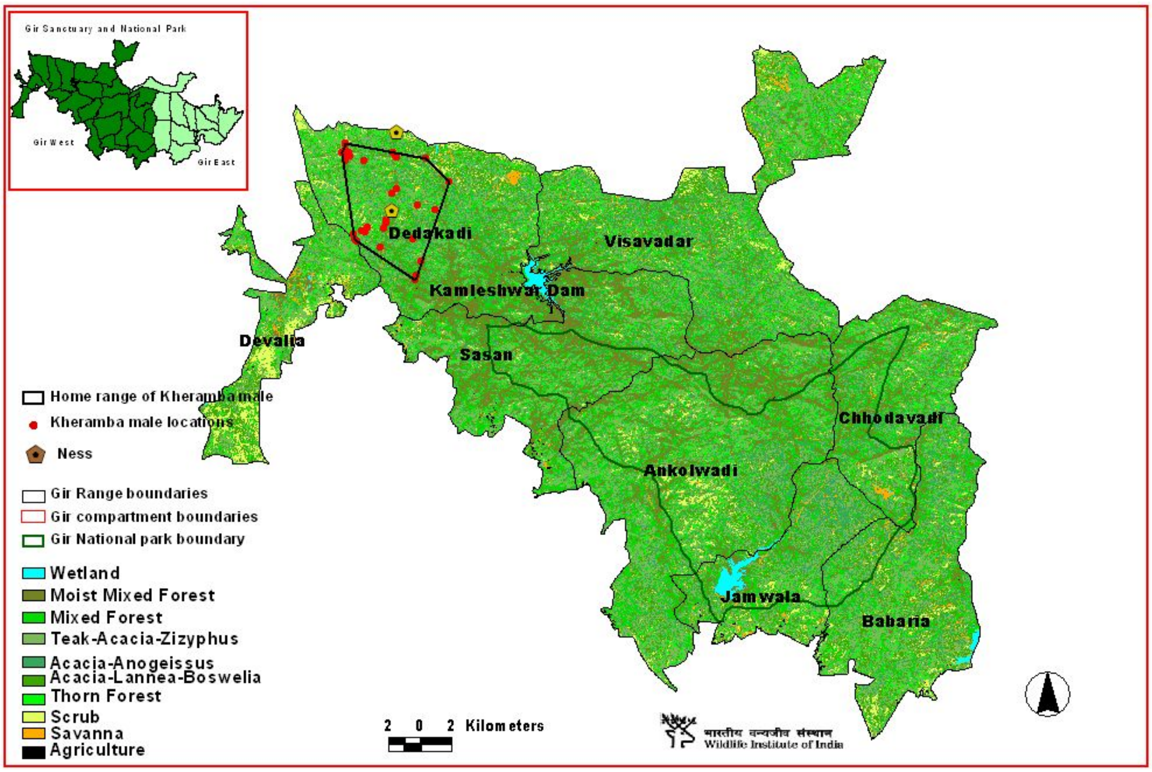


Fig 4.8: Home range of Kheramba male (100% MCP) from 2002 -2006 in Gir PA

Pilipat male: At the time field study was initiated in 2002, the Pilipat male had lost his partner and was the resident male of Kamleswar area. On 23 December 2002 at about 3:00 a.m. there was territorial fight between two prime (young) males and the resident lone male, the Pilipat male, in the Kamleswar area. The incoming males came to be called *Kamleswar males*. As a result, two four-month-old cubs were killed by the two incoming males. The Pilipat male was ousted from this area following this incident the male shifted its range and moved more in the Pilipat, Vasador, Sasan, Bombapor and Khuthni areas. During (2005 -2006), another coalition, the K-males had taken over, the *Pilipat* male ranges in the edge of former territory in areas such as *Karsangad, Nanava*, Periphery of *Sasan* village with occasional entry in areas such as *Panchari, Paravia* and *Juni-Raidi*.

The range of the *Pilipat male* (Fig. 4.9) overlapped with that of the *Kheramba* males and also marginally with that of the *Kamleswar males* (Fig.4.13). In spite of being older and without a partner, this male held prime territory defending it effectively against territorial males. On a few occasions there have been aggressive encounters with the *Kheramba* males when the *Pilipat* male proved to be more dominant.

Alavani male: Prime (old) male was captured from *Chachai-Pania* sanctuary. The male was brought to the hospital in *Sasan*, treated and released back in the area on 4th November 2004. I re-located him in *Alavani* area on 19th November 2004 over 30km form the area where he was resident. Since then this lion has taken residence to an area close to *Sasan*. This perhaps means that the lion has lost hold over his earlier territory while undergoing treatment. It is not clear if he is currently a “nomadic” or has taken permanent residence as a territorial male. This male was involved in aggressive encounter with other territorial males. The recurring injury had resulted in making the male very aggressive. The male was captured yet again treated and released. This time the range was much wider covering areas from *Balsel* to *Kasia*. The male died during 2006 monsoon in captivity.

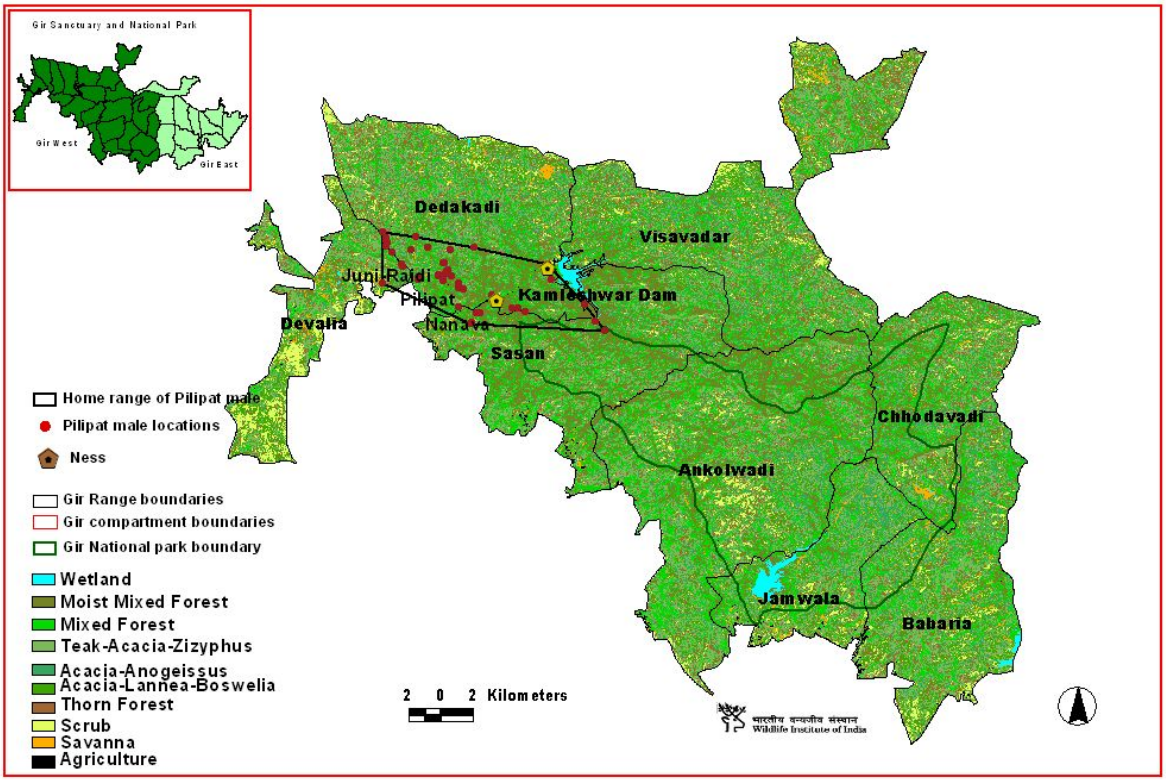


Fig 4.9: Home range (100% MCP) of Pilipat male in Gir PA

Kokra males: A two male coalition, the *Kokra males* had taken residence in the area in December 2003. Their area of operation overlapped with that of the *Janvadla* males in *Devadungar*. An encounter with the *Janvadla* coalition in March 2005, resulted in death of three cubs sired by one of the males. Between April 2002 and Febuary 2003 the same area was occupied by another male coalition that dispersed from the area. In 2005, one of the males died, the lone Kokra male still holds territory (Fig. 4.10).

Janvadla males: The *Janvadla* male coalition includes three individuals over ten years of age. Their 2002 range included *Kokra, Shirvan* and *Devadungar* (Fig. 4.10). But in the following years, they were sighted more in the national park area of *Janvadla, Mundachowk* and *Singoda*. Thus, these males have been holding a very large area for over four years and have been observed to have aggressively defended this area on two occasions. One of the males died in 2005. The other two males range in the border areas of their former territory (*Rasulpara – Ankolwadi*).

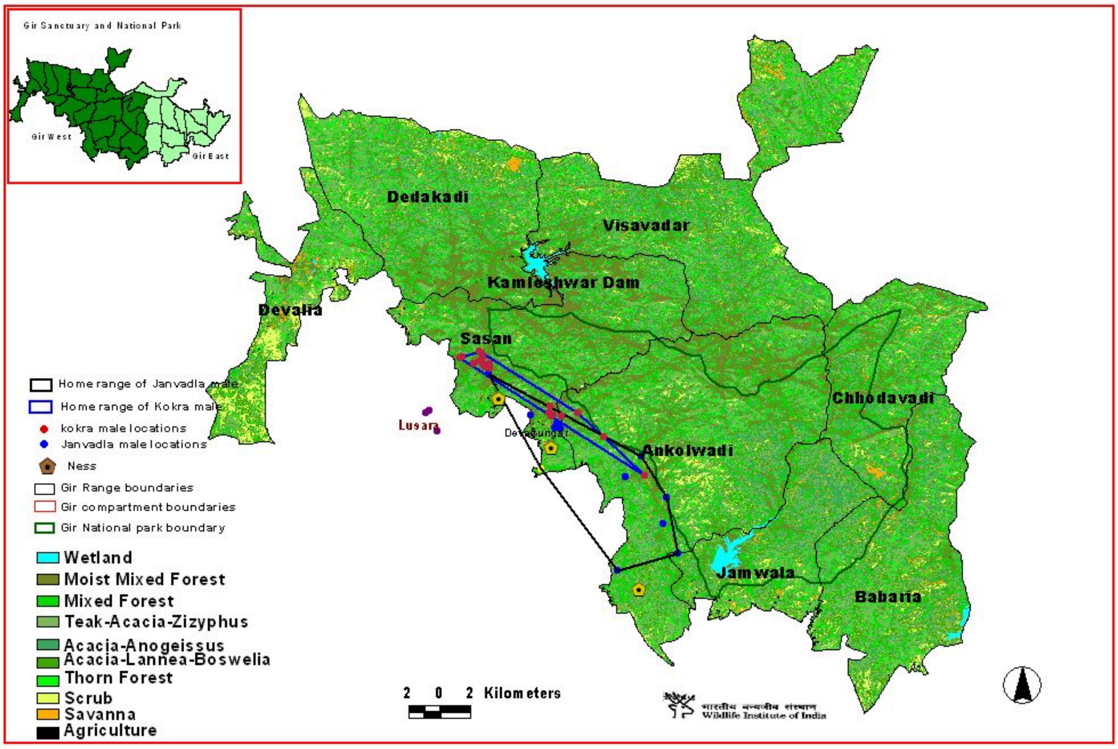


Fig 4.10: Home range (100%) of Kokra and Janvadla male in Gir PA

<u>K-male:</u> Two prime young males of four to five years of age started to establish in 2005 in the *Kamleswar* area that had lost its territorial males during the same time. These males in that year however remained largely to the north of this territory towards the *Barwania* area. In 2006 December one of the males was collared and monitored. Observations on the territorial movements and behaviour were made and the males were monitored intensively throughout 2006. Their exploratory forays and encounters with territorial males were also observed. The 100 % MCP was 129 km² (Fig 4.11) and 90% home-range was 74 km^2.

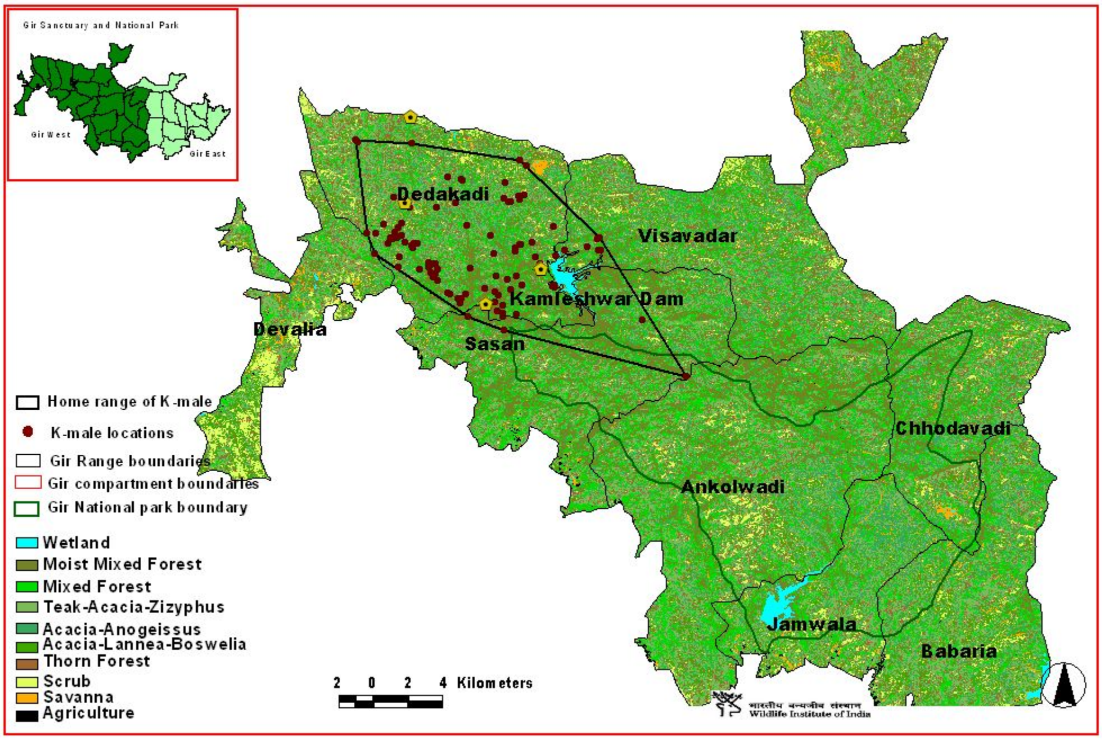


Fig 4.11: Home range (100% MCP) of radiocollared K male in Gir PA

<u>Buathirth males:</u> *Buathirth* males were a two male coalition that were located in *Kankai* area in 2004. Subsequently in December 2005 one of the males were collared. In June 2006, the coalition partner went missing, presumed to be dead, and since then the collared male began to show erratic movements and finally in May 2007 dispersed to eastern part of Gir. As territorial males, the *Buathirth* males covered a total area of 175 km^2 area (Fig 4.12). However, the 90% MCP covered an area of 64 km^2 and this can be considered to be their actual range.

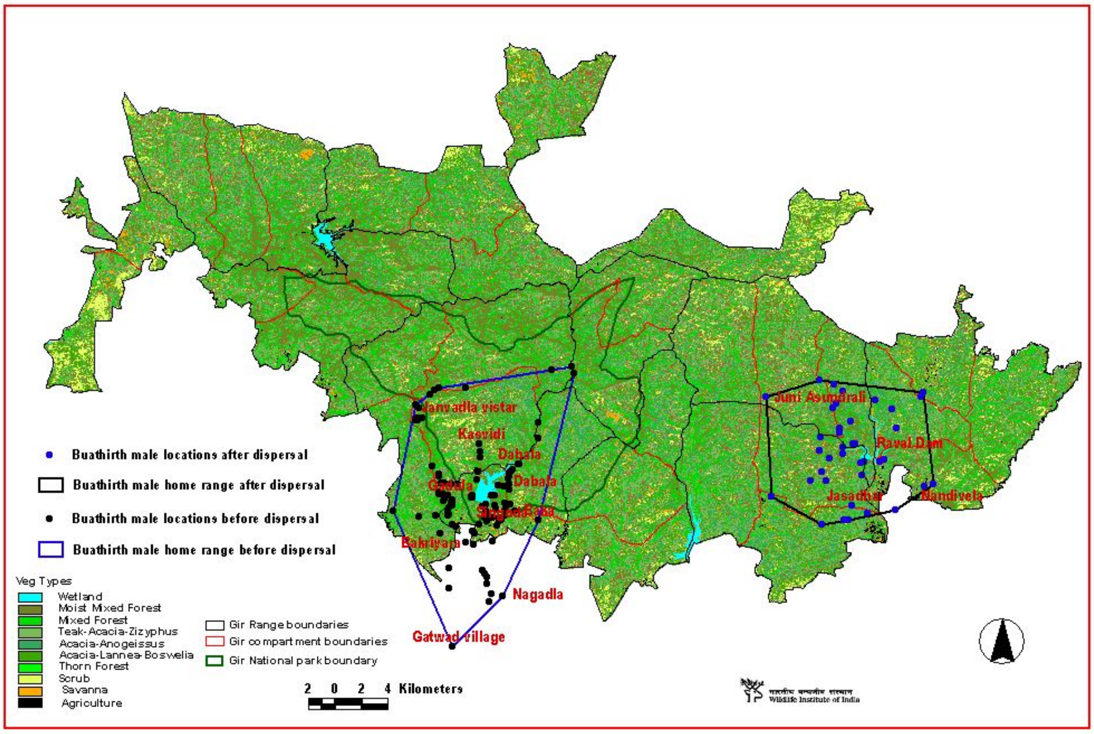


Fig 4.12: Home range (100%) of Buathirth male in Gir PA

Table 4.7: Home range of adult male lions in the Gir PA showing their total range (MCP) and core area (Kernel home range estimate)

Lion ID	Monitoring period	N (fixes)	100% MCP (km^2)	50 % Kernel (km^2)
Kamleswar male	2002 – 2005	43	60	11.05
Pilipat male	2002 – 2006	52	48	7.74
Kheramba male	2002 -2005	51	37	5.74
Kokra male	2003 -2005	24	12	NA
Janvadla males	2002 -2005	30	59	NA
K-male (444)	2005 -2007	115	129	9.49
Buathirth male	2004 -2007	138	174	15.91

Territory size of the Asiatic male lion coalitions: The core area or the territory size defined as the intensively used area within the home-range, was calculated for five territorial adult males. The 50% and 60% intensive use area (± SD) was 10 (3.9) and 15 (5) km^2 respectively.

Male ranges showed considerable spatial overlap (Fig 4.14). 35% (13.1 km^2) of Kheramba male range overlapped with Kamleswar male and 13% (5.1 km^2) of its range overlapped with the Pilipat male. The Kamleswar male shared 21% of its range with Kheramba male and 52% (30.8 km^2) with Pilipat male. The Pilipat male shared 65% with Kamleswar male and 10% with Kheramba male

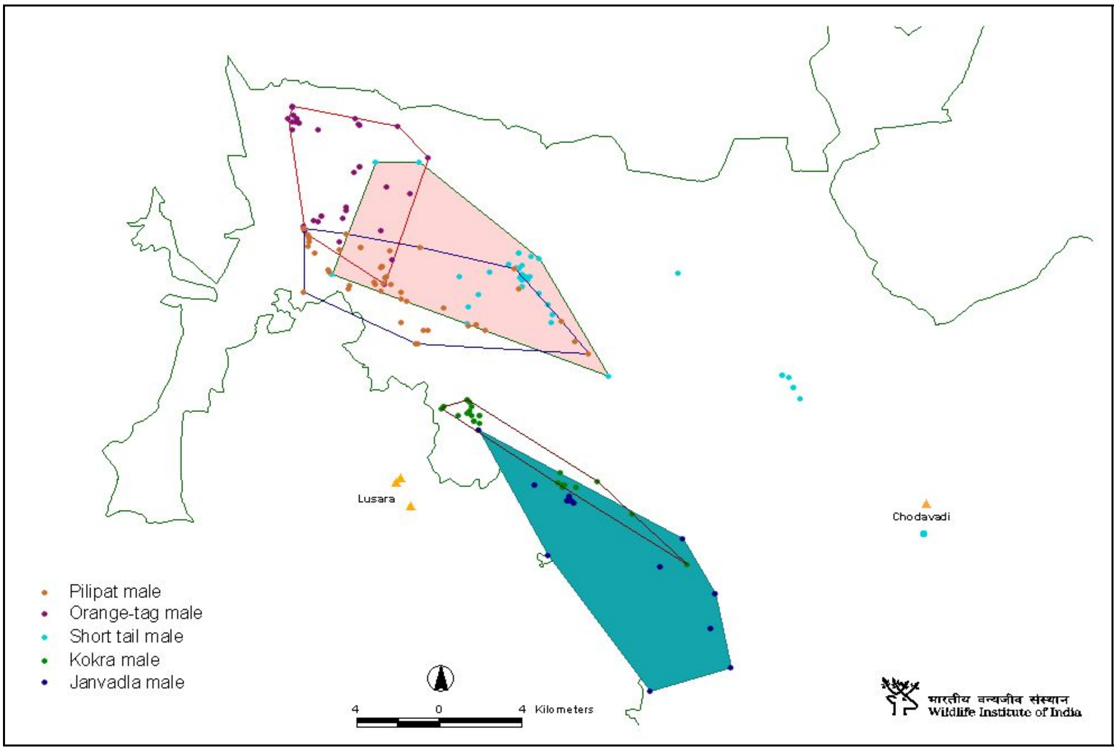


Fig 4.13: Male Range overlap

Adult female lions

Ramzana:

The female was a radio-collared female monitored from 2002. The female successfully raised two female cubs and in 2005 had moved to the edges of her range which fell outside the park boundaries. The sub-adult females have also dispersed outside this range.

Raidi female:

The *Raidi* female has been monitored from 2003 and has successfully two litters during the course of the study period. The first was a female cub and the second was a two females and one male litter that have also reached sub-adult stage. The Raidi female has shown very little shift in the range and has been intensively monitored during the study period.

Hathodia female:

This female ranged extensively and largely very close to the *Sasan* area and was also intensively monitored. The female had minor range shifts and a few exploratory movements. The female successfully raised three litters during the study period - two litters of single female cubs and a subsequent litter consisting of a male and a female cub.

Table 4.8: Home range of adult female lions in the Gir PA showing their total range (Minimum Convex Polygon) and core area (Kernel estimate)

Lion ID	Monitoring period	N (fixes)	100 % MCP (km^2)	50 % Kernel (km^2)
Kankavati female	2002 – 2004	38	31	
Ramzana female	2002 – 2005	50	43	4.47
Hathodia female	2002 -2006	56	37	7.13
Raidi female	2003 -2006	46	26	3.92

Territory size of the female Asiatic lion coalitions: The core area or the territory size was calculated for four adult females. The 50% and 60% intensive use area (± SD) was 5 (1.7) and 7 (2.3) respectively. Female ranges overlapped less than male ranges (Fig 4.14): 12% (2.75 km^2) of Raidi female overlapped with Ramzana and 20% (4.66 km^2) with Hathodia female. The home range of Hathodia female overlapped with the Raidi female by 13%

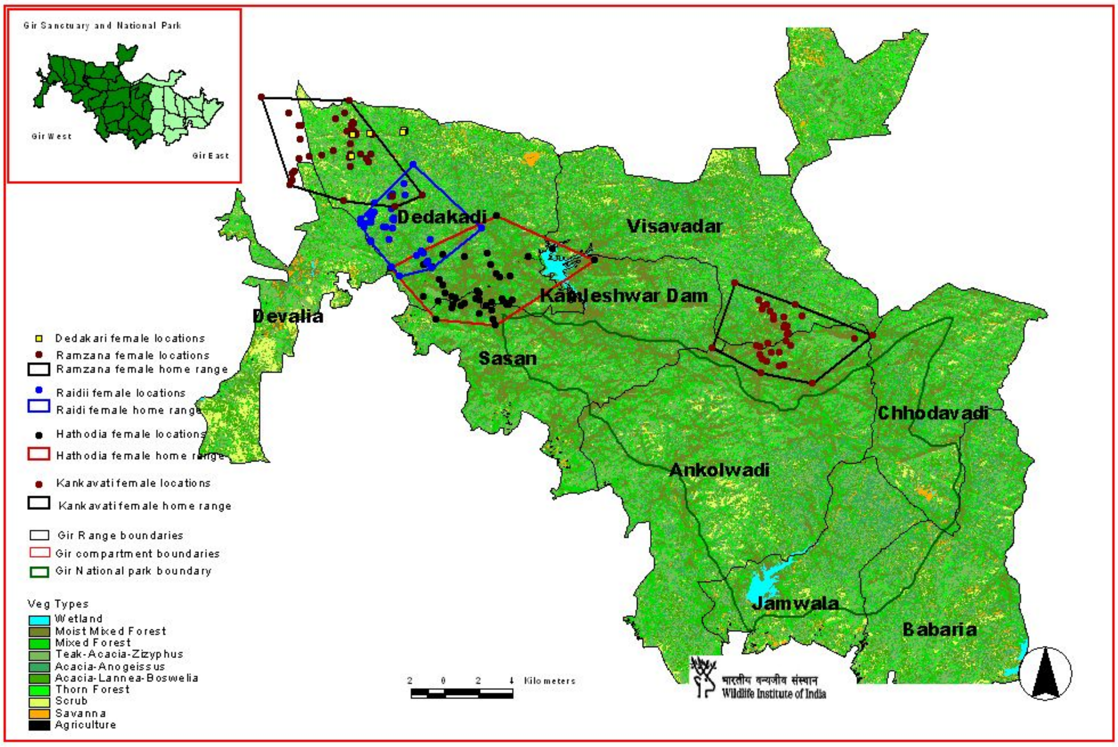


Fig 4.14: Female Ranges and overlap

Sub-adult males

At three years of age male lions are either expelled or leave their natal prides voluntarily. At this stage they have scanty mane but are sexually active (Bertram 1975) and become resident in the first pride when they are about four years old (Packer and Pusey 1987). Thus, after leaving the natal territory sub-adult males go through a brief nomadic period until they establish their territory (Bertram 1975).

Such wide-ranging nomadic behaviour was observed in the two collared sub-adult males called the *Patriyala* males. The males were first observed in summer of 2005 in association with a prime-old female that was in all probability, the mother of the two males. These males were radio-collared in January 2006 and their movements monitored till they established territory and started mating in December 2006 (Fig 4.15). The range of the Patriyala male (100% MCP) was 182 km²

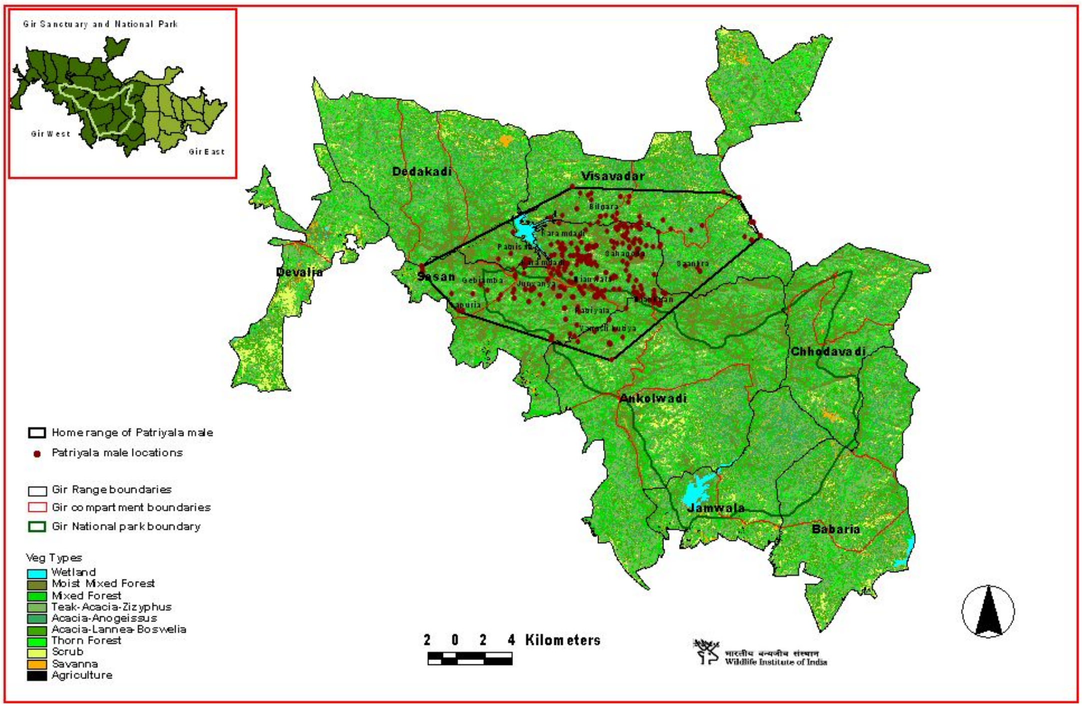
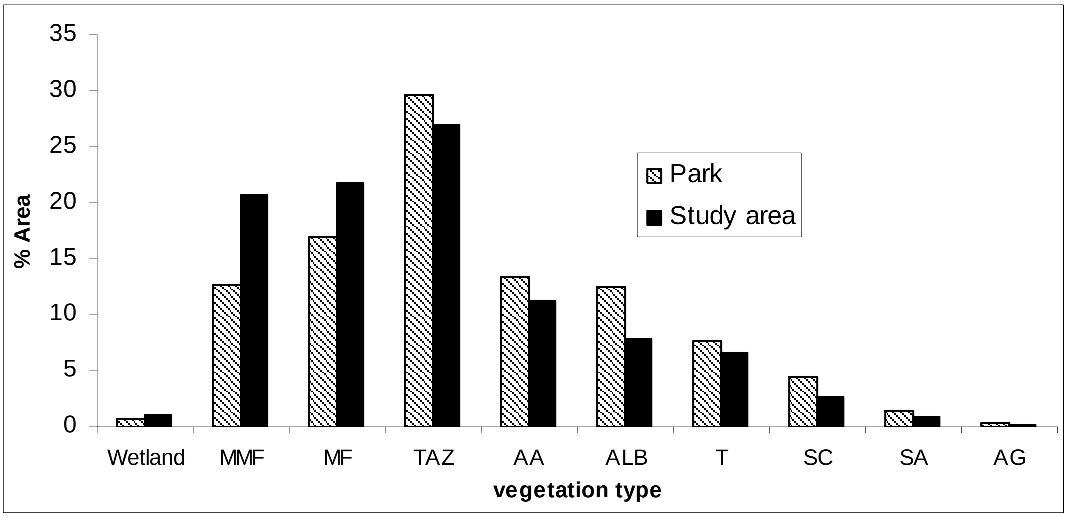


Fig 4.15: Patriyala male

4.4.2 Habitat-Use

4.4.2.1 Lion habitat use-availability



MMF: Moist Mixed Forest, **MF:** Moist Forest, **TAZ:** *Teak-Acacia-Zizyphus,* **AA:** *Acacia –Anogeissus,* **ALB:** *Acacia-Lannea-Boswelia,* **T:** Thorn, **Sc:** Scrub, **SA:** Savanna, **AG:** Agriculture

Fig 4.16: Proportion of vegetation types within intensive study area and the Gir PA

Table 4.9: Area (km^2) under each habitat type within home-range (100% MCP) of individual lions

	OT	ST	RC444	Pilipat	Buathirth	Hathodia	Ramzana	Raidi
MMF	3.31	18.01	33.82	18.17	14.39	17.53	1.21	3.42
MF	6.19	13.15	24.35	12.07	26.51	10.76	3.62	5.27
TAZ	12.83	12.87	26.86	8.81	39.57	6.36	11.43	8.19
AA	5.48	7.02	14.93	4.28	18.19	3.52	2.54	3.69
ALB	3.70	2.93	8.41	1.66	17.42	0.97	2.87	2.28
TAZ	4.21	3.08	6.71	1.83	7.90	1.18	4.45	2.30
SC	0.92	0.60	2.16	0.32	5.80	0.28	1.96	0.37
SA	0.39	0.30	0.99	0.26	1.94	0.22	0.20	0.21
AG	0.00	0.10	0.13	0.12	0.36	0.14	0.01	0.00
Total Range	**37.03**	**58.06**	**118.36**	**46.52**	**132.08**	**40.96**	**28.29**	**25.73**

Table 4.10: Area (km^2) under each habitat type within home-range (50 % Kernel) of individual lions

	OT	ST	RC444	Pilipat	RCB	Hathodia	Ramzana	Raidi
MMF	0.41	3.93	2.28	1.97	2.30	4.15	0.42	0.77
MF	0.97	2.30	2.28	2.11	3.79	1.93	0.81	0.99
TAZ	2.21	1.26	2.20	1.94	3.40	0.48	1.73	1.10
AA	0.48	0.73	1.14	0.92	1.27	0.40	0.40	0.33
ALB	0.58	0.29	0.85	0.37	1.90	0.06	0.34	0.30
TAZ	0.84	0.24	0.53	0.35	0.51	0.03	0.59	0.37
SC	0.22	0.11	0.13	0.04	0.52	0.01	0.15	0.07
SA	0.03	0.08	0.07	0.04	0.41	0.03	0.02	
AG	0.00	0.07	0.22	0.00	0.05	0.03		0.00
Total	**5.74**	**9.01**	**9.70**	**7.74**	**14.15**	**7.12**	**4.46**	**3.93**

Table 4.11: Lion Habitat-use ($P< 0.001$) (Neu et al. 1974) and selectivity

	χ^2	df	**MMF**	**MF**	**TAZ**	**AA**	**ALB**	**Thorn**	**Scrub**	**SA**
All	84.2	8	Prefer			Avoid	Avoid			Prefer
male	71.48	8						Avoid		Prefer
female	41.17	8	Prefer			Avoid	Avoid			

MMF:Moist Mixed Forest **MF**:Moist Forest, **TAZ**:Teak-Acacia-Zizyphus, **AA**:Acacia –Anogeissus, **ALB**:Acacia-Lannea-Boswelia, Thorn, Scrub, **SA**:Savanna

4.4.2.2 Habitat Preference ranking (Aebischer et al 1993)

The order of habitat preference by lions within the MCP ($\chi^2_{(7\ df)} = 22.5$, $P < 0.05$) was Moist Mixed forests > Mixed forests > *Acacia-Lannea-Boswellia* forests > Teak-*Acacia-Zizyphus-Anogeissus* forests > *Acacia-Anogeissus* > Scrub forests > Thorn forest.

The order of habitat preference by lions within the core area of home range ($\chi^2_{(7\ df)} = 26.07$, $P < 0.001$) was Mixed forests > Moist Mixed forests > Savanna habitat > Teak-*Acacia-Zizyphus* > Thorn > *Acacia-Anogeissus* > Scrub forests.

4.4.2.3 Lion habitat preference model based on habitat covariates

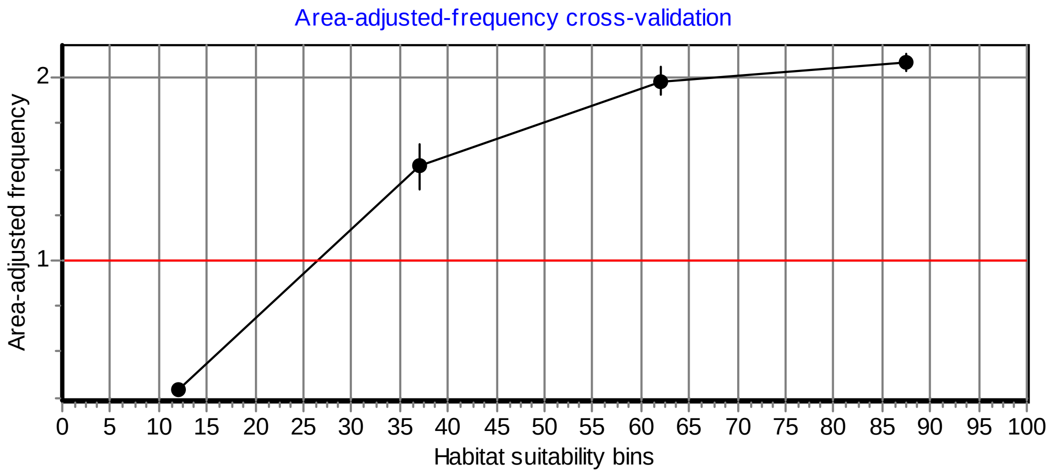


Fig. 4.18 Area adjusted frequency showing the mean and standard deviation of Boyce index values

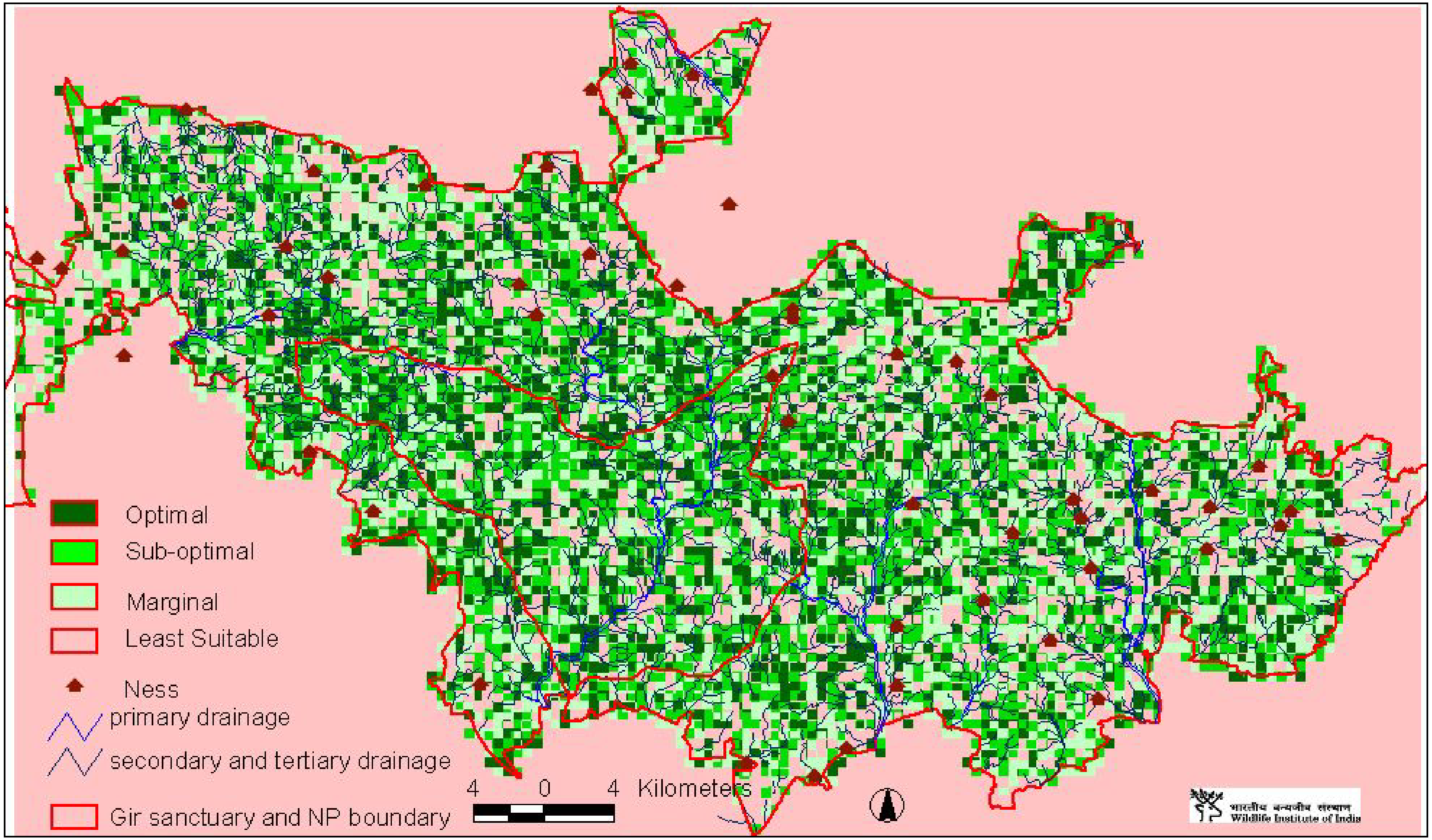


Fig 4.17 Habitat suitability map of lions in the Gir Sanctuary and National Park

Number of factors :	3
Explained information :	0.97
Explained specialisation:	0.93
Marginality:	1.08
Specialisation:	2.81
Tolerance (1/S):	0.36
Boyce index (SD)	0.90 (.076)

Table 4.12 Cross validation: Absolute Validation Index &Contrast Validation Index

AVI	CVI
0.73	0.37
0.72	0.37
0.72	0.37
0.72	0.37
0.72	0.36
0.72	0.37
0.73	0.38

Table 4.13 Factor scores explaining marginality and specialization

Variables	Factor 1	Factor 2	Factor3
Acacia-Boswelia	0.11	0.01	-0.03
Acacia-Anogeissus	0.14	0	0.02
Agriculture	0.13	-0.04	-0.02
Chital-enfa-model	0.41	-0.11	-0.01
CV of DEM	0.32	-0.06	0.18
Mean DEM	0.4	0.56	0.68
Road–euclidean distance	0.16	0.46	-0.17
River–euclidean distance	0.19	0.31	-0.11
Settlement–euclidean distance	0.40	-0.58	-0.68
Mixed Forest	-0.13	0.05	0.05
Moist Mixed Forest	-0.02	0.01	0.01
Nilgai_enfa_model	0.31	0.03	0
Sambar_enfa_model	0.36	-0.15	-0.01
Savanna	0.16	0.01	0.04
Scrub	0.05	-0.02	0.03
Teak-Accia-Zizyphus	0.07	-0.03	0
Thorn	0.1	0	-0.02
Wetland	0.08	-0.02	0.01

4.5 Discussion

Across many taxonomic groups, seasonal availability and distribution of prey is the most important aspect determining home range and territory size of carnivores (Adams, 2001). However, this relationship could be influenced by competitive quality of territorial neighbours, interspecific competition and also to access to specific resources (Adams, 2001).

4.5.1 Home range and territoriality

Lion home range size is negatively correlated with prey abundance during periods of prey scarcity (van Orsdol et al. 1985) and this relationship is not merely linear (Carbone and Gittleman 2002) but rather, is exponential (Hemson 2003). Dispersion of prey and their spatial and temporal distribution are the important correlates of lion home range (Hemson 2003). However, these relationships maybe not apply when predation is related to preferred prey (Hemson 2003) or related to presence of competing species and anthropogenic factors (Bailey 1993, Caro 1994, Loveridge and Macdonald 2002). The Gir has a high density resident prey population (Khan et al. 1996b) and about 10,000 cattle resident within the park and 95,000 in the periphery of the park (Gir management plan 2005). Therefore, drastic seasonal shifts in the range are not expected. Previous study however, did show a marginal difference in the ranges between the dry and wet season (Chellam 1993). This study could not adequately address seasonal range shifts owing to the changing social status of the intensively monitored animals. In order to be able to understand the influence of the habitat, the relationship of space use and several habitat covariates were instead taken up. Overall the ranges reported for Asiatic lions in previous study (Chellam 1993) were much larger than observed in this study. Male ranges were larger than that of the females and included 2-3 female prides. Male territories were also larger (10 km^2) than female territories (5 km^2).

Land tenure system

The land tenure systems of felids – whether they maintain exclusive or overlapping ranges – are highly varied (Sunquist 1981) and depend on home range size, habitat characteristics and prey availability (Sunquist 1981). Again, in a situation where prey are widely distributed or tend to make extensive seasonal movements, carnivore ranges would be likely to overlap with conspecifics. This is because the cost of maintaining exclusive rights to a large area becomes uneconomical (Schaller 1972, Hanby et al. 1995). In Gir, male ranges showed remarkable overlap and up to 50% overlap in the case of two pairs of coalitions. Female ranges were more defined and showed better turnover and recruitment than males. Clearly as supported from other literature on carnivores (Bailey 1993, Sunquist 1981, Caro 1994, Schaller 1972) the females are selecting the resources as also strongly indicated by the analysis of data on habitat utilization while the movement patterns of males were related to the female resource (see chapter VI, Fig 6.1-6.2). The importance of access to the female resource is an important aspect of male lion movement taking into consideration, the limited tenure period of territorial males (Packer and Pusey 1988). A similar relation between territoriality and coalition formation observed in male cheetahs is related to reproductive success and access to females (Caro 1994).

Distribution of conspecifics is known to influence ranging patterns as much as the habitat characteristic, dispersion and availability of prey (Sunquist 1981). This was evident when my intensive study area occupied by three males till 2005 (Fig 4.14) was later occupied by two male coalition, the K-males. This was following changes in the social status of resident males – two coalitions lost their partners respectively while the third lone male had restricted its range. The combined ranges of these three males (Fig 4.20) became available to incoming males. Indeed in 2006, the collared males increased their range to cover this entire area (Fig 4.20).

Thus, home range is influenced by prey, female resource and presence of conspecifics for male lions. However, in summarizing an average space-use of an individual male lion we are limited by the following- Although the concepts of territory and home range are applicable to lions, they are useful only if the complexities of male and female systems and the variation between prides are taken into account as the land tenure pattern of some females and all males change during the course of their lives (Schaller 1972). In this study individuals were monitored for a five-year period and much of the tracking was done by conventional tracking without the aid of radio-telemetry. It was realized home range stabilization of lions were not merely about increasing sample sizes but entirely depended on the animal’s changing social status and changing movement patterns. For instance, the cumulative area curve (Odum and Kuenzeler 1955) of locations and home range should reach an asymptotic limit when the appropriate sample size is achieved. However, the home range of study lions seemed to constantly vary with changes in the social status of the animal (Fig 4.21) emphasizing that it is very important to design studies and data collection specific to research objectives. However, it appears that a minimum of 50 data points for a one-year period would be necessary to come to any conclusion.

This could be shown to be true for the lions monitored through the study period. The Pilipat male shifted its range after the *Kamleswar* males took over in 2003 and by 2005 began to restrict itself to a very narrow part of its range as new males began to establish in the area. The Kheramba male, following death of the coalition partners, and the female, Ramzana also exhibited similar range shifts to the periphery of their ranges over time. In the case of the latter, as the daughters reached dispersal age, the group had moved towards the park boundaries and the Dedakari female (Fig 4.15) who used to associate with Ramzana earlier (daughter or sibling) moved into this territory. Thus, with the change in the social status it appears that lions tend to limit themselves to smaller portions of the range as seen in the case of tigers (Chundawat et al. 2001) or exhibit nomadic movement on being evicted or losing the coalition partner in the case of males (Chellam 1993, Schaller 1972, present study).

4.5.2 Habitat- use

The importance of the moist forest habitat for lions turned up as a significant factor in all habitat models. The moist forests largely includes the riverine tracts of the Gir provides important cover for hunting and resting for the lions. Following this, the *Teak-Acacia-Zizyphus* and Savanna habitats were more preferred over the other vegetation types falling under the categories of hill and thorn forests. Females seem to be more selective and the male movements covering a larger area seem less so.

The ecological niche factor analysis shows the lions to be quite specialized in their choice of habitat based on the lower tolerance values. Optimum lion areas are in the areas located close to settlements that are sources of a more vulnerable prey-base and at the same time to water sources and riverine areas. The National Park (NP) area is an area with lower lion densities. The model also shows that only the areas around the perennial river to be the best lion area within the boundaries of the NP while other areas show poor occupancy. The areas that have highly undulating terrain towards the northern area of the park (Fig 2.3) are also poor lion areas. Although the AVI and CVI show the model to be reasonable, the Boyce index values are very high. This is expected as the global area and the species distribution area chosen for the model are almost the same within the Gir PA. A larger landscape of the global distribution would have perhaps given a sharper distribution map. Overall, the factor maps reveal the terrain, drainage, settlement and prey to have a more positive effect on the marginalization factors while the specialization is influenced by river, elevation and settlements.

4.5.3 Conservation Implication

The implication for conservation is not in home range size per se but rather the constant turnover of range establishment and strife. These result in dispersal of lions from one area to another. The term “dispersal” includes both sub-adults establishing their territories as well as adult males dispersing and establishing to new areas. Dispersal has been identified to have three phases, namely, emigration (leaving the social group or natal territory), a transient phase of traveling through unfamiliar territory and immigration (establishing in a new place) (Wolff 1994). In plains habitats it has been suggested coalitions disperse considerable distances (120km) (Schaller 1972; Bertram 1978; Hanby & Bygott, 1987; Pusey & Packer, 1987) while in the wooded environments they settle closer to their natal range (Funston *et al.*, 2003). For instance, dispersal distance records were 16.5 km from centre of natal territory to area of initial dispersal and a distance of 37 km from centre of natal home range during the previous study (Chellam 1993). During the present study, the following dispersal events were recorded:

1. Territorial males dispersal from the resident area:
    - *Devadungar* males dispersed (apparently no territorial conflict with other coalition) from the *Devadungar* area to *Devalya* area from prime sanctuary area to almost the edge of the park covering a distance of 20 km
    - *Buathirth* male had dispersed after losing coalition a partner to a distance of 29 km from their established territory
2. Sub-adult male dispersal from natal territory to establish territory:
    - *Kamleswar* males had covered a distance of 23 km from their natal territory to establish their territory.
    - *Patriyala* males moved from centre of nomadic phase range to a distance of 19 km to their new territory.

Thus, dispersal distances due to shifts or establishment of a new territory for male lions ranges between 20-30 km. Significantly, the length of Gir forest is about 70 km in length and breadth about 20 km this means that dispersing lions are prone to turn up outside protected area boundaries in which case they are susceptible to accidents and would be in conflict with surrounding communities (Fig 3.10). Lions would therefore be expected to adapt by having smaller ranges, ranges with a greater overlap or exhibit increased dispersal outside the protected area. Thus, land tenure system of lions is in a constant state of flux within the lifetime of individual animals especially so when the spaces available to them are limited to the size of the protected area. This highlights the fact that in many areas, large carnivore densities are determined as much by anthropogenic factors, such as local tolerance of their presence, as by ecological factors such as prey abundance and habitat requirements (Woodroffe 2000; Sillero-Zubiri & Laurenson 2001). It is evident yet again that sub optimal habitats are very important for survival of the Asiatic lions as shown in other studies (Hanby et al 1995) and thus understanding spatial ecology (ranging patterns and dispersal events) is fundamental to effectively managing large, wide ranging carnivores (Marker and Dickman 2005) especially male lions that are transient associates of a pride (Packer and Pusey 1987). The size of the conservation area must thus be substantially greater than the average home range size of resident lions (Funston 2002)

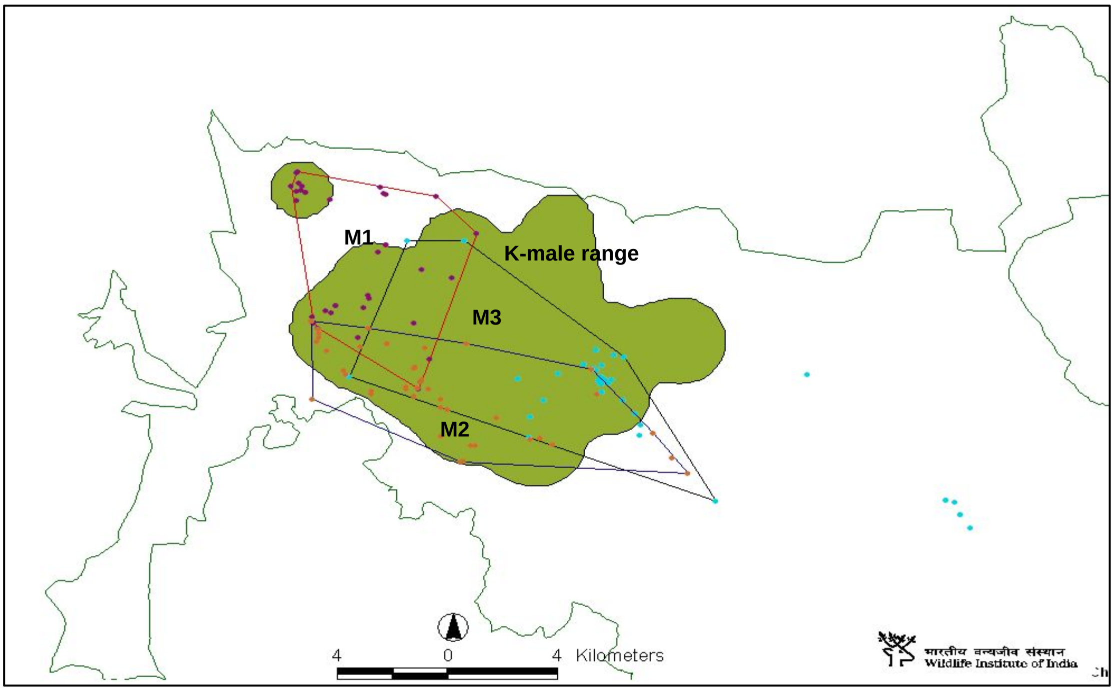


Fig. 4.20 K-male range coalition in 2006 including ranges of three male coalitions

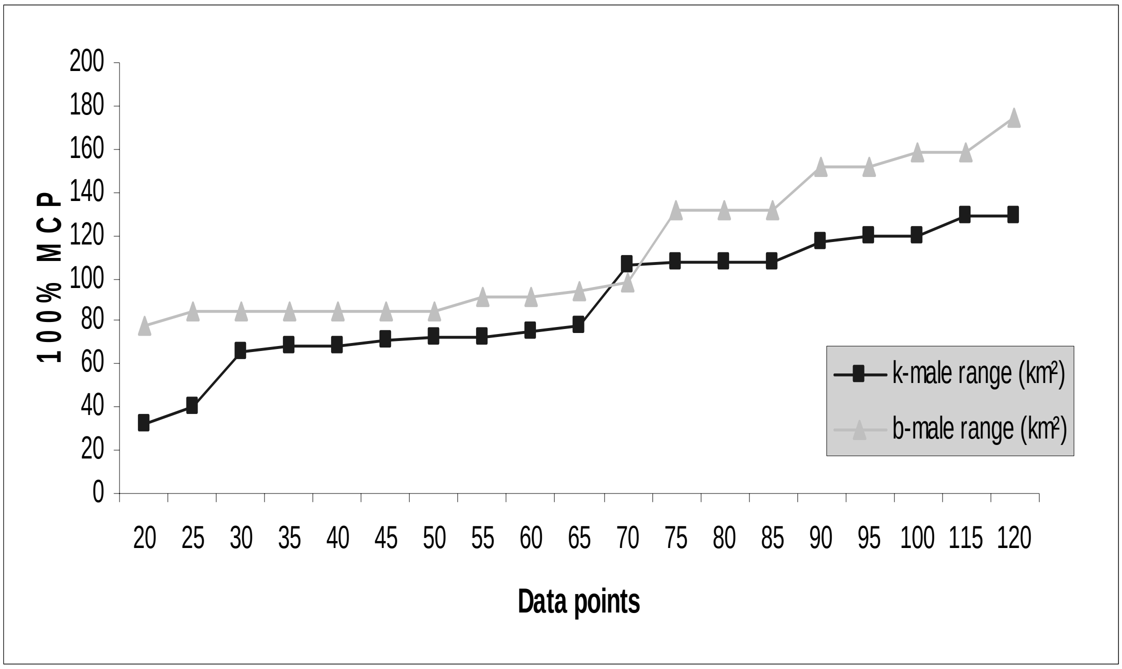


Fig. 4.21 Cumulative area curve with increase in sample size of two collared males

Chapter 5

Movement, Activity and Diet

5.1 Activity in relation to diet

Habitat use and activity of an animal depends on interactions with other species, social factors and the availability of resources (Bailey 1993). Activity patterns of large cats are influenced by the presence of inter- and intra-specific competitors (Hayward and Hayward 2006, West and Packer 2002, Bailey 1993.A major part of the predators' time and energy are expended in locating and securing food (Sunquist 1981). It has been proposed that the activity schedules of predators would correspond to the activity of prey and a variable activity pattern would be required when prey have different activity time (Sunquist 1981). Tigers are nocturnal and crepuscular and their seasonal activity patterns are influenced by several environment factors including the activity schedules of prey (Sunquist 1981). On the other hand, the leopard is active by day where it is the dominant predator (Eisenberg and Lockhart 1972) whereas in areas such as Chitwan where its activity patterns is influenced by the presence of tigers, it tends to be nocturnal in order to avoid agnostic interactions with the dominant competitor (Sunquist 1981).

In proportion to the number of research studies done on lions, few have focused on documenting the activity patterns of lions (Hayward and Hayward 2006). Studies on lions that have used behaviour observations to support research hypotheses are rare. Primarily, such studies have focused on hunting behaviour (van Orsdol 1984), competition (Hayward and Hayward 2006), comparison of lion behaviour in contrasting habitats (Hanby et al. 1995) or in preparing behaviour ethogram in order to record the repertoire of lion behaviour (Schaller 1972, Joslin 1973).

Hunting strategies and activity of lions vary in different areas based on prey availability (Schaller 1972, Stander 1991, Eloff 1984, Patterson et al. 2004). Daily movement of lions also depends on prey abundance (Schaller 1972, Eloff 1973, Stander 1991). Social interactions of lions are lower in areas of scarcer resource (Hanby et al. 1995). Habitat, particularly stalking cover, influences daytime activity (Bailey 1993). Therefore, diurnal hunting is common in areas that provide sufficient cover (Van Orsdol 1984). Serengeti lions were characterized by nocturnal activity in areas lacking cover, and diurnal in areas with cover and prey congregation (Schaller 1972).

Lions are primarily nocturnal hunters unless conditions favour diurnal hunting (Schaller 1972). Lions are known to actively hunt large prey during night time and feed opportunistically during day on small prey (Van Orsdol 1984). Livestock depradation, however, occurs largely in the night (Patterson et al. 2004, Joslin 1973). In Gir, activity patterns of lions were found to depend on whether their diet included domestic prey, in which case they tended to be more active by night (Joslin 1973). However, in the past two decades, as a consequence of regulation of livestock grazing in the park, the lion’s diet has altered with a shift towards consumption of greater proportion of wild prey (Chellam 1993).

The wild ungulate species of the Gir include chital (*Cervus axis*), sambar (*Cervus unicolor*), nilgai (*Bosephalus tragocamelus*), wild pig (*Sus scrofa*), chousingha

(*Tetracerus quadricornis*), chinkara (*Gazella gazella*). The common langur (*Semnopithecus entellus*) is the primate species that is an important prey-base for leopards (Khan pers comm.) and occasionally lions. The prey is resident throughout the year and seasonal variation is minimal (Khan 1996). An earlier estimate of total prey biomass of Gir PA was 2,764 (kg/km^2) (Khan 1996). The recent estimate of the overall density (±SE) of all wild ungulate species of Gir has been estimated at 48.3 (±6.1) individual/ km^2 (Dave unpublished). Chital is the most common species with a density of 44.8 (±7.2) individual/ km^2 (Dave unpublished). Approximately, 1,06,916 livestock are present in the peripheral villages and nesses in and around Gir PA (Pathak et al. 2002).

Foraging patterns in terms of distance traveled, time of hunting and diet are factors that influence activity of lions. This chapter looks at the diet of the Asiatic lions, with particular emphasis on the proportion of livestock uptake and its influence on lion activity.

5.2 Activity in relation to reproduction

In different studies on big cats it has been observed that there exist important behavioral differences between adult males and females in terms of space use and activity (Joslin 1973). As compared to females, adult males travel farther between locations, visiting all parts of the range more frequently in order to detect both estrous females and intruders. There is also a difference in the activity and movement depending on the social status and reproductive condition (Sunquist 1981). For instance, the birth of young has a marked localizing effect on the females (Sunquist 1981, pers. obs).

Male coalitions are known to hold tenure for a definite period of their lifetime (Bertram 1975) and therefore it is proposed that territory defense would be the most important activity for males in order to optimize reproductive success within the tenure period. It is therefore evident that movement activities of males would include hunting, feeding, patrolling and exploring new areas. Hence, males are expected to extensively use various forms of advertisements such as roaring, spraying and scraping. It is hypothesized that a male lion would invest a greater amount of time guarding territory as compared to other day-to-day activities.

Movement of male lions and territorial behaviour (patrolling and vocalization) are likely to influence the daily activity of male lions.

5.3 Objectives

- To determine the diet composition of the Asiatic lion
- To look at movement and patrolling behaviour of male lions
- To estimate time activity budget

5.4 Methods

5.4.1 Diet assessment

Kill data: Data on lion kills was collected in order to assess prey selection. Cues like odour, prey alarm calls, lion signs (drag marks) were also used to locate kills in addition to intensive search across the study area, and also the data collected from radio-collared animals. In the absence of scavenger vultures owing to a population decline in recent times, crows were the other indicators of the presence of kills. Once located, the kill location, habitat features, the age and sex of the prey and behaviour observations were noted down. Since the Gir had already good studies on prey selection in the past (Joslin 1973, Chellam 1993) and since the present study coincided with other studies on the same topic (Khan et al. unpublished, Dave unpublished), data on prey abundance, prey health and other details were not collected in order to avoid repetition. On location of a kill, the identification of prey and predator was based on details in a previous study (Chellam 1993). The identification of the lions on the kill, nature of food sharing among the lions and also incidents of kill takeover were recorded. Intensive monitoring data of radio-collared animals was undertaken to obtain data on kill frequency and kill sharing behaviour. In addition, information of livestock kills was obtained from nesses and villages as the case may be. Data on time of attacks on livestock was obtained from the Gujarat Forest Department.

Data analysis: The frequency of occurrence of a prey item was calculated as the number of times a specific prey item occurred and expressed as percentage of all prey occurrence. Seasonal diet variation as well as differences in diet between park areas was tested using chi square analysis.

Questionnaire survey: A survey of livestock was conducted in twenty nesses that included seven nesses in central Gir and thirteen nesses in Gir-west. Information on the number of families, number of individuals in each family, the livestock holding in each ness was collected. Data on livestock mortality was also collected and from this information on the relative loss due to predation in one year was deduced.

Scat collection: For scat collection, intensive search across the study area particularly along roads and forest tracks was done while ensuring that all areas of the park were well covered. Lion scats are clearly distinguishable from leopard scats and therefore there was little chance of misclassification. However, signs associated with scats such as pugmarks were nevertheless noted to avoid misidentification. The scat samples were preserved in a tagged polythene bag and later washed thoroughly using a sieve. Prey remains such as hairs, bones, hooves, feathers, quills, claws etc. were air dried and later examined. Features such as hair structure, colour, cuticular and medullary patterns were used to identify the prey species (Koppikar and Sabins 1976) and standard protocols were adopted to arrive at the minimum reliable sample size (Mukherjee et al. 1994). Examination of a minimum of 20 hairs/scat and a total of 30 scats has been recommended to provide a reliable estimate of lion diet based on the per cent occurrence of prey species hair in the scats (Mukherjee et al. 1994). Prey hair morphology was further scrutinized under a light microscope (both 10× as well as 45× magnifications). Microscopic slides of at least 20 randomly picked hair from a sample were prepared in DPX medium for examining medullary characteristics. Cuticular imprints of hair were made on a gelatin layer prepared on microscope slides and then further examined. Prey identification was based on standard known reference of prey obtained from kill sites and captive animals collected and made available at the Wildlife Institute of India.

Data analysis: Frequency of occurrence of different prey species was determined from the above analysis. The frequency of occurrence of a prey item was calculated as the number of times a specific prey item was found to occur in scats and expressed as percentage of all prey occurrence. Only the seven major prey species were used for comparison between management areas and seasons. The relative contribution of prey species in the diet is varied owing to their differing body size (Ackerman et al.1984).

To overcome this bias, a correction factor developed by Ackerman, Lindzey & Hernker (1984) for the cougar *Felis concolor*, L. was used, while assuming that lions have a similar digestive physiology to cougars. The equation is: $y = 1.980 + 0.035\ x$, where y is the biomass of prey consumed (kg) to produce a single field collectable scat and x is the average body weight of the prey species (kg). The body weights of the potential prey species were taken from literature (Schaller 1967).

Kill interval: Three radio-collared lions, namely K-male, Buathirth male and Patriyala males, were tracked continuously for periods ranging from 5 – 10 days in order to understand the inter-kill intervals as it was perceived that carnivores have a starve-feed cycle and their movement is related to feeding and hunting success.

5.4.2 Lion movement and patrolling behaviour:

Movement of coalition male lions was classified as movement (walking, hunting or stalking) and patrolling (walking associated with marking territory). The distance moved by territorial males, sub-adult males and nomads were compared. The data for this was collected by continuously tracking the three radio collared animals falling in each of the social categories mentioned above.

In the event of patrolling, the lions were continuously followed and GPS fixes were noted. The time and substrate on which the marking occurred was also noted. The coalition partner marking or initiating vocalization was noted down. Later, the total distance of patrolling and marking intervals was calculated in GIS domain and the mean patrolling distance was calculated. The time and duration of patrolling event was also derived. The frequency of marking behaviour was also calculated.

The frequency of vocalization was noted as and when the event occurred, along with data on the time, coalition partner initiating vocalization and also the event associated with the behaviour (such as response to roaring of a male or female in adjoining areas).

Time activity budget: Behaviour observations were made using three methods, namely, *ad libitum* sampling, focal animal sampling and scan sampling (Altman 1974). *Ad libitum* sampling involves recording all occurrences of behaviour events and states of interest as and when they occur at varying sampling intervals. This method was used to record events of mating, feeding and hunting. Focal animal sampling involves observing an individual for a specified amount of time, at pre-determined time intervals, and recording all instances of its behaviour. Scan sampling method involves rapid scan of a group at regular intervals and record of behaviour of each individual at that instance (Altman 1974).

Focal animal sampling method was used to understand social as well as self-directed behaviour. However, sample sizes were not adequate to address social behaviour due to failure of the radio-telemetry aspect of the study and hence accurate conclusions could not be drawn.

Scan sampling was used to develop time activity budget of lions with the main objective of finding out the proportion of time invested in hunting/feeding, reproduction and territory defense. For this purpose, three to fifteen day continuous day-night monitoring of the three radio collared males was undertaken. Behaviour states were recorded through half hour scans and included the following:

1. Sleeping
2. Sitting and standing
3. Moving
4. Patrolling (moving accompanied by marking territory. Another event – vocalization also pooled under 'patrolling'
5. Mating
6. Feeding (including drinking and Hunting)

Activity budget was calculated as the proportion of time spent in various activities such as resting or sleeping (stationary phase), moving (including random movement and patrolling), hunting and feeding and mating. Sitting and standing were also included under one state termed as 'sitting' in order to differentiate between resting and alert behaviour.

5.5 Results

5.5.1 Diet

A total of 258 kills were located in the intensive study area covering west and central Gir. Domestic kills constituted 56% and wild kills 44% of the total kill. Domestic cow constituted 35% of the total kills, Chital 26%, Buffalo 15%, Sambar 10%, Nilgai 3%, Wild boar 6% and other domestic species 5% (Fig. 5.1). Thus all prey species contributed significantly to the diet of lions. Interestingly, the number of wild kills in summer was greater (Fig. 5.2-a), owing perhaps to the fact that water sources are limited and prey can be easily ambushed around water sources. Another interesting fact is the majority of the prey killed were adults (Fig. 5.2-b and c). This could be because of a inherent sampling bias because kill of smaller prey is harder to detect in field. The intake of wild and domestic prey varied between revenue areas around the PA, Gir-west and national park (χ^2=12.3, df = 2, p< 0.001). Livestock was part of the diet in all park areas – 38% in National park, 50% in Gir-west and 76% in the revenue areas. The consumption of wild and domestic prey also varied between seasons (χ^2=22.3, df = 2, p< 0.0001) showing a greater proportion of wild prey during summer months.

A total 310 scats that were analyzed revealed twelve prey species. A total of 295 (95.2%) scats had a single prey item while 15 (4.8%) scats had two prey species. Chital contributed to 37% of diet, Sambar 19%, Wildboar 13%, Buffalo 8%, Nilgai 6%, Cattle 7% and langur 7% (Table 5.1). There was no significant difference in the diet between management zones and between seasons. Livestock contributed only 14% of the scats analyzed and wild prey contributed to 86% of the scats analyzed (Fig. 5.1). Chital and sambar contributed to up to 56% of the lion’s diet. Other minor prey included peafowl, porcupine, an unidentified bird species, camel and domestic dog. Two scats had claws of cubs. However, it was not clear whether they belonged to lion or leopard cubs. Prey species composition and their relative biomass contribution in the diet across different seasons in the entire Gir PA, as well as in different management zones based on analysis of scat is summarized (Table 5.2 and 5.3, Fig. 5.3-a and 5.3-b). A population of 1408 cattle graziers having a livestock holding of about 3800 buffalos and 790 cattle were resident within the intensive study area (Table 5.4). Sixty five percent of their livestock loss was due to predation. Most attacks on livestock by lions occurred during dusk between 4:00 to 8:00 p.m (Table 5.5). Lions made kills once in every 3.9 days (Table 5.6).

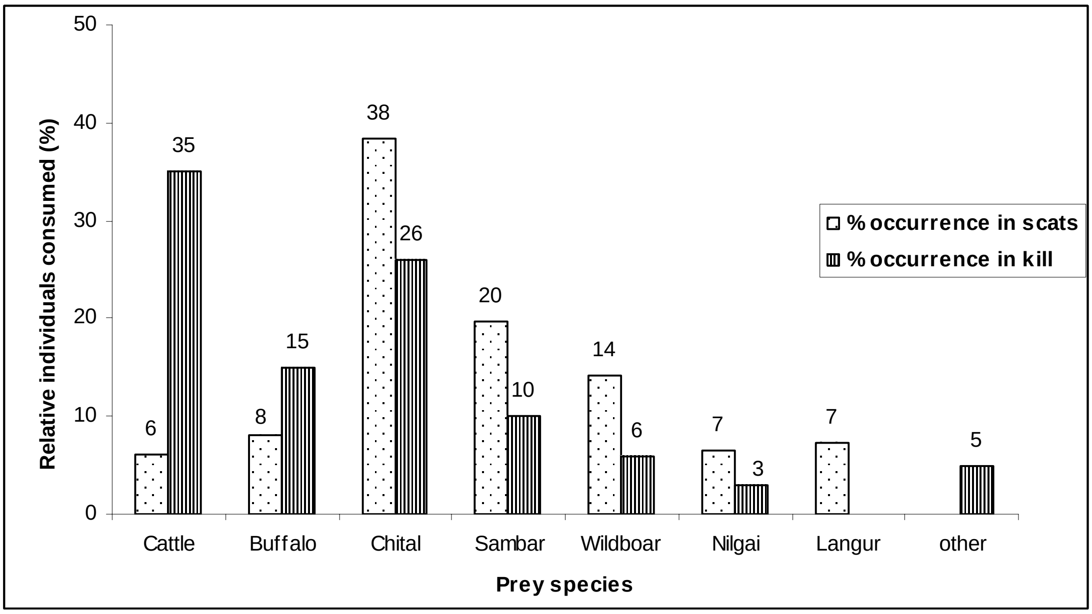


Fig. 5.1 Frequency of occurrence of prey species and diet composition of Asiatic lions (*Panthera leo*) from scat analysis (N = 314) and lion kill data (N = 258) in the Gir PA based on analysis of scat (2002 -2006)

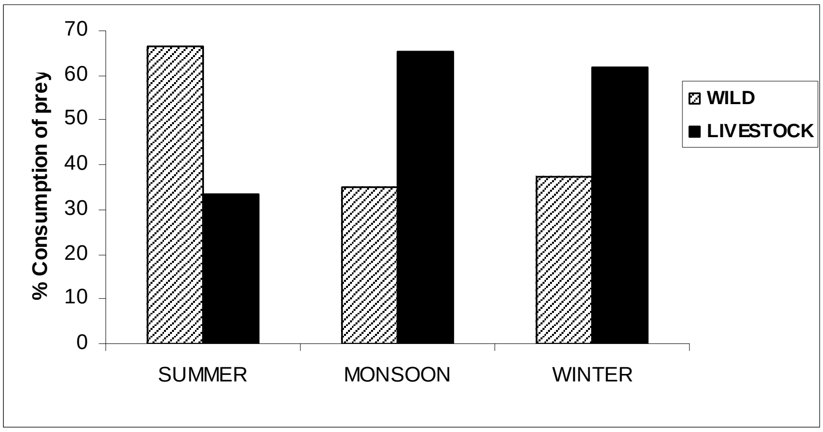
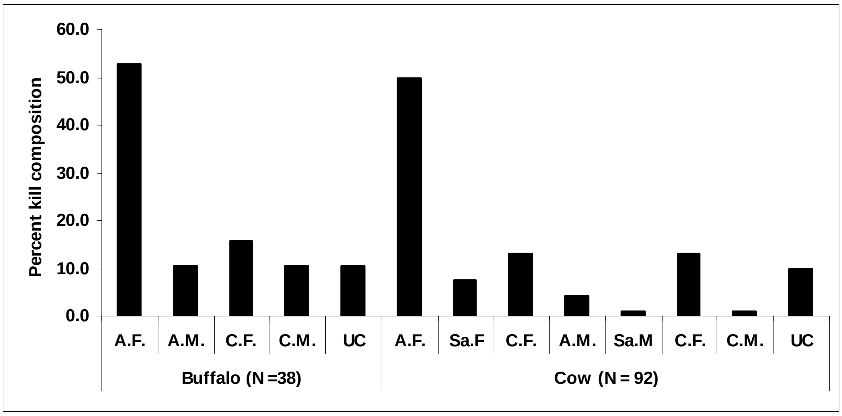
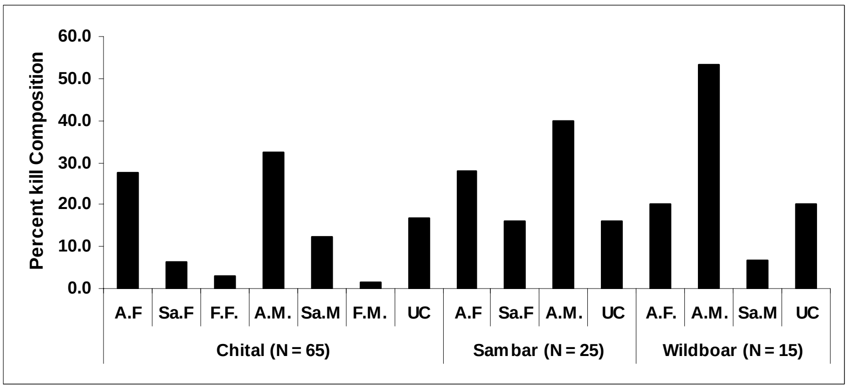


Fig. 5.2-a Seasonal diet composition of lions



5.2- b: Age-sex composition of domestic prey consumed by lions



5.2–c: Age-sex composition of wild prey consumed by lions in west and central Gir

A.F: Adult female, A.M: Adult male, Sa. F: Sub adult female, Sa. M: Sub adult male, C.F: Calf female, C.M: Calf male, F.F: Fawn female, F.M: Fawn male, UC: Unclassified

Fig. 5.2 (a-c): Diet composition and seasonal consumption of domestic and wild prey species based on lion kill data (N = 258) by Asiatic lions (*Panthera leo*) in Gir-west and National park (2002 -2006)

Table 5.1. Prey species composition of Asiatic lions (*Panthera leo*) and their relative biomass contribution in the diet in the Gir PA based on analysis of scat (N = 323)

Species	Weight (kg)	Frequency of occurrence (%)	Bootstrapped CI (95%)	Relative biomass consumed (%)	Relative number of individuals consumed (%)
Cattle	150	8.7	3 - 13	11.6	6.0
Buffalo	150	11.2	3 - 15	21.1	7.7
Chital	45	32.3	22- 41	32.0	36.7
Sambar	134	26.1	17 - 34	5.5	18.7
Wildboar	32	9.6	4 - 15	14.9	13.4
Nilgai	180	9.3	5 -16	14.2	6.2
Langur	9	1.9	1 - 7	0.8	6.8
Peafowl	5	0.3		0.1	1.9
Porcupine	8	0.6	0 - 5	0.3	2.5

Table 5.2: Prey species composition of Asiatic lions (*Panthera leo*) and their relative biomass contribution in the diet in different management zones in the Gir PA based on analysis of scat

Species	Frequency of occurrence (%)	Bootstrapped CI (95%)	Relative biomass consumed (%)	Relative individuals consumed (%)
Gir-West (N = 155)				
Cattle	11	5 - 17	14	8
Buffalo	12	7 - 20	16	9
Chital	29	21 - 39	19	34
Sambar	25	17 - 33	30	19
Wildboar	11	5 - 17	6	16
Nilgai	10	4 -16	14	7
Langur	2	1 - 7	1	7
National Park (N = 94)				
Cattle	5	1 - 9	7	4
buffalo	9	4 -16	11	6
Chital	33	25 - 43	21	40
Sambar	33	22 - 42	40	25
Wildboar	9	5 - 15	5	13
Nilgai	11	6 -18	16	8
Langur	1	0 - 5		4
Gir-East (N = 54)				
Cattle	9	5 -15	13	7
Buffalo	11	5 -16	15	8
Chital	41	30-50	27	47
Sambar	20	12 - 29	26	15
Wildboar	7	2 -12	4	11
Nilgai	9	5 -17	14	6
Langur	2	0 -1	1	7

Table 5.3 Prey species composition of Asiatic lions (*Panthera leo*) and their relative biomass contribution in the diet during summer, winter and monsoon in the Gir PA based on analysis of scat

Species	Frequency occurrence %	Bootstrapped CI (95%)	Relative biomass consumed	Relative no of individuals consumed
Summer (N=141)				
Cattle	7	2 - 12	9	5
Buffalo	10	4 -15	13	7
Chital	35	25 - 44	23	42
Sambar	25	15- 32	31	18
Wildboar	10	3 -15	6	14
Nilgai	11	4 -15	17	8
Langur	1	0 - 4	1	5
Winter (N=142)				
Cattle	8	4 -15	10	5
Buffalo	13	6 -19	17	9
Chital	27	17 - 35	18	32
Sambar	32	23 - 41	38	23
Wildboar	11	5 - 17	6	15
Nilgai	6	3 - 13	9	4
Langur	3	1 - 8	1	11
Monsoon (N=32)				
Cattle	16	10 - 23	21	11
Buffalo	6	2 – 12	8	5
Chital	44	35 - 55	29	52
Sambar	9	4 - 17	12	7
Wildboar	9	4 - 16	5	14
Nilgai	16	11 - 25	24	11
Langur	0	0	0	0

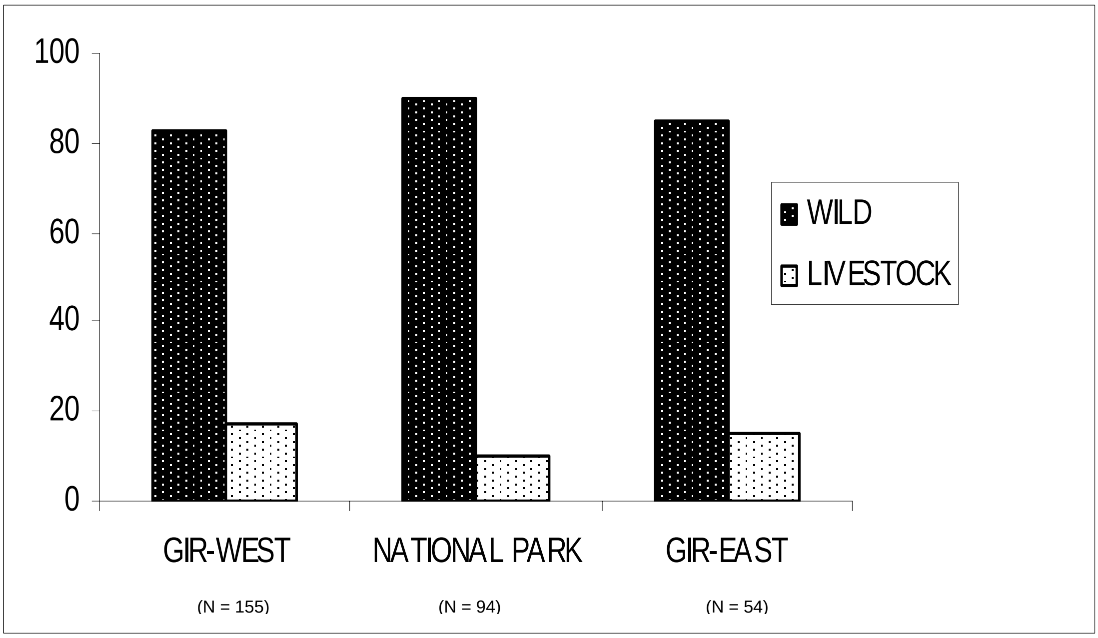


Fig. 5.3-a Proportion of wild and livestock consumed by Asiatic lions (*Panthera leo*) in different management zones in the Gir PA based on analysis of scat

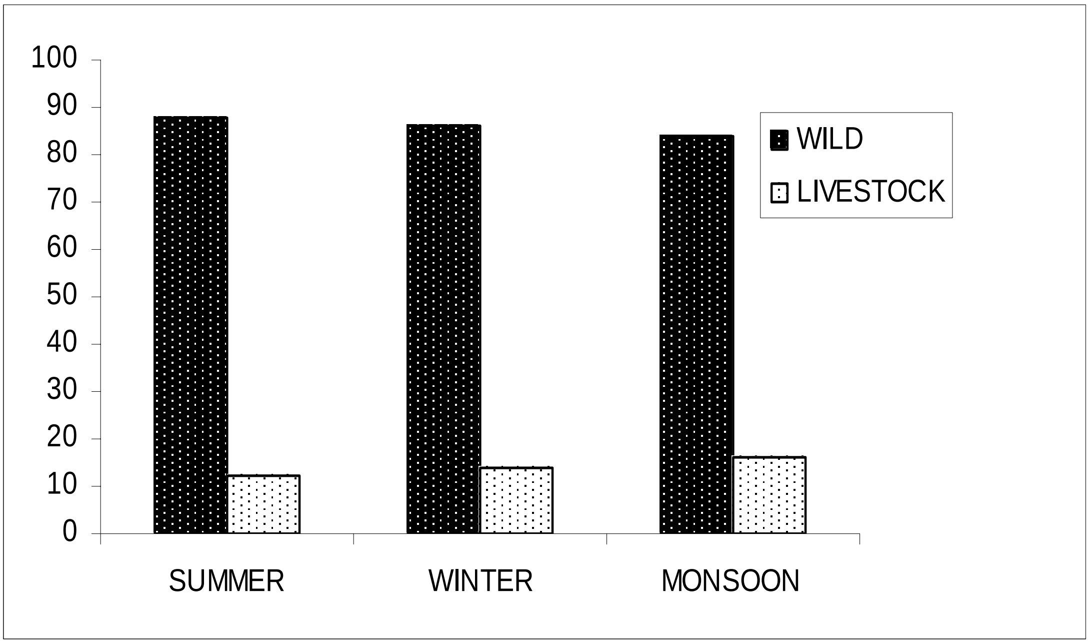


Fig. 5.3-b Proportion of wild and livestock consumed by Asiatic lions (*Panthera leo*) during summer, winter and monsoon in the Gir PA based on analysis of scat.

Results of Ness survey in west and central Gir conducted for the year 2003 -2004

Total number of settlements: 20

Number of *Maldhari* families: 165

Total population: 1408

Table 5.4: Livestock composition in different age-classes of buffalo and cattle in 20 nesses in west and central Gir for the year 2003- 2004

Park Area	No. of nesses	Buffalo				Cattle			
		<2	**SA**	**A**	**Total**	**<2**	**SA**	**A**	**Total**
Gir-west	13	317	722	1166	2205	188	92	261	541
Central Gir	7	216	562	808	1586	82	63	106	251

Table 5.5: Livestock mortality in different age-classes of buffalo and cattle relating to natural causes and predation in 20 nesses in west and central Gir for the year 2003- 2004

	< 2	S.adult	Adult	Total
Natural mortality				**125**
Buffalo	20	12	62	94
Cattle	11	0	20	31
Predation				**191**
Buffalo	15	37	50	102
Cattle	23	4	62	89

Total loss for 2003 – 2004: 361

Natural mortality: 35%

Predation: 65%

Table 5.6: Kill events during continuous monitoring of the three radio-collared males, K- male, Buathirth male (B) and Patriyala male (P) showing kill interval

ID	Monitoring Start	Monitoring End	Total days	Kill Date	Kill Time	Type	Age	Sex	Kill rate Mean (± SD)
K	10-Nov-06	19-Nov-06	8	15-11-06	17:30	Buffalo	Calf	M	
				19-11-06	16:30	Chital	Adult	F	0.25
K	19-Apr-06	23-Apr-06	5	23-4-06	19:30	Buffalo	Adult	F	0.2
B	23-Nov-06	2-Dec-06	10	26-11-06	13:55	Chital	Adult	M	
				30-11-06	4:30	Cattle	Calf	M	
				30-11-06	NA*	Buffalo	Adult	F	0.3
B	20-Dec-06	25-Dec-06	6	21-12-06	14:30	Chital	S Adult		
				25-12-06	NA*	Cattle	Adult	F	0.3
P	24-May-06	1-Jun-06	9	24-5-06	18:00	Sambar	Adult	M	
				31-5-06	4:00	Sambar	Adult	F	0.2
Mean kill rate for male lions								**0.26 (0.055)**	

Note:* - Not Kills but scavenging events

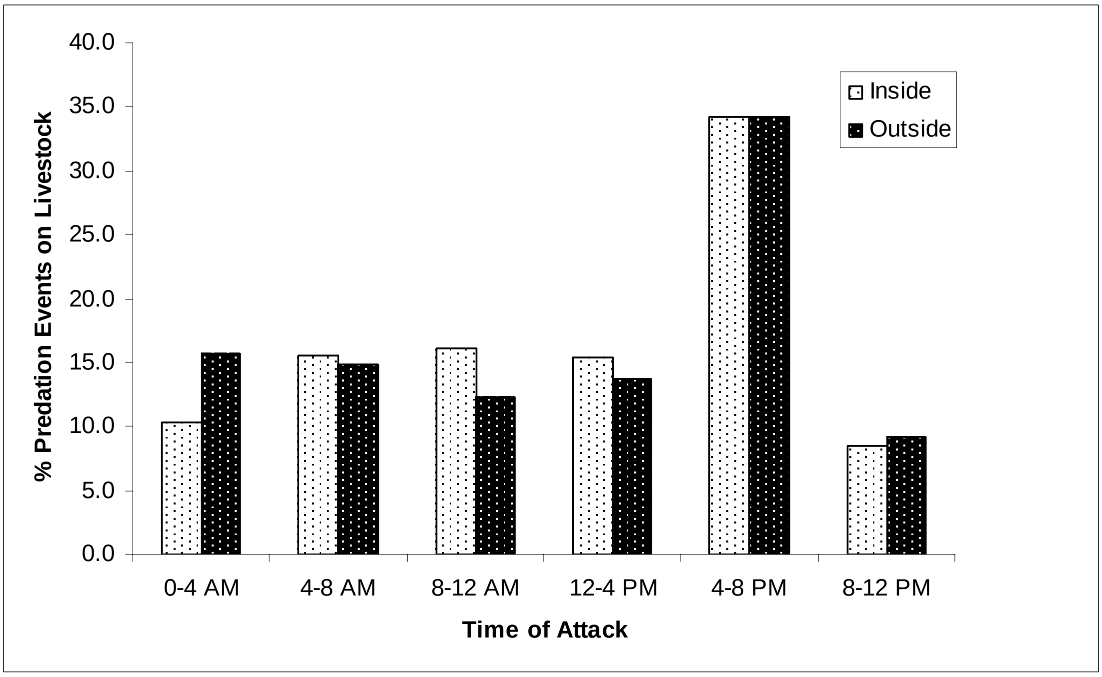


Fig. 5.4: Proportion of livestock attacks by Asiatic lions in different times of day: within (N = 436) as well as outside (N = 1130) the Gir PA in the year 2007

Table 5.7: Time of livestock attack by Asiatic lions within and outside the Gir PA in the year 2007

Time period		**Inside sanctuary (N = 436)**		**Outside sanctuary (N = 1130)**	
From	To	total	%	total	%
0:00	2:00	7	1.6	59	5.2
2:00	4:00	38	8.7	119	10.5
4:00	6:00	35	8.0	102	9.0
6:00	8:00	33	7.6	65	5.8
8:00	10:00	39	8.9	75	6.6
10:00	12:00	31	7.1	64	5.7
12:00	14:00	26	6.0	36	3.2
14:00	16:00	41	9.4	119	10.5
16:00	18:00	100	22.9	251	22.2
18:00	20:00	49	11.2	136	12.0
20:00	22:00	15	3.4	56	5.0
22:00	0:00	22	5.0	48	4.2

5.5.2 Movement and territory defense

Roaring, spraying, scraping and defecation were the different forms of territory advertising among adult males. Marking (spraying urine) was the most common way of advertising territory followed by vocalization. The frequency of scraping and defecating was relatively rarer. While in a single patrolling event, territorial males were observed to mark a maximum of 21 times, nomadic males did so only twice during the entire day.

Ten independent patrolling events of four male coalitions showed that males covered an average of 2.5 km (0.41 – 4.5 km) distance during a patrolling event. Both coalition partners participated equally in patrolling and advertising their territory and often marked at the same spot. Patrolling occurred during early morning and late evening (Fig 5.9).

Distance moved between two successive days was calculated for a period of one month was derived from GPS downloads in the case of sub adult males. The subadult males before they became territorial moved an average (±SD) distance of 3.6 (±2.9) per day and their daily movement ranged from 0.3 –13 km in a day.

Based on two sessions of continuous observation totaling 132 hours, frequency of vocalization was deduced for two territorial males. Vocalization happened during early morning hours from 12:00 to 9:00 a.m. when the animals were stationary and occurred infrequently while patrolling. Maximum vocalization was between 2:00 to 6:00 hours and another bout followed between 8:00 to 9:00 a.m. The average (±SD) roaring events per individual was 2.7(±1.3) per hour and there could be a maximum of four vocalizations per hour. This was based on three monitoring sessions of territorial males of 18 days totaling 47 vocalizations. Each individual in a coalition roared about 13 times in a day whereas a nomadic male vocalized only three times during the day (11 monitoring days). In addition, on two occasions the lone male kept very silent and motionless in the presence of other coalition males. In the event of mating, males did not vocalize at all during a 24-hour monitoring period. Typically, during the stage when the mating pair establish, the male is observed to roar after the first few mating bouts and again towards the end of the mating period, the male begins to vocalize and joins the coalition partner and resumes patrolling the territory.

Time activity

A total of 1356 scans of about 700 hours of observation on the three collared males, namely adult K-male which was territorial and part of a two male coalition, Buathirth male was also a two-male coalition territorial male. However, this male lost its partner in June 2006, continued to range in its territory and became nomadic in May 2007. The third radio-collared males was the Patriyala male also part of a two male coalition. Three day-night monitoring sessions of K-male, four sessions of Buathirth male and one session of Patriyala male totaling about 181, 335 and 165 hours of observation on each of the males respectively.

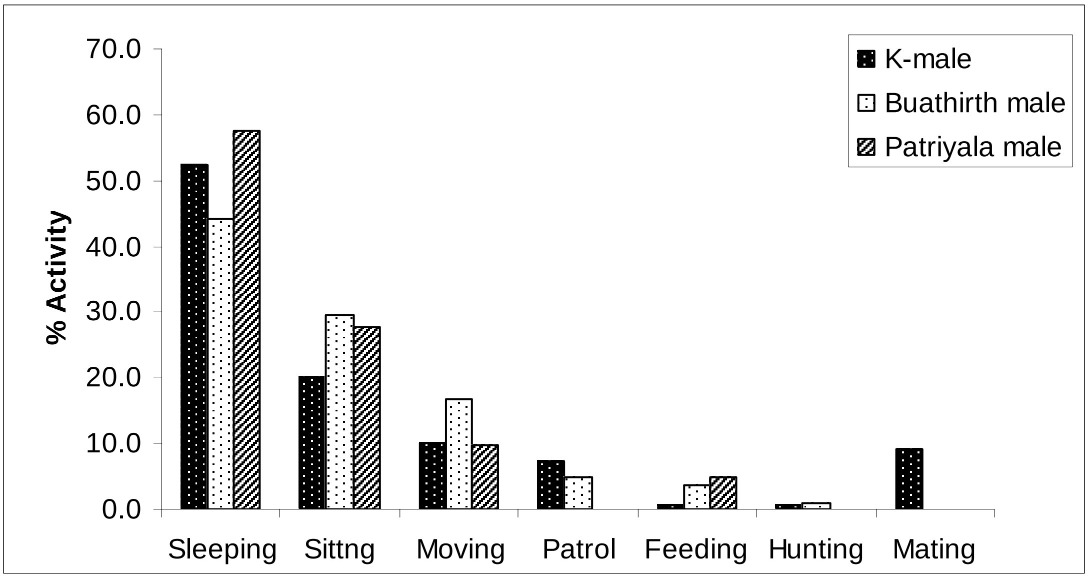


Fig. 5.5: Proportion of time spent in various activities in the day by three collared males including two adult males, K-male (N = 360), Buathirth male (N =669) and sub adult Patriyala male (N =327) based on scan samples during continuous monitoring

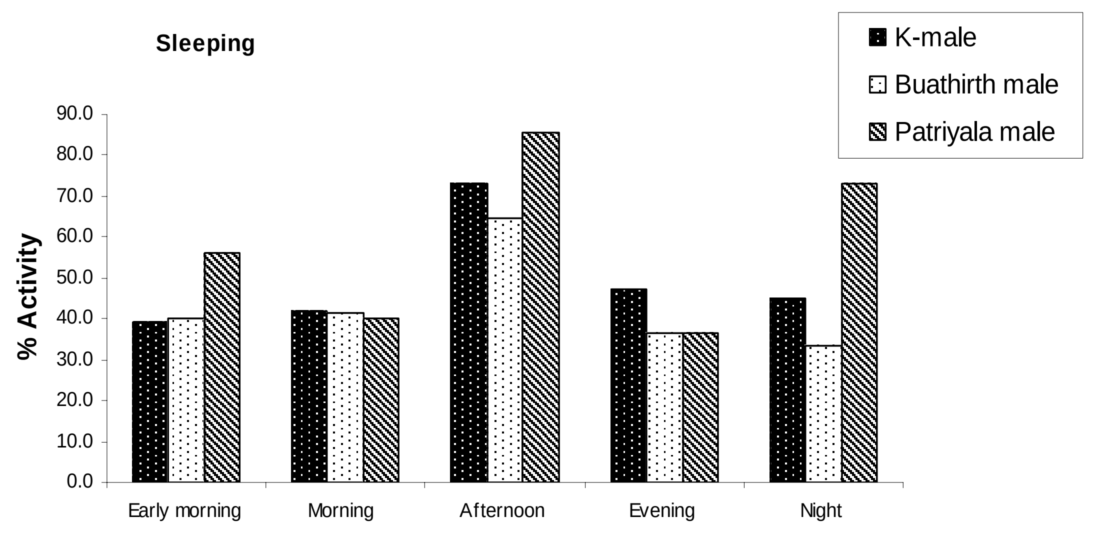


Fig. 5.6: Proportion of time spent ‘sleeping’ by two adult males- K-male (N = 189) and Buathirth male (N =295) and one sub adult Patriyala male (N =188) based on scan samples during continuous monitoring in different times of day - early morning (0:00- 5:30), morning (6:00 -11:30), afternoon (12:00 -16:00), evening (16:30 – 20:00) and night (20:30 – 23:30)

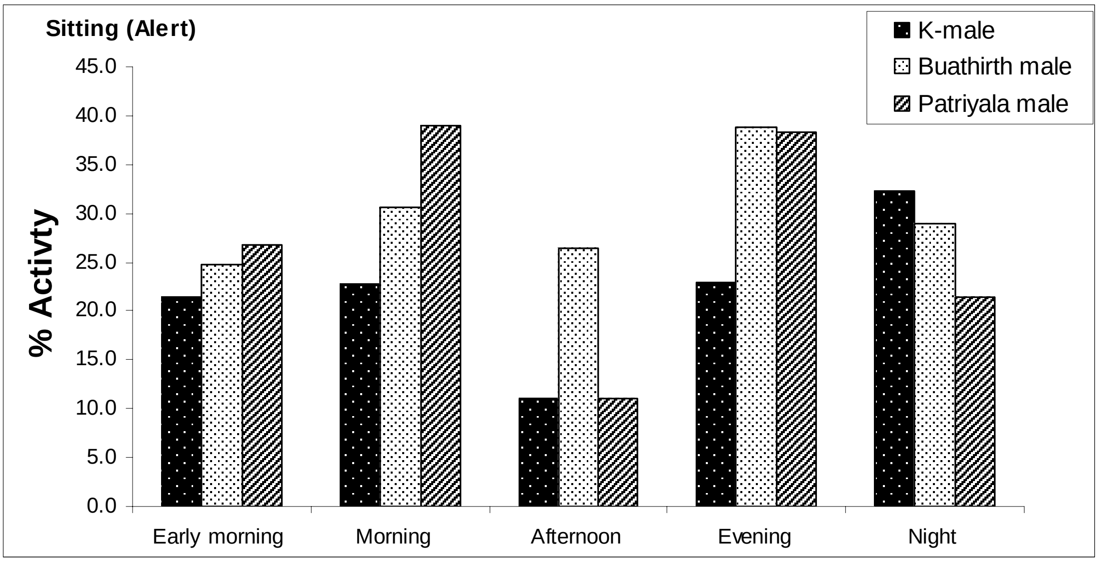


Fig. 5.7: Proportion of time spent 'sitting' by two adult males- K-male (N = 72) and Buathirth male (N = 198) and one sub adult Patriyala male (N = 91) based on scan samples during continuous monitoring in different times of day - early morning (0:00-5:30), morning (6:00 -11:30), afternoon (12:00 -16:00), evening (16:30 – 20:00) and night (20:30 – 23:30)

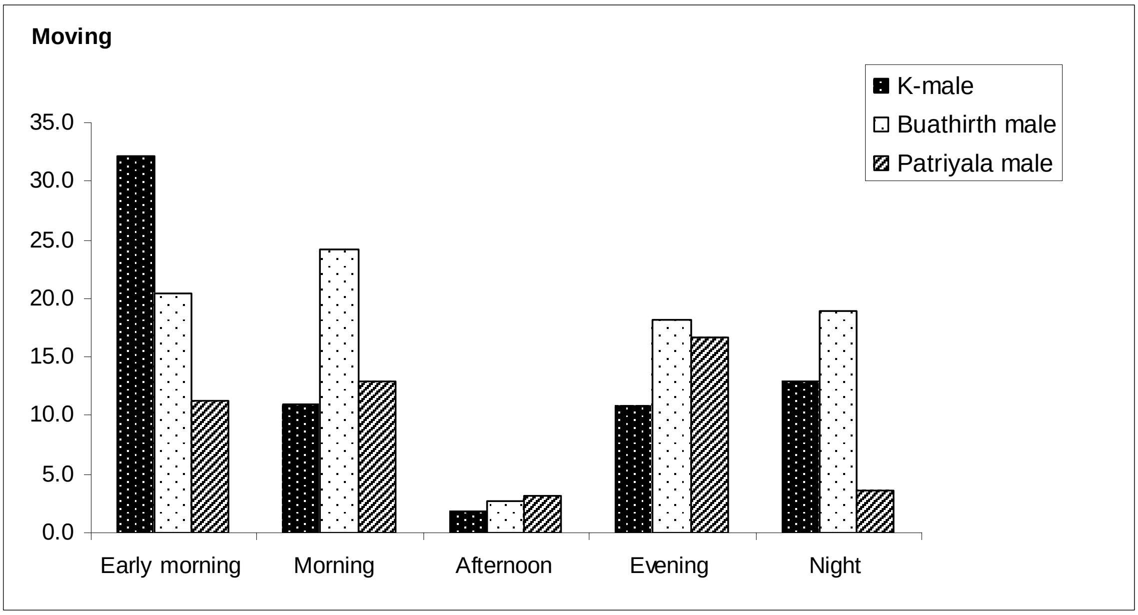


Fig. 5.8: Proportion of time spent 'moving' by two adult males- K-male (N = 36) and Buathirth male (N = 113) and one sub adult Patriyala male (N = 32) based on scan samples during continuous monitoring in different times of day - early morning (0:00-5:30), morning (6:00 -11:30), afternoon (12:00 -16:00), evening (16:30 – 20:00) and night (20:30 – 23:30)

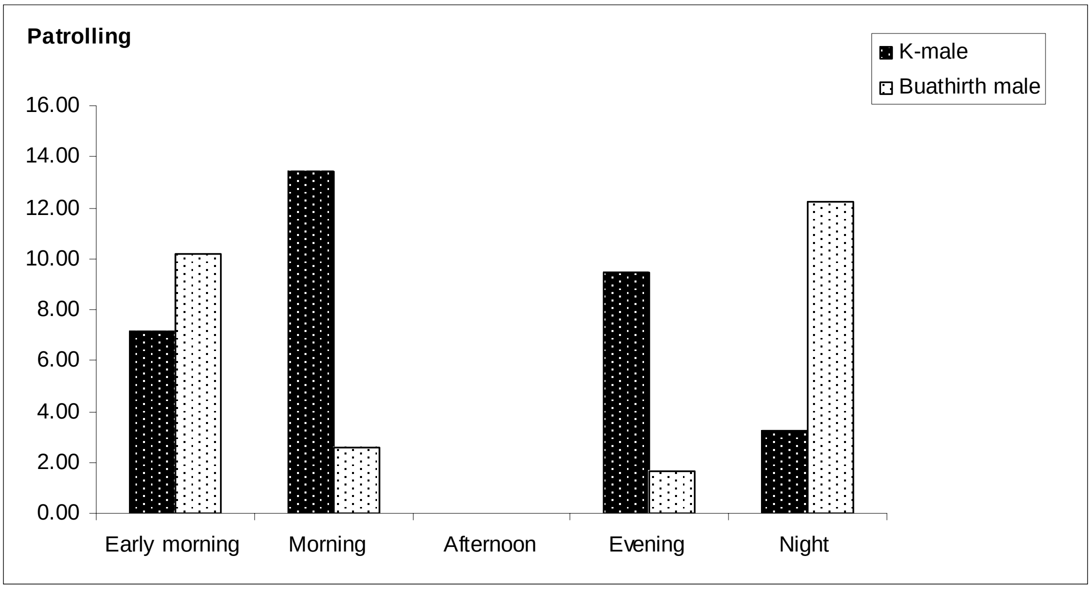


Fig. 5.9: Proportion of time spent 'patrolling' by the two adult territorial males, K-male (N = 26), Buathirth male (N = 33) based on scan samples during continuous monitoring in different times of day - early morning (0:00- 5:30), morning (6:00 - 11:30), afternoon (12:00 -16:00), evening (16:30 – 20:00) and night (20:30 – 23:30)

5.6 Discussion and Conclusion

Daily Activity: Lions were found to be active 41% of the occasions when they occurred in small groups (Hayward and Hayward 2006). However, Gir lions spend a large amount of time resting (Fig. 3.4) as reported elsewhere (Hanby et al.1995). Lions spent 80% of their time resting and less than 1% of their time in activities in marking and patrolling in Ngorongoro crater as well as Serengeti Plains (Hanby et al.1995). Although the categorization of lion activity slightly varied, in comparison to the above study, it appears that Asiatic lions spent greater proportion of their active time in moving and patrolling (Fig. 5.5). The coalition males did not spend any time in socializing with other lion groups except when associating with oestrous females (pers. obs). Minimum time was spent in hunting and feeding (Fig. 5.5). Though all males spent all times of day sleeping or resting (Fig. 5.6) there seemed to be some difference in the proportion of time spent sleeping between adult and sub-adult males during different times of the day (χ^2=17.5, df = 2, p< 0.0001). The sub-adult spent a greater proportion of the night and early morning time sleeping when the adult males were active (Fig. 5.6). The reason for this apparent difference in activity time could be because sub adults, nomads and subordinate coalitions are known to temporally vary their activity time in order to minimize agonistic interactions with dominant males (Hayward and Hayward 2006).

Movement: The distance covered by lions in a single day varies in different areas. In areas of prey abundance, distance moved by lions belonging to prides varies from 5 to 6.5 km per day. However, in Kalahari, where prey density is low, lions move about 11 – 26 km per day. In Etosha, where there is seasonal variation in prey availability, lions walked an average of 13.2 km per day (N = 76, SD = 4.9, SE = 0.56, range 0 -29.6) (Stander 1991). Social status of the lion is another factor determining movement of lions. In Serengeti, nomads were less sedentary than residents (Schaller 1972) and covered an average of 12 km per day. In areas where male lions are not constrained by the presence of other adjacent coalition males they tend to roam and cover large distances (Loveridge 2002). They are known to cover as much as 80 km in two days (Loveridge 2002).

An earlier study of the Asiatic lion, assessed movement and home range of lions based on intensive monitoring of two prides and one male (Sinha 1987). Two prides consisting of four and three lionesses respectively were each associated with a two-male coalition (Sinha 1987). Approximate estimate of movement and range of individually identified animals showed that adult males covered a maximum of 15 km in a day and an average distance of 3 km per day while adult females covered a maximum of 12 km in a day and an average distance of 2 km per day (Sinha 1987). The present study used a more rigorous field schedule and used GPS tracking device and analysis in GIS domain to calculate distances moved. Territorial male covered a maximum distance of 4.5 km in a single patrolling event. Sub-adults covered up to 13 km in a day.

The Buathirth male became nomadic, held territory from July 2007 to May 2008 after losing his partner (Chapter 4, Fig. 4.6). The male dispersed from this area on May 2008 to Raval Dam area in Gir-East and showed erratic and random movement for the next one week (Fig. 5.10). During this time, the male was attacked by the resident males showing that males although may tolerate overlap with adjacent ranges are intolerant to nomads within their range.

Patrolling behaviour: Patrolling (roaring and scent marking) can be summarized in three ways: i) Proportion of time spent in patrolling as compared to other daily activities ii) Frequency (event/individual/hour) iii) duration of the patrolling event. In the case of Asiatic lions, females were never observed to patrol or advertise their territory and were observed to roar or mark only during oestrous. This conclusion was drawn from the mating episodes that followed. On the other hand, in the Serengeti plains and Ngorongoro crater, females showed patrolling behaviour (Hanby et al.1995). However, males roared and marked more frequently than females and in terms of frequency, these behaviours were related to prey availability (Hanby et al. 1995).

In Gir, during early morning and night adult males vocalized and patrolled their area (Fig. 3.8). This time appears to be avoided by sub-adults and they were never observed to patrol or vocalize. The sub-adult males were monitored from December 2005. In May 2006, the sub-adult males began to vocalize infrequently and the roaring was yet incomplete and unlike adult males which are characterized by an average of 9 (4 -18) roars followed by 15 (0 – 57) grunts lasting for 20 - 40 seconds (Joslin 1973, Schaller 1972).

Territorial K-males spent 63% of their active time (excluding the time sleeping or sitting) in actively patrolling, vocalizing and moving through their territory. One patrolling event associated with scent marking on an average (±SD) lasted for 2.13 (±0.9) hours (0.8 – 3 hours, N = 6). One vocalization event lasted for 6.5 hours (N = 2) associated with roaring and roaring at the rate of 2.7(±1.3) per hour.

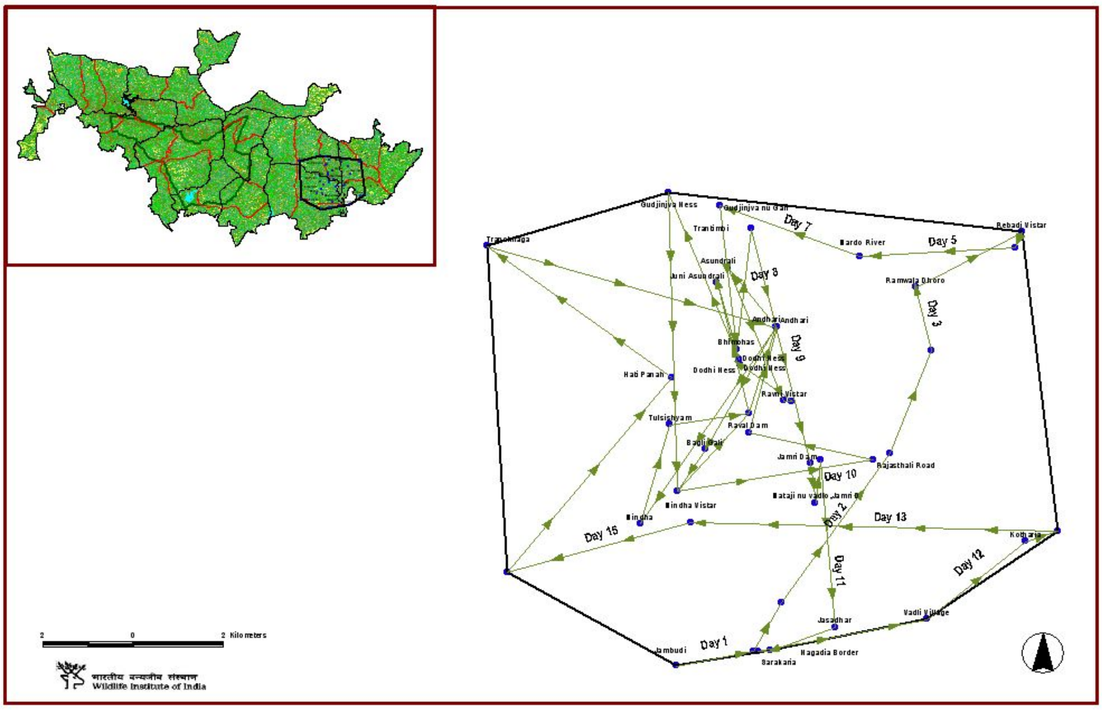


Fig. 5.10: Nomadic movement of radio collared Buathirth male following dispersal to Gir –East from 29.04.07 to 13.05.07

The activity of Asiatic lion varies across the day (Fig. 5.5 – 5.9) and they can be described as being both crepuscular and nocturnal based on their activity patterns. In summary, territorial males were observed to start vocalizing in the early morning period when they were largely stationary. They begin to start moving and patrolling in the morning hours (6:00 – 8:00 a.m.); towards late morning (10:00 – 11:00 a.m.) they rest and in the evening, from about 6:00 pm they resume patrolling the area and move through the night.

Hunting and feeding: Males did not actively hunt and did so opportunistically when they came across prey. Males made kills all times of day (Table 5.6, Fig. 5.7) and most successful in attacking livestock in the evening time when they were grazing rather than when they were kept enclosed in stockades within the ness (Table 5.6). Continuous monitoring of lions revealed that lions made one kill in every 3-4 days (Table 5.7). There was a significant seasonal variation in the diet based on the kill data. This is because during summer, when water sources are localized it is easy to prey on wild ungulates congregating around the waterholes. Diet composition based on scat analysis did not reveal substantial seasonal variation (Fig. 5.3b)

Knowledge of predator diet is crucial for their management (Hayward et al. 2006). The ability to predict response of predators to changes in prey abundance is vital for the success of conservation initiatives (Hayward et al. 2006). Assessment of diet of the Asiatic lion too has important management implications. Hence, three studies on lions have focused on diet composition (Joslin 1973, Sinha 1987, Chellam 1993). With implementation of conservation programs and livestock regulation, lion diet has progressively shifted from a diet predominantly consisting of domestic prey to consumption of greater proportion of wild prey. Across the time period of the above studies, the diet of the Asiatic lions varied. Scat analysis revealed that livestock formed 75% of prey consumed during the first study (Joslin 1973). However, during the subsequent period wild prey formed 75% of prey consumed (Chellam 1993).

In the present study, kill data revealed a greater proportion of cattle in the diet. On further examination, these kills were found to be located largely in the revenue areas and peripheral areas of the park. Compared to the revenue areas surrounding the park, there were fewer attacks on livestock within the park (Table 3.7). The proportion of predation on cattle is much less in the lion diet deduced through scat analysis as there is a significant difference in the livestock uptake within and outside the park. The forest department records also reveals that while the average livestock lost to predation within the sanctuary is 45 per month, the average predation outside the sanctuary is 89 per month (Pathak et al. 2002). This is because within the park, the *Maldharis* have fewer cattle than buffalo (Table 3.7). It is also important to note that the livestock population in the 97 peripheral villages of Gir is 94,582 and livestock population of the *Maldharis* residing in the park is 12,334 (Pathak et al. 2002). Besides, kill data tends to be biased towards large bodied prey and particularly to domestic prey, when kill location information is from secondary sources. This may explain the disparity between the results from the kill and scat data (Fig. 5.1).

Livestock depradation continues to be a major issue of conflict between the local communities and the Asiatic lion population (Saberwal et al. 1994, Pathak et al.2002). For instance, the annual loss of domestic livestock to lion and leopard predation was 9,596 for the year 2000-01(Pathak et al. 2002). The average number of livestock killed by lions and leopards in and around Gir from the period 1995 to 2002 is 134 per year (Pathak et al. 2002). Based on this study, domestic prey contributes more than

56% of the lion diet based on the kill records. Chital was the most common wild prey consumed. Lions also feed on small prey such as peafowl, porcupine and mongoose. Cannibalism has been reported in lions (Eloff 1984) and was also observed in Asiatic lions. Lions were observed to scavenge on dead carcass and also to snatch kills from leopards.

Results of the scat analysis revealed that livestock contributed about 14% of the lion diet within the park in terms of the relative number of individuals consumed. However, the analysis also revealed that domestic prey contributed to 27% of prey biomass consumed. Lions preferred prey in the adult age class (Fig. 5.2 b-c) and a showed a preference for large-sized prey. In captivity, Asiatic lions (average body mass 100 kg) fed on buffalo meat and consumed 6% of their total body mass (Mukherjee and Goyal 2004). Lions are known to preferentially prey upon species of an average of 350 kg within a range of 190 – 550 kg (Hayward and Kerley 2005). The present study showed that livestock is still a significant part of the diet of lions with proportion of intake varying in different parts of the park and proximity to the revenue villages.

The fact that lions predominantly consume wild prey viewed in isolation could be seen as a management success. However, from the Maldharis' point of view, livestock depradation causes significant economic loss contributing to 65% of the annual livestock mortality. "Even one cow in a hundred would be one too many if it happened to your cow, and the loss of livestock can have severe emotional, political and financial costs" (Macdonald and Sillero-Zubiri 2002) – aptly summarizes the sentiments of the local community. Although the management offers compensation there are yet many inadequacies with regard to this scheme (Saberwal 1994). It appears that livestock depradation is an issue that is bound to exacerbate in the future with lions increasingly dispersing from the park boundaries and straying to adjoining forest patches, revenue and agriculture loss with a decreasing tolerance for predators by local communities (Saberwal et al. 1994).

This study was limited by the number of radio-collared animals and the functioning of the collars as a result of which behaviour data could not be collected adequately enough to conclude on many aspects of the hypothesis on adult male territorial behaviour. However, since this was the first study on Asiatic lion that was designed to collect behaviour data based on standard protocols, many interesting facets of male lion behaviour have come up. The objectives of the chapter were to answer the following questions: What proportion of the daily activity time did adult males spend on patrolling territory? What time of day were lions most active – are they diurnal, nocturnal or crepuscular? Is lion activity influenced by prey and do lions predominantly feed on livestock? How much distance do male lions, belonging to different social status, walk in a day?

The Asiatic lions spent a large proportion of their time resting and were largely crepuscular and nocturnal in activity. The territorial males spent major part of their active time in patrolling. Nocturnal activity was not related to livestock depradation, as concluded from previous study. Rather, livestock attacks were most frequent in early morning and dusk while the domestic prey were moving to and from nesses and the grazing grounds. Inside the protected area, wild prey formed major part of the diet. Livestock contributed significantly to the lion’s diet in the peripheral areas and outside the protected area boundaries. The sub-adult males slightly varied from adult territorial males in their activity and were not territorial.

Chapter 6

Male Strategies

6.1. Male Reproductive Strategy

"Breeding in lions is intimately connected with their social organization" (Bertram 1978) Lions are social felids and group territoriality (Bygott et al. 1979; McComb et al.1994, Grinnell et al. 1995, Heinsohn et al. 1995), group hunting (Scheel and Packer 1991, Stander 1992) and communal cub-rearing (Pusey and Packer 1994) form the basis of cooperation. Lion social groupings are determined by patterns of territoriality and relatedness (Loveridge 2002). Lions exhibit behavioural flexibility and their socioecology is strongly influenced by the ecology of the area (Funston et al. 2003). "Lion social systems can be regarded as strategies that have evolved through which individual fitness is maximized under various environmental restraints." (Sunquist 1981).

In the East African system, the sub-adult males tend to disperse long distances and go through a brief nomadic phase before acquiring territories (Schaller 1972, Hanby and Bygott, 1987, Pusey and Packer 1987) and finding a partner often entails years of nomadic existence (Schaller 1972; Pusey and Packer 1987). Competition between males is intense and the reproductive success of solitary males is typically low (Bygott et al. 1979, Packer et al. 1988). Females give birth synchronously so as to ensure that their offspring leave the natal territory together with other cubs born in the same pride (Bertram 1975) so that a large cohort of dispersing sub-adults would have higher fitness and a better chance of survival (Packer and Pusey 1987). Male lions provide a valuable opportunity to test evolutionary models of cooperation and three factors influence the tendency to cooperate within pairs or groups: a low probability of success when alone, a low probability of replacing the current partner and a large number of interactions before the end of the association (Grinnell et al.1995).

Male lions cooperate to maintain exclusive access to groups of females (Bygott et al. 1979; Packer et al. 1988). Distribution of females determines space use by males. Male-male competition for access to fertile females should lead to differential male reproductive success. Therefore, the way mate-resource is shared during the tenure is an important aspect of the coalition tenure (Bertram 1975). Males would have to optimize their reproductive success within this defined period of their life and would therefore have to invest a lot on territory defense (Bertram 1975).

Coalition formation and subsequent takeover and control of pride females are important determinants of male reproductive success (Packer et al. 1988). However, the reproductive fitness depends on the nature and size of the coalition. Larger coalitions are more likely to gain residence in a pride, remain in residence longer and gain access to more females than do small coalitions (Bygott, et. al. 1979, Pusey and Packer 1987). Large coalitions can also maintain residence for longer periods and sire greater numbers of surviving offspring than small coalitions (Bygott et al. 1979; Packer et al. 1988). However, the individual reproductive success of coalition partners becomes increasingly skewed with increasing coalition size (Gilbert et al. 1991; Packer et al. 1991). Therefore, a male would be part of a small coalition if his individual mating success is ensured or would prefer to be a part of a larger coalition if that at least ensures the inclusive fitness of the group by enhancing the reproductive success of his closely related brothers (Packer et al. 1988, Packer et al. 1991, Gilbert et al.1991). Although female pride-mates are always close relatives, male coalitions are often composed of non-relatives as well as close kin (Packer et al. 1991). It has been observed that large coalitions consist of closely related males while smaller coalitions are those of non-relatives (Packer et al. 1991).

The Kruger ecosystem is in contrast to the East African system (Serengeti and Ngorongoro Crater) and sub-adult males exhibit a markedly different dispersal pattern. A similar dispersal pattern is seen in Selous Game Reserve, Tanzania (Spong 2002). Sub-adult have a prolonged period of association with the natal prides and also acquire territories closer to the natal ranges (Funston et al. 2003). Pride males defend territories rather than prides and gain access to adjoining prides and sire more cubs (Funston et al. 1998). In other areas, fewer male coalitions in relation to prides result in extensive, unrestrained movement of male lions between prides (Loveridge 2002, 2007).

Thus, the patterns of cooperation and group formation are different for different areas. This study addressed the reproductive strategies of Asiatic male lions of the Gir PA and addressed the following questions:

1. What is the nature of social bonding in Gir lions?
2. How does demography (population parameters) relate to male strategy?
3. Do males move with respect to female resources?
4. How much time does a male spend in vocalization and other ways of marking or declaring his territory?

5. How long is the coalition tenure of males and how frequently are they challenged?
6. How are the mating opportunities shared among the coalition partners?
7. What is the relationship between the coalition partners?

The answers to the above questions are based on the preceding chapters and interpreted in terms of male life history strategies. The last three questions could not be adequately addressed owing to problems relating to radio-telemetry.

Social structure of the Asiatic lions: Males and females form weak bonds and associate only at the time of courtship and mating. Only 12% of the total (N = 521) sightings were of male-female associations. Males exist in ratio of 76.4 males to 100 females and in the intensive study area there were eight females to three male coalitions (5 males). Thus, males defended 2-3 prides and tended to defend territories rather than prides.

Male ranging: Females showed stronger relationship with habitat features. Males had a much larger range than females and there was considerable overlap between male ranges. These were tested by overlaying the 100% followed by 50% home ranges. In order to explain the overlap, female core areas were overlaid on the observed male ranges. Interestingly, the ranges overlapped in the area where the female core area was concentrated (Fig. 6.1a & b). It is evident that movement of males was related to the areas where females where concentrated. Apparently there was a temporal separation of the males and unfortunately this could not be tested in the field. As a result I had to resort to simplistic interpretation of field data.

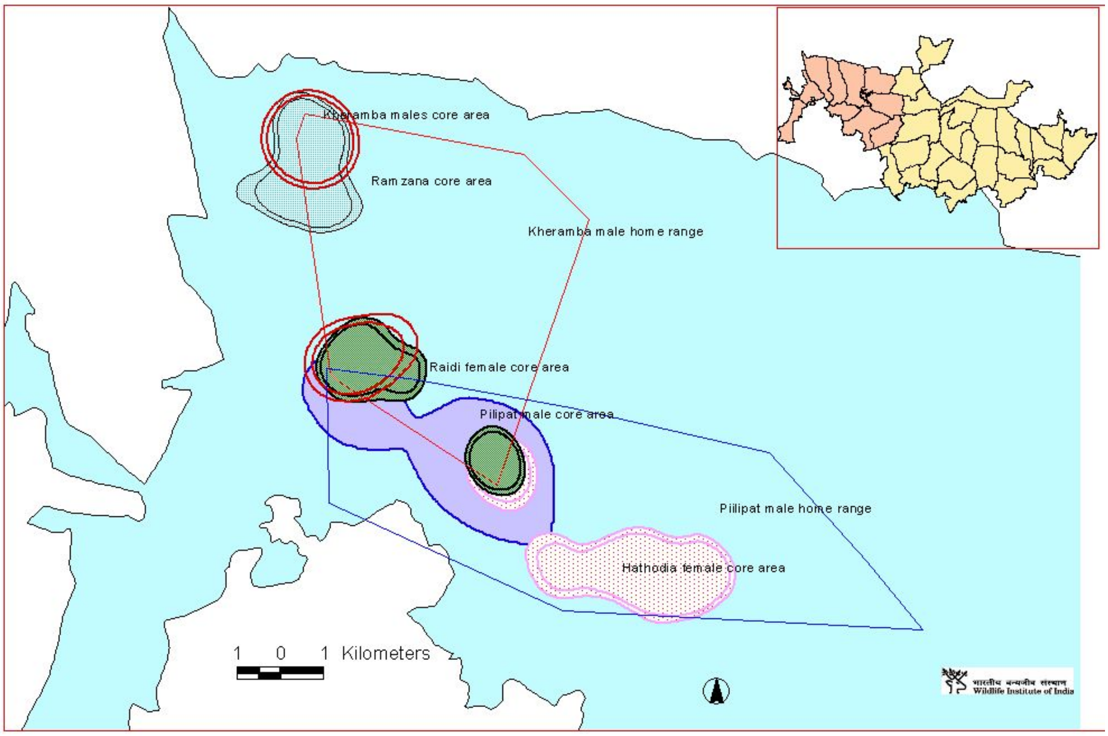


Fig. 6.1-a: Home-range of two males and three female lions showing range and core area overlaps. The male ranges tend to overlap in core areas of females.

Territorial behaviour: Males actively patrolled and defended their territories. They patrolled their territories during dawn and dusk. Peak vocalization occurred during the early morning hours and less during the patrolling. This indicates the males are advertising their presence during the active part of their day. Territorial K-males spent 63% of their active time (excluding the time sleeping or sitting) in actively patrolling, vocalizing and moving through their territory. A single patrolling episode associated with scent marking on an average (±SD) lasted for 2.13 (±0.9) hours (0.8 – 3 hours, N = 6). A vocalization episode typically lasted for 6.5 hours (N = 2) associated with roaring at the rate of 2.7(±1.3) per hour.

Mating Opportunities: Of the two coalition partners, the one to first approach the oestrous female tended to consort with the female during the entire mating period. The coalition partner was found in the vicinity of the mating pair majority of the time (Fig.: 6.2)

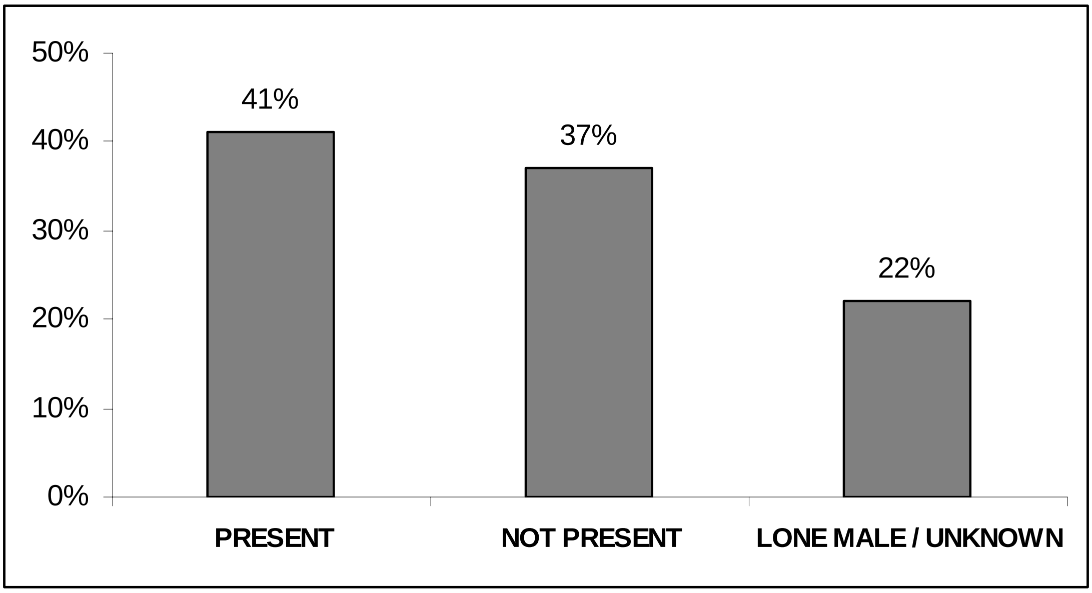


Fig. 6.2: Presence of coalition partner (N = 51) during mating in the Gir PA from 2002 -2006

Sometimes, an oestrous female followed by the mating male walks towards the associate male and the latter has to move away quickly or he is liable to be attacked (Betram 1978). On three occasions this occurred while observing the collared male.

Genetic relationship: The coalition males share their mating opportunities and also risk their lives in territorial fights unmindful of the participation of the group members (Spong 2002, Heinisohn and Packer 1995). The most important aspect or measure of the reproductive strategy of the coalition males is the relationship between the coalition partners. It would be interesting to see if the partners were siblings or close relatives. However, this objective could not be addressed in this study due to several limitations.

6.2. Conclusion

Thus, male Asiatic lions form small coalitions of 2-3 males that include ranges of 2 or more prides. They form weak bonds with females, associating only at the time of mating. Ranges of adjacent coalitions overlap considerably. The overlap occurs in the areas of intensive use or core areas of females. There seems to be equal mating opportunities for both males. Territory advertisement is an important activity of males.

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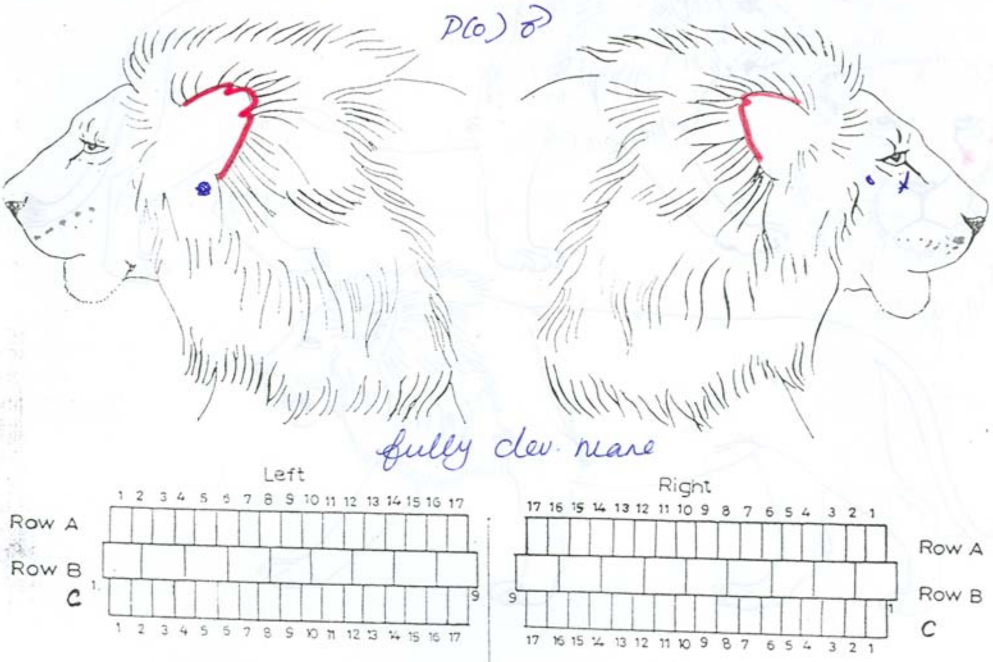
Appendix-I

1. Name of Scientist:
2. Study Area:
3. Climate:
4. Vegetation type:
5. Cover (open, medium, dense)
6. Aspect of study (topic)
7. Estimate of lions in the study area:
8. Density of lions:
9. Other carnivores:
10. Competion among carnivore:
11. Prey species diversity: Biomass:
12. Prey availability: nomadic, migratory, resident
13. Livestock:
14. Livestock up take High: Low:
15. Lion Group size
16. Male group size
17. Female group size
18. Male interaction with female Occasional: throughtout tenure:
19. Any other details about lion social organization you are willing to discuss
20. Other parks for which you would be able to provide the above information

21.2.06
6:00pm
Alladal kutiya Devkanya

(139)

D(o) ♂



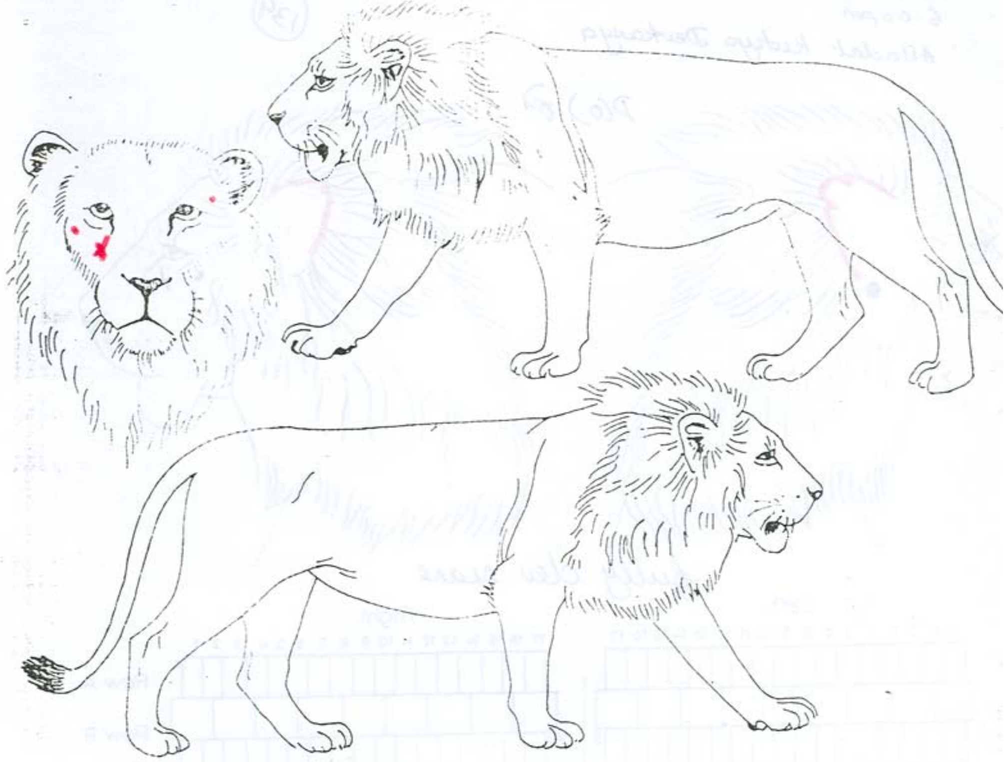
fully dev. mane

A = 0
B = 6
C = 4½, 5½

A = 0
B = 6 (2 close spots not coun
C = 3,4 - like extensions or scratches in B-row

Remarks:
17.03.06 - recapture.
22.3.06 "

new



Appendix- III

Table showing details on ness survey conducted in intensive study area in 2005

		BUFFALO							COW						
NESS	MEMBERS	<2	S A	ADULT	LF	NLF	P	m	<2	S A	ADULT	LF	NLF	P	m
khada	22	19	24	51	16	10	2	0	2	0	0	2	0	0	0
Kadeli	18	18	29	50	9	5	36	3	1	2	2	1	0	1	0
Dudala	40	24	66	95	18	24	53	3	13	4	11	9	0	2	2
Barwania	50	11	85	71	23	10	39	2	14	1	17	10	6	1	1
Amrutvel	88	22	45	87	33	23	31	10	8	8	11	2	1	8	6
Siruvang	119	3	18	42	18	3	21	1	27	2	15	6	4	5	16
Jamutala	113	20	27	74	23	12	39	7	11	14	24	6	5	12	12
Katithar	15	14	52	64	30	16	28	4	6	11	9	6	0	3	6
Dadia	91	37	69	102	26	25	51	13	16	8	11	6	2	3	2
Navi alalvani	113	40	88	134	36	39	59	8	22	12	45	18	13	14	5
Juni alalvani	102	32	64	141	61	22	58	13	17	13	26	12	5	7	0
Gangajaria	141	46	83	143	60	9	73	8	32	7	69	34	5	23	1
Kasia	106	31	72	112	48	34	30	5	19	10	21	11	1	9	0
Biliat	38	11	25	75	32	3	40	3	0	0	0	0	0	0	0
Goradvara	48	30	102	136	24	33	83	1	9	6	10	3	6	1	0
Jamwali	25	10	33	30	12	3	15	2	2	0	2	1	1	0	0
Kankai	0	0	0	0	0	0	0	0	25	30	30	10	5	15	1
Lilapani	53	20	75	95	37	10	48	1	4	5	11	3	8	0	0
Sapness	176	106	245	343	114	83	146	17	36	18	44	19	19	3	1
Suvadi	50	39	82	129	39	27	63	4	6	4	9	2	7	0	0

S A: Sub adult; LF: lactating female; NLF: Non lactating females; Pregnant females; m: males