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DR.A.J.T.JOHNSINGH
ASSOCIATE PROFESSOR

NO.WII/WB/MSC/90 Dt. 26.3.90

Dear Dr.Joshi,

Please find enclosed herewith the slide taken by me in Dholkand watch tower when you visited Dehradun as an examiner.

With kind regards,

Yours sincerely,

A.J.T. Johnsingh

(A.J.T.Johnsingh)

Encl: as above.

Dr. Niranjan Joshi,
Centre for Ecological Sciences,
Indian Institute of Science,
BANGALORE - 560 012

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भारतीय वन्यजीव संस्थान
Wildlife Institute of India

D.O.No. WII/RES/IRAC/B.46 May 21st, 1999

Dr. A.J.T. Johnsingh
Senior Faculty Coordinator (Research & Education)

Sub. : Review of research proposal.

Dear Niranjan,

Please find enclosed a copy of the research proposal titled "Social organisation and dispersal in asiatic lions". At WII we have set up a process of internal and external peer review of research proposals so that they can enhance the quality of the proposal prior to funding.

I request you to kindly review this proposal and send me your comments latest by 15th July, 1999. Please feel free to communicate with me by e-mail <ajtjohnsingh@wii.gov.in> if required.

Looking forward to receiving your comments.

Warm regards.

Yours sincerely,

(A.J.T. Johnsingh)

Encl : As above.

Dr. NIRANJAN JOSHI
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Title:	SOCIAL ORGANISATION AND DISPERSAL IN ASIATIC LIONS
Name and designation of Principal Investigator:	Dr. Ravi Chellam, Scientist 'SE'
Name of the Institution in which the project will be carried out:	Wildlife Institute of India, Dehra Dun
Name of the other Institution involved:	Wildlife Institute of India, Dehra Dun Gujarat Forest Department
Time required for the commencement of project on receipt of approval:	One month
Duration of the project:	Five years
Total amount of the financial layout:	Year 1: **32,04,201** Year 2 : **7,55,240** Year 3 : **7,14,524** Year 4 : **7,03,184** Year 5 : **4,17,240** **Total : 57,94,389**
Documents enclosed:	
Statement I	Abstract
Statement II	Detailed project proposal
Statement III	Project Budget
Signature of Chairman, IRAC	Signature of the Investigator,
Date:	Date:
Signature of Director, WII	
Date:	

INTRODUCTION

Asiatic lions (*Panthera leo perisca*), as a subspecies separated from African lions between 50,000 and 200,000 years ago (O' Brien *et al.,* 1987). Historically the Asiatic lion ranged from Syria through Iraq, Iran, Pakistan and most of northern and central India (Joslin 1973). Enough evidence of its existence in the Arabian Peninsula has not yet been found.

The Asiatic lion attained its most extensive distribution in India, having ranged over the present day states of Rajasthan, Gujarat, Haryana, Punjab, Uttar Pradesh and Madhya Pradesh. Single sightings, one each from Bihar and Orissa have also been reported (Joslin 1973). Generally, the river Narmada was considered the southern boundary of its distributional range in India (Joslin 1973).

The decline of the Asiatic lion has been well documented by Fenton (1909), Kinnear (1920), Pocock (1930) and Joslin (1973). They are unanimous in the opinion that hunting, and destruction and fragmentation of lion habitats by humans were the main reasons for this decline. By 1900 the Asiatic lion was rare outside the Gir forests in the Junagadh province of Gujarat. The timely action of the Nawab of Junagadh in affording protection to the lions in Gir saved the subspecies from extinction. A more detailed account of the historical distribution of the Asiatic lion can be found in Joslin (1973).

Today the Asiatic lion is given full protection under the Wildlife (Protection) Act (Anon. 1972). The Gir forests have been protected as the Gir National Park and Sanctuary. The current population of Asiatic lions is estimated at around 300 animals according a recent census conducted by the Gujarat forest department.

The Asiatic lion and its conspecifics have been the attention of some research over the past 35 years. Joslin (1973) focussed on the behaviour and ecology of the lions based largely on visual observations. Food habits were studied based on faecal analysis and observations on carcasses. Berwick (1974) studied the food habits of livestock and wild ungulates and investigated the factors limiting the wild ungulate population.

Sinha (1987) examined various aspects of the ecology of the Asiatic lion and determined food habits and movement patterns. Khan *et al.*, (1990) studied wild ungulates and their relationship with various habitat factors in Gir.

Ravi Chellam (1993) was the first to use radio-telemetry to study the ecology of the Asiatic lion. The major objectives of his study were to assess the predation ecology, habitat use and the ranging patterns of lions in the Gir forest.

Most of the studies conducted so far seem to have had broad level objectives with an extensive scope and to generate base line data for planning the management of the Gir forests and its lions. However, none of these studies have investigated in any detail, the social behaviour of Asiatic lions compared to the kind of research carried out on African lions (Schaller 1972; Bertram 1975a,b; Hanby & Bygott 1979, 1987; Hanby *et al.* 1995; Packer and Pusey 1982, 1983 a, b, c; Pusey and Packer 1987; Packer *et al.* 1990; McComb *et al.* 1994; Heinsohn & Packer 1995; Heinsohn 1997 and Funston *et al.* 1998).

Ravi Chellam (1993) hypothesised that ecological conditions in Gir may be modifying lion social organisation when compared to the classic pattern reported from the savannah grasslands of east-Africa, the habitat in which sociality in lions is believed to have evolved (Packer 1986).

He also suggested that detailed follow up studies to the one that he did, are essential to understand social organisation, inter-pride dynamics and dispersal patterns among other behavioural and ecological aspects of Asiatic lions.

This study therefore will concentrate on studying social organisation and dispersal of lions in the Gir Protected Area (PA).

Objectives

The objectives of this study are to determine:

1. The ranging patterns of lions: individually and in relation to other lions.
2. The seasonal and temporal habitat use of lions.
3. The structure of the habitat used by lions.
4. The effect of habitat structure on the ranging of lions.
5. The composition and distribution of wild prey species.
6. The effect of wild prey species composition and distribution on the ranging of lions.
7. The effect of the presence of livestock and human disturbance on the ranging of lions
8. Dispersal patterns of sub adult male lions.

LITERATURE REVIEW

The evolution of sociality in lions

Lions are unique amongst felids since they live in permanent social groups called prides. The evolution of such a high degree of sociality in lions has elicited much interest among scientists. This has led to the generation of several hypotheses to explain the phenomenon (Schaller 1972; Alexander 1974; Bertram 1975a,b; Caraco & Wolf 1975; Rubenstein 1978).

Packer (1986) suggested that lion sociality results from the unique combination of three factors: preference for large prey, openness of habitat, and high population density of lions.

Lions are found at higher densities than any of the big cats and their preferred prey species are also found in large concentrations. As a result of high density, lions at a kill are particularly likely to attract other lions simply because there are more of them in the vicinity. In an open habitat a kill can be seen easily due to high visibility, and lions can join a feeding lion from several kilometres away. Large carcass size ensures that food will still be available by the time scavenging lions arrive. It would be very difficult for a single lion to defend a kill from scavengers, be they strange lions or hyenas. Therefore the presence of close relatives might be an advantage in defending a large carcass since it would be less harmful to the lion to lose a part of her kill to close kin rather than to distantly related neighbours or other carnivores.

These evolutionary pressures seem to have acted more on females rather than males, since the basis of lion sociality are groups of females. Related females are the permanent members of a pride, while males form coalitions varying in size from two to seven to improve their chances of gaining access to females and their tenure in a pride is relatively short.

The preference for lions to co-operatively hunt large prey is evident from studies in Africa, which suggest that group hunts are more successful at capturing (Packer and Ruttan 1988, Stander 1992a,b) and killing very large prey (Packer 1986). Stander and Albon (*1992*) found that hunting success, even for smaller antelope prey, increased linearly with foraging group size in the semi-arid open plains of Etosha National Park. Caraco and Wolf (1975) showed that group size is determined by prey size and capture efficiency. However, what would seem to be the most obvious explanation - increased hunting success yields more food - becomes less clear if we examine the following points.

- After a hunt, even of large prey, the presence of numerous non-hunting "hanger-ons" (Packer and Ruttan 1988) within the pride can reduce per capita food intake to the point where co-operative hunting does not appear to be economical for the hunters.

- The highest rate of food intake per hunt appears to be gained by solitary females (Packer 1986).

Packer (1986) suggested that co-operative hunting might be an adaptation to group living rather than the evolutionary force resulting in it.

Packer *et al.* (1990) have shown that the number of surviving offspring per female is significantly higher in prides of three to ten adult females than in either smaller or larger prides. Intruding males attempting a take-over kill small cubs and moderate sized prides suffer lower frequencies of male take-overs than do smaller or larger prides (Packer & Pusey 1983a,c).

The maintenance of long term territories (Packer *et al.* 1990), insurance against individual injury or incapacity (Schaller 1972) and minimisation of chances of getting no food at all (Caraco and Wolf 1975; Rubenstein 1978) are also advantages of sociality in African lions.

Being the only felids to live in permanent social groups seems to have conferred distinct advantages to lions. Having evolved in Europe in the early Pleistocene, lions as a species first appeared nearly 600,000 years ago (Savage and Russell 1983). From Europe they radiated across Asia and into Alaska (Kurten 1968). A second lion species was also found in North and South America during the upper Pleistocene but became extinct during historic times. Therefore, apart from man and his commensals, the lion achieved a range greater than any other terrestrial mammal. Within historic times the lion ranged over much of Africa to Greece and Central Asia and northern India.

Since sociality in lions evolved in the open savannah habitat of sub-Saharan Africa, their continued presence and survival in a forested habitat like Gir poses several interesting evolutionary and ecological questions. A brief look at the ecology of African lions and comparing it with what is known about Asiatic lions raises some interesting questions regarding the possibility that lions in Gir, living in a closed habitat may have a social structure and behaviour markedly different from the lions in Africa

Social Organisation

African lions

The core unit of the lion's matrilocal society -the pride- consists of a group of related females (none dominant) and their dependent cubs. Pride sizes vary between two to eighteen related adult females (Schaller 1972, Bertram 1975a, Packer *et al.* 1991a) and a coalition of two to seven adult males that have entered the pride from elsewhere (Schaller 1972).

Prides are "fission-fusion" social units: membership is stable, but the pride members are often scattered in small sub-groups throughout the pride range, and each individual spends a considerable amount of time alone (Schaller 1972, Bertram 1978, Pusey and Packer 1987). Females demonstrate several co-operative behaviours unique among the felids. Pride members often give birth in synchrony, and the young are reared communally, with cubs suckling freely from any available lactating female (Schaller 1972, Bertram 1975b).

Asiatic lions

Like their African cousins, Asiatic lions are highly sociable animals. There are however differences in pride make up between the sub-species. Mean pride size, measured by the number of adult females, tends to be smaller than for African lions: most Gir prides contain just two adult females, with the largest having eleven (Joslin 1973), compared to averages of six in African lions (Schaller 1972). However, despite the small population size individual animals are not well known. It is therefore possible that what are currently identified as separate prides may instead be smaller foraging groups from larger prides (Ravi Chellam 1993).

Male coalitions

African lions

A single male or coalition of males (up to seven) holds tenure over one or more prides, and effectively excludes strange males from siring cubs with pride females (Packer *et al.* 1991a). Competition among males for pride tenure is intense, and average tenure is only two (Packer *et al.* 1988) to three years (Stander 1991). Males will only seek tenure over or breed with related pride females under unusual

circumstances *e.g.*, when the population is small and there are barriers to dispersal: (Pusey and Packer 1987, Packer *et al.* 1991a,b).

Males are also highly social: coalitions in the pre- and post-tenure periods hunt and scavenge co-operatively and larger coalitions stand a better chance of gaining tenure of a pride (Bygott *et al.* 1979). Coalitions of four or more males are always related (being born in the same pride, but not necessarily of the same mother), while pairs frequently consist of unrelated males and less frequently, a related pair teams with an unrelated male to form a trio (Packer *et al.* 1991a). Grinnell *et al.* (1995) found that relatedness did not alter a lions behaviour towards its pride mates. They conducted play back experiments of lions roars and found that cooperative behaviour in males to fend off intruding males did not depend on the relatedness or behaviour of their companions.

Asiatic lions

As in Africa coalitions of up to seven males defend territories containing one or more groups of females. Gir males generally associate with their pride females only when mating or on a large kill. Joslin (1973) observed that Asiatic lions associated preferentially with their own sex. Males interacted more with males of their coalition than with females of the pride they associated with. Lions were observed to be in the company of the opposite sex in only 32% of observations of both sexes. Ravi Chellam (1993) found similar grouping patterns among his radio-collared animals. Joslin (1973) also observed extensive overlap of home range between males of adjoining prides. However, Ravi Chellam (1993) maintained that males are highly territorial and that they regularly mark their territories by spraying and roaring.

Social behaviour

African lions

When a male coalition "takes over" a pride of females, most females with dependent offspring lose their cubs within a month of a take-over due to infanticide by the incoming males, and those that are pregnant lose their cubs shortly after giving birth (Packer & Pusey. 1983a,c). In this way, males increase their chance of siring cubs during their short reproductive lifetime, which is generally only as long as their period of pride tenure. In response, females show a burst of heightened sexual

activity for about three months following a take-over, attracting other males and encouraging competition that ensures that the fittest (often largest) coalition is able to gain tenure (Packer and Pusey 1983a). They remain infertile (anovulatory: Smuts *et al.* 1978) during this "testing" period, and only afterwards, when tenure has stabilised, tend to breed in synchrony (Packer and Pusey 1983a). Litters born synchronously have a higher survival rate (probably due to maximal maternal care [Bertram 1975b]), and tend to show a sex ratio biased toward males (Packer and Pusey 1983c). Reproductive success of males increases with coalition size since males in groups of three or more can reliably gain tenure of prides, retain tenure for longer, mate with a greater number of different females and produce more surviving offspring when compared to singletons and pairs (Bygott *et al.* 1979, Packer *et al.* 1988). Although, at least one member of male coalitions larger than two fails to breed successfully, through kin selection (Bertram 1976) related non-breeding helpers still ensure that some proportion of their genes are passed on to the next generation (Packer *et al.* 1991a)

Asiatic lions

Apart from anecdotal reports no detailed information is available on male take-overs and female responses to incoming males.

Dispersal

African lions

Subadult animals usually leave their natal territory between the ages of 24-36 months. The dispersal of subadult animals is usually triggered by the arrival of new males attempting a takeover. Subadult males are evicted at once from the pride, usually never to return, while subadult females that are not ready to mate leave temporarily, but return with the onset of sexual maturity. Subadults leave the natal pride along with their age-mates. The young males disperse outside the natal territory and are often sidelined to poor quality habitats. The survival of the young males depends on the number of age-mates with them. Sub adults with more age-mates stand a better chance of survival, since they will be able to procure food more easily, fend off other lions, and take over a pride much faster (Hanby and Bygott 1987).

Asiatic lions

Information on the dispersal of young Asiatic lions is largely anecdotal. Most of the observations of dispersing subadult lions deal with the colonisation of patches of forest outside the Gir protected area (Singh 1997).

Food acquisition

African lions

In a pride groups of females do most of the hunting because they are probably more efficient than males. They lack the conspicuous mane which would be a handicap in the open grasslands while stalking prey and are also lighter in body weight than the males and hence more agile (Packer 1986). Also all-male groups generally associate in smaller average group sizes than females do, and group size is an important variable affecting hunting success (Scheel and Packer 1991). Males by virtue of their larger size dominate the females while feeding on the carcass and get a larger share of the meat (Schaller 1972; Packer 1986). However, in habitats that have a denser vegetation structure, offering better ambush cover, males are frequent and successful hunters (Funston *et al.* 1998). If males are not present then females respect the ownership of the kill to the female that actually brought the animal down.

In general, prides often divide into smaller sub-groups when foraging (Stander 1992a, Scheel 1993). Stander (*1992b*) found a complex division of labour among hunting lionesses, with individuals repeatedly playing the same role during hunts.

Asiatic lions

The Gir forest has a closed and dense vegetation structure and prey size and availability is different from what is seen in most parts of Africa. The presence of livestock (an extremely vulnerable prey) and a closed habitat enables males to hunt efficiently (Ravi Chellam 1993). This may explain their weaker social bonds with females, as they no longer depend on them for food. Also the modal prey species in Gir is the medium sized (40-60 kg.) chital deer (*Cervus axis*)(Ravi Chellam 1993). Females that bring down a chital would not have much left to eat if a male were to take-over the kill. Thus if males spent a larger proportion of their time with the females they would be competing with them for food. This would not be in the male's interest in the long term in two ways

- It would lead to a loss of body condition for females affecting their reproductive capacity and
- It would reduce his reproductive success if cubs dependent on females died due to starvation.

Apart from food acquisition there may be other reasons as to why lions in closed habitat behave differently from lions in open habitat as suggested by Funston *et al.*, (1998)

1. Territory defence: Males defend prides of females in open areas rather than territories. In open areas visibility over the pride range is unhindered and males are able to detect intruders in their female's territories from far away. Therefore their mere presence with the females and cubs acts as a deterrent. In a closed habitat however, intruders are less conspicuous and it becomes necessary for males to patrol their territory and repel other males by advertising their presence through scent marking and roaring.
2. Competition with other carnivores: In areas where spotted hyaenas occur at much higher densities than lions, they appropriate large amounts of meat from female kills (Schaller 1972; Cooper 1991). Females are unable to defend kills from hyaenas if they are outnumbered four to one, whereas hyaenas are unable to appropriate a kill if a territorial male is present. Therefore a combination of open habitat and high density of competitors would mean that territorial male lions would associate more with resident females.

The Gir forest is however, neither open nor does it have a high population of competitors such as spotted hyaenas. Therefore, male lions in Gir would tend to associate less with resident females. To better understand the behaviour of lions in Gir, with respect to social organisation and habitat structure, the following questions form the basis for this study.

Questions that the study proposes to answer

1. Movement patterns of male lions.

1.1. What are the factors that influence the movement patterns and behaviour of males?

1.1.1. How is a male influenced by the presence of his coalition partners?

1.1.2. What effect does the size of the coalition have on the movement patterns of males?

1.1.3. How do a male and his coalition respond to the movement of males from adjoining coalitions?

1.1.4. What effect does a female from the same pride have on a male's movements?

1.1.5. How does a male respond to the presence of females from adjoining prides?

1.1.6. How many prides do male coalitions overlap?

1.2. Why do Asiatic lion males spend more time solitarily than they do with the pride?

1.3. Would the home ranges of individual males in the pride overlap completely with that of other males in the pride? I.e. is there a division of labour when it comes to patrolling the territory?

1.4. Does carcass size have an effect on grouping patterns in males?

2. Population structure

2.1. What is the age and sex class structure of the pride?

2.2. Does the size of the pride govern the home range of the pride?

3. Dispersal

3.1. What are the dispersal patterns of young male lions in Gir?

3.2. What is the dispersal age?

3.3. Do young male lions disperse to areas outside the protected area?

3.4. What are the post dispersal movement patterns of male lions?

4. Habitat Use

4.1. What are the seasonal habitat use patterns of lions in the intensive study area (National park and sanctuary west)?

4.2. Does the habitat structure and density of vegetation have an effect on the habitat use of the lions?

4.3. Do availability, density and distribution of prey affect habitat use and ranging in lions?

4.5. Is there difference in habitat use between the sexes with relation to presence of livestock?

4.6. What effect does human presence have on the habitat use patterns of lions?

Justification for this study

Most of the detailed ecological information on lions comes from the Serengeti ecosystem in Africa, which is typified by an open habitat, an abundance of prey, a high degree of seasonality in the availability of prey and a high density of predators. However, even in Africa, this represents only one of the many habitat types in which lions are found. Also most studies have concentrated on female ecology. Male behavioural ecology is given lesser attention, probably because of their regular attendance with their pride females. Studies on male lions conducted in savannah woodland habitats (Funston *et al.* 1998) have shown facets of ecology and behaviour different from what is seen in the open grassland ecosystem.

The Gir forests of Gujarat which have the only population of Asiatic lions are quite different from those present in the savannah of east Africa in terms of habitat structure, prey species assemblage as well as the community of predators found there. No detailed long-term research has been conducted in the Gir forests aimed at studying the social behaviour and dispersal of Asiatic lions. Since this study aims to study male socio-ecology and territoriality, it will provide valuable information on the factors governing the spatial distribution of lions in Gir. Moreover, this study will also aim to address management concerns about the increasing vegetation density of the Gir forest and its possible negative impact on the lion's ability to use these habitats (Sharma and Johnsingh 1996; Johnsingh *et al.* 1998).

Study Area

The Gir National Park and Wildlife Sanctuary (20° 57' to 21° 20' N lat. And 70° 27' to 71° 13' E long.) located in the centre of the Kathiawar peninsula in the state of Gujarat covers and area of 1412.13 sq. km. (NP area 258.71).

Detailed descriptions of the Gir forest can be found in Joslin (1973) Ravi Chellam (1993) and Sharma and Johnsingh (1996). In relation to this study, a brief description of the area is given.

Topography

The terrain is hilly, with the altitude ranging from 131m to 587m asl. Five perennial rivers drain the Protected Area (PA) which have been dammed and as a

result form large reservoirs. Apart from this, the only other sources of water are several small seasonal streams that flow through the forest.

Climate

Gir's climate is heavily influenced by the monsoon. The rainy season starts from mid-June to September and is followed by a hot and humid post monsoon season, which eases out into a mild winter from mid-November to February. The rest of the year is a very hot summer with maximum temperatures of upto 45°C. There is a rainfall gradient on a west to east axis with the west receiving an average of 1000mm/year and the east 600mm/year.

Vegetation

The forests in Gir have been classified as 5A/C1 (very dry teak forest), 5/DS1 (dry deciduous scrub forest) and 5/DS2 (dry savannah forest) by Champion and Seth (1968). For further classification of the vegetation types see Sharma and Johnsingh (1996).

Fauna

The Gir forest supports several large mammalian species that are of interest to this study. The wild prey population of Gir consists of chital, sambar (*Cervus unicolor*), nilgai (*Boselaphus tragocamellus*), chousingha (*Tetracerous quadricornis*), chinkara (*Gazella bennetti*), wild pig (*Sus scrofa*), common langur (*Semnopithecus entellus*), porcupine (*Hystrix indica*) and rufous tailed hare (*Lepus nigricollis*). The peafowl (*Pavo cristatus*) also forms part of the prey base.

Carnivore species include leopard (*Panthera pardus*), jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*), striped hyaena (*Hyaena hyaena*), jackal (*Canis aureus*), Indian fox (*Vulpes bengalensis*), ratel (*Mellivora capensis*), common mongoose (*Herpestes edwardsii*), ruddy mongoose (*H. smithii*) and small Indian civet (*Viverricula indica*) (Ravi Chellam 1993).

Human presence

A pastoralist community called the *Maldharis* reside in small hamlets called *ness* in most parts of the sanctuary but have been relocated from the National Park area. They number about 2500, and have about 10,000 –12,000 livestock most of which are buffaloes (Sharma and Johnsingh 1996). Outside the PA, 206 villages consisting of 1,60,000 people and 1,00,000 cattle are present within a 10 km radius (Sharma and Johnsingh 1996). Gir also has five temples inside the sanctuary area which attract tourists, travellers and pilgrims (Ravi Chellam 1993).

This study will be conducted in the National Park and Sanctuary West areas, which will form the intensive study area.

Methods

Radio telemetry:

Capture and radio-tagging

The first six to twelve months of the study will be utilised in surveying the intensive study area and identifying prides of lions and their accompanying male coalitions. This will be done with the help of assistants and forest department trackers who are familiar with the area and its resident lions.

After the identification and choice of study animals the lions will either be located at wild kills in accessible areas or baited with young buffaloes for darting. Drug dosage will be calculated using an ocular estimate of the lion's body weight. The lions will be chemically immobilised using a mixture of Ketamine-Meditomedine (Jalanka *et al.* 1990). A DANINJECT gun will be utilised for administering the dose. After immobilisation, all precautions will be taken to ensure the safety of the animal. All physiological parameters will be monitored. The lion will be weighed, measured, sexed and categorised in an age class. The dental condition and ectoparasite load will be checked. The lion will then be fitted with a radio-collar with an activity switch. After the radio collaring is complete a dose of Atipamazole – a specific antidote to Meditomedine- will be administered to revive the animal. The animal will be monitored for at least 12 hours after revival to ensure its safety. The entire operation will be performed carried by trained personnel in the presence of experienced veterinarians.

Number of lions to be radio-collared

Ravi Chellam (1993) noted that males in coalitions of two or three spend less than ten percent of the time alone. Therefore, only one male of a coalition of two or three will be radio collared. However if there are coalitions of more than three males, than all the males of the coalition will have to radio-collared. Males from at least two more coalitions adjacent to the focal study coalition will be similarly radio collared.

It will be necessary to radio-tag 1-2 females of the resident pride and 1-2 females each of 2 adjacent prides to determine the pride home ranges.

To study the dispersal of subadult lions, it will be necessary to collar atleast 5-6 subadult male lions. The radio collaring operation will be performed preferably in winter to prevent heat stress on the animal. Animals will be re-immobilised and re-tagged as and when required. Subadults will be fitted with expandable or breakaway collars to allow for growth in body size. It is planned to radio collar 15-20 lions in total.

Monitoring

To fulfil the objective of determining movement patterns of lions two kinds of radio-tracking regime will be followed: continuous and discontinuous.

Continuous tracking will involve homing in on a particular animal and keeping it in visual contact every hour and monitoring its activities. Previous studies have shown that lions move mostly at night. Therefore, during daylight hours, the lions will be monitored every 2 hours. once As the lions become active before dusk, they will be followed continuously throughout the night till about one hour after dawn or when they rest for a period greater than an hour. This will be done over a period of six consecutive nights. Positional fixes of the visually sighted animals will be obtained using a GPS. Multiple tracking teams will be operated to simultaneously track more than one animal.

To study the influence of adjacent prides on the movement patterns of the lions, the animals that will be simultaneously tracked will be one from the resident coalition and one from an adjacent pride that are not in visual contact with each other.

Discontinuous tracking will involve radio-location of the animal either through triangulation or homing in once in every predetermined time interval. Precise location of the animals will be attempted by minimising triangulation errors. Directional

readings will be taken from less than 500 m from the animals (Harris *et al.* 1990). Errors due to movement of the animal will be minimised by taking simultaneous bearings from multiple tracking stations (Shmutz and White 1990). Compass bearings will be fed into a suitable triangulating program to obtain UTM coordinates.

Initially the interval between consecutive radio tracking will be one day. The data gathered will be tested for independence to decide the minimum time interval needed for statistical independence of observations (Swihart & Slade 1985).

Home range estimation

Home range analysis will be done by using appropriate home range estimation software. Two methods of home range estimation will be used. The minimum convex polygon method (Mohr 1947) that connects the outermost points of the range and the harmonic mean (Dixon and Chapman 1980) method to find centres of activity and range shifts between seasons. Most home range estimations ignore the effect of topography and assume that the terrain is flat, thus underestimating home ranges in hilly terrain. To overcome this problem, a digital terrain model in conjunction with satellite imagery will be used to correct for estimates of home range size in undulating terrain (Moore *et al.* 1988).

Individual identification of lions

To observe social behaviour it will be necessary to individually identify lions. This will be done based on natural facial markings as described in Pennycuick and Rudnai (1970). Close up facial photographs at various angles will be taken to identify lions based on their vibrissae spots and nicks and cuts on their face and ears (Pennycuick and Rudnai 1970). A reference sheet will be built up for each lion that is identified and will include information such as identity number, sex, age class, identifying marks, pride or coalition identity, area of use, and other information that will be continuously updated.

Behavioural Observations of lions

To study behavioural interaction between individual lions, *ad libitum* sampling will be done (Altmann). These observations will be done during the continuous

monitoring of the lions. To minimise chances of missing out on interactions, all activities will be recorded using a digital video camera.

Study of Food habits

To understand the food habits of lions, scats will be systematically collected along trails, numbered and tagged. Information collected will include place, date and season of collection, freshness of the scat and the presence of associated pugmarks or scrapes. Microhistological methods as described in Mukherjee *et al. (*1994) will be used to identify hairs of prey in the scats.

The scat analysis results, in the form of percent frequency of each prey type, will be boot strapped to obtain confidence intervals and estimates of sampling error (Reynolds and Aebischer 1991). The diet of lions in different areas and seasons will be compared using the G test for frequency for each prey species separately.

A systematic search for kills will also be made to find out the age and sex class of prey killed. Sites where a lion has spent a long time will be investigated to check for the presence of a kill. Information on age classes based on tooth wear and sex of prey if possible will be collected.

Quantification of prey density

Line transects, will be randomly laid in proportion to the area of the habitat type (Buckland *et al.* 1993) These transects will be walked at dawn to estimate densities of prey species. Replicates of each transect will be done till at least sixty sightings of each species of interest are encountered. This intensive sampling will however be done if time and manpower resources permit. Otherwise, an *ad hoc* encounter rate of prey species will be noted down during tracking sessions. Results of an earlier study by Khan *et al.* (1990) will also be used as a comparison to this study.

Quantification of Habitat structure, availability and preference

Vegetation classification and maps prepared by Sharma and Johnsingh (1996) will be used as base maps for determining the extent of habitat patches and their availability in the intensive study area. A fixed number of randomly chosen radio-locations and an equal number of random points will be plotted on the map and

habitat sampling will be done on these points. The following habitat parameters will be quantified seasonally.

1. Tree species density within a 10m radius circular plot .
2. Canopy cover, using a spherical densiometer at 10 points within the 10m circular plot
3. Shrub density within a 5m radius circular plot.
4. Visibility using a cover board at ten points within the 10m circular plot at distances of five, ten and fifteen meters from the sampling point (Jones 1968).

This data will be collected seasonally for a period of two years. The number of radio-locations in each habitat type within the home range will be taken as an index of use of that habitat type. The proportion of habitat types in the home range will be the proportional availability (Aebischer *et al.* 1993). Since each individual lion will have a usage and availability ranking of each habitat type, a multivariate Hotellings T^2 test will be used to find habitat preferences (Johnson 1980).

Justification for the budget

Studies that involve radio telemetry are often very work intensive, especially so when studying large carnivores. Since this study will involve radio collaring and tracking of several lions, there is a need for more than just two field assistants, therefore three have been budgeted for. Casual daily labour has been included if the need for extra manpower arises, eg. when radio collaring the animals, laying transect lines or when an assistant is temporarily unavailable. Moreover, a Technical Assistant has also been added to ensure that field work continues uninterrupted when the researcher has to come back to WII for ARS and other activities such as consultation and report writing.

Since lions are known to travel great distances and have large home ranges, a four-wheel drive vehicle will be an absolute necessity. Moreover since the study plans to have multiple tracking teams, there is requirement for more than one vehicle. Therefore, a motorcycle has been budgeted for as well, that will provide the extra mobility, and will help in cutting costs of POL for the four wheeler.

To individually identify lions, it will be necessary to take high quality close-up photographs of their faces. This will only be possible with a high power telephoto lens and a fast auto-focussing camera. Apart from this, binoculars, rangefinders, spotting scope and microscope have been included for field observations and data

collection. Since night observations are an essential part of the study, a night vision scope will be necessary. While observing social interactions between lions, it is possible that small but important interactions might be missed out during visual sampling in the field. Recording of social interactions using a video camera can easily overcome this problem. Therefore, a video camera has been budgeted for.

To efficiently enter, collate, and analyse data in the field, a laptop computer with printer will be necessary. This will also help in correspondence and preliminary report writing. Connection with the Internet will allow fast and easy correspondence with supervisors data and other information can also be transferred via email.

Projected outputs of this study

1. The study will produce annual progress reports, which will be submitted to the collaborating organisations as well as the concerned state forest departments.
2. A presentation of the preliminary results of the project will be made every year at the Wildlife Institute of India's Annual Research Seminar. Scientists of various research organisations in India and abroad and top officials from different state forest departments as well as the ministry of environment and forests attend this seminar.
3. A detailed final report of the study will be published and sent to various agencies and libraries.
4. Management strategies based on the results of the study will be recommended and after discussions with the concerned forest department officers, steps as to how to implement the recommendations will be drawn out.
5. The study will form the basis of a Ph.D. Thesis by the researcher.
6. The results of the study will be sent to peer reviewed international scientific journals for publication.

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HEAD	1st YEAR	2nd YEAR	3rd YEAR	4th YEAR	5th YEAR	TOTAL
SALARIES AND WAGES						
Salary of JRF @ 5000/Mnth: SRF @ 5600/Mnth	60,000	60,000	67,200	67,200	67,200	321,600
Salary of T.A. @ Rs 4000/Mnth for 5months/year	20,000	20,000	20,000	20,000		80,000
Salary of F.A @ 2000/Mnth X 3 with 10% increment per year	72,000	79,200	87,120	95,112	7,394	340,826
Salary of driver @ 2200/Mnth X 1with 10% increment/year	26,400	29,040	31,704	34,872	4,646	126,662
Casual daily labourers	12,000	12,000	8,000	8,000	4,000	44,000
Honararium	10,000	10,000	5,000	5,000	2,500	32,500
TRANSPORTATION and TRAVEL						
T.A./ D.A. for P.I.	40,000	40,000	30,000	35,000	10,000	155,000
TA/DA for researcher	25,000	25,000	25,000	25,000	7,000	107,000
Purchase of Four wheel drive vehicle	350,000					350,000
Purchase of 135cc motorcycle	50,000					50,000
Vehicle Accessories (foglights, tools, tarpaulins, tyres etc)	50,000					50,000
POL for four wheeler	125,000	125,000	125,000	125,000	75,000	575,000
POL for two wheeler	25,000	25,000	25,000	25,000	15,000	115,000
Maintenance for four wheeler	30,000	30,000	30,000	30,000	20,000	140,000
Maintenance for two wheeler	10000	10000	10000	10000	5000	45,000
ACCOMODATION						
Accomodation rent charges	15,000	15,000	18,000	18,000	10,000	76,000
Camp establishment and running	25,000	10,000	10,000	15,000	10,000	70,000
Furniture and other accessories	50,000	10,000	5,000	5,000		70,000
Kitchen accessories	25,000	2,000	2,000	2,000	1,000	32,000
Electrical fixtures and consumables	10,000	5,000	5,000	5,000	2,500	27,500
Camp shifting charges	20,000				30,000	50,000
Sleeping bags for researcher and field assistants	5,000					5,000
Rucksacks and haversacks	5,000		2,500			7,500
Portable generator set	20,000					20,000
Solar panels and inverter with batteries	10,000					10,000
EQUIPMENT						
Immobilising equipment						
Tranquiliser Gun - Daninject with darts	230,000					230,000
Immobilising Drugs	150,500	50,000	25,000			225,500
Stretcher	1,000					1,000
Weighing scale	5,000					5,000
Complete medical kit	2,000					2,000

Telemetry equipment							
Radio collars with activity switch- 15 nos @$350	225750					225,750	
Expandable Radio collars with activity switch - 10 nos @450	387,000					387,000	
Telonics receivers 4 nos- 3TR4@$900, 1TR2@$2100	206,830					206,830	
Telonics Antenna: Flexible H type -3 nos, @$250	32,250					32,250	
Yagi 3 element1 no. @$120	5,160					5,160	
Omni directional 1 no. @$90	3,870					3,870	
Head phones 2nos @$175	15,050					15,050	
Replacement cables 6nos 60" cables @$17, 1no 9' cable @ $35	5,891					5,891	
GPS 2 nos	100,000					100,000	
Two way radio set	10,000					10,000	
Compasses 2 nos	15,000					15,000	
Photography and sighting equipment							
Nikon F100 camera with 400mm f.4. Lens and accessories	150,000					150,000	
Tripod with ball head	10,000					10,000	
Car mountable tripod head	5,000					5,000	
Purchase of film 25 rolls of slide + 20 rolls of print/year	8,250	8,250	8,250	8,250	5,000	38,000	
Processing and printing of film	10,250	10,250	10,250	10,250	7,000	48,000	
Video camera, accessories and consumables	60,000	5,000	5,000	5,000	2,500	77,500	
Rangefinder	21,500					21,500	
Binoculars	20,000					20,000	
Night Vision Binoculars	30,100					30,100	
Microscope	10,000					10,000	
Spotting Scope	8,600					8,600	
Computer							
Laptop computer	150,000					150,000	
Deskjet printer and consumables (paper and ink cartridge)	20,000	5,000	5,000	5,000	5,000	40,000	
Maintenance contract	15,000	15,000	15,000	15,000	15,000	75,000	
Email connection	5,000	5,000	5,000	5,000	5,000	25,000	
Software	10,000					10,000	

Miscellaneous equipment							
Multitool set and toolkit	8,000					8,000	
Hipchain	5,000	1,000	1,000	1,000	500	8,500	
Densiometer	4,300					4,300	
Spotlights and flashlights	7,000					7,000	
Weather Instruments	10,000					10,000	
Pedometer	2,000					2,000	
Miscellaneous equipment	10,000	10,000	5,000	5,000	5,000	35,000	
Recurring costs							
Baits	20,000	20,000	10,000	5,000		55,000	
Field dress allowance for researcher	2,500	2,500	2,500	2,500		10,000	
Batteries	20,000	20,000	20,000	20,000	10,000	90,000	
Stationery	12,000	12,000	12,000	12,000	20,000	68,000	
Post and telephone charges	20,000	20,000	20,000	20,000	10,000	90,000	
Books	10,000	10,000	10,000	10,000	10,000	50,000	
Miscellaneous	25,000	25,000	25,000	25,000	25,000	125,000	
Consumables (ropes, buckets, tags, plastic equipment etc)	10,000	10,000	10,000	10,000	10,000	50,000	
Insurance							
Medical Insurance for researcher	1,000	1,000	1,000	1,000	1,000	5,000	
Group insurance for assistants and driver	3,000	3,000	3,000	3,000		12,000	
Insurance for Vehicles and equipment	15,000	15,000	15,000	15,000	15,000	75,000	
Total	3,204,201	755,240	714,524	703,184	417,240		
				Grand Total		5,794,389