A Preliminary Study on the Ecology of the Leopard, *Panthera pardus fusca* in the Sanjay Gandhi National Park, Maharashtra

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SUMMARY

A preliminary study of the ecology of the leopard, Panthera pardus fusca, was done at Sanjay Gandhi National Park (SGNP) in Maharashtra. The diet of the leopard was determined by analysing leopard scats. The major prey of the leopards was found to be domestic dogs, domestic buffalos and rodents. Primates, including rhesus macaques, bonnet macaques and common langurs and cervids, comprising chital, sambar and barking deer were also preyed on.

Sections of 8 dirt roads, termed as trails T1 to T8, were monitored for intensity of leopard use. An index of prey abundance, human disturbance, stalking cover and density of trees along the trails was calculated. Intensity of use of trails by leopards was not related to the measured habitat parameters of the trails.

Instances of leopard-human conflict was analysed using secondary records of the Maharashtra State Forest Department from 1986 to 1996. It was found that most instances of conflict occurred in summer and monsoon seasons. Seventy eight per cent of the deaths were of children.

Awareness about leopards and attitudes towards them were quantified using a questionnaire. Tribals showed a more positive attitude score than non-tribals. No such difference was seen for awareness. There were no differences in awareness and attitude among literate and illiterate people. A positive correlation between awareness scores and attitude scores was found.

Suggestions for the management of leopards in SGNP include the experimental augmentation of the prey base with wild caught ungulates, monitoring for domestic dog transmitted disease, avoiding reintroduction of leopards trapped on the periphery and outside the Park boundaries into the Park and monitoring for inbreeding depression by comparing the percentage of abnormal sperm in samples from male leopards in SGNP with those from a larger population of free ranging leopards elsewhere in the country.

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INTRODUCTION

1.1 The distribution and taxonomy of the leopard

There are 36 species of cats extant in the world. India has fifteen of them, including five of the large sized cats: the tiger (*Panthera tigris*), the lion (*Panthera leo*), the leopard (*Panthera pardus*), the snow leopard (*Uncia uncia*) and the clouded leopard (*Neofelis nebulosa*)(nomenclature from Wozencraft 1993).

The leopard is the most widely distributed of all the wild cats (Nowell and Jackson 1996). It is found in almost every kind of habitat, from the rainforests of the tropics to desert and temperate regions (Kitchener 1991). It is known to occur from across Africa to South Asia northwards to Central Asia and east to the Amur Valley in Russia (Bailey 1993). The leopard in India is distributed all over the country except the arid regions of Rajasthan and above the tree line in the Himalayas (Prater 1980). Although it is the most common of the large cats, Myers (1976) recommended that it remain in Appendix 1 of CITES because extensive hunting had depressed populations in several parts of Africa. In India too it figures in the Schedule I of the Indian Wildlife (Protection) Act, 1972 (Anonymous 1993).

The leopard shows considerable variation in its physical appearance, having a coat of any colour from pale yellow to deep gold, patterned with black rosettes. Melanistic individuals, in which the rosettes are faintly seen, are also found. Average adult weights, obtained from Sri Lanka, are 56 kg for males and 29 kg for females, while two males from Central India weighed 50 and 70 kg (Nowell and Jackson 1996). One adult male from the Sanjay Gandhi National Park, found dead in what was probably a road kill, weighed 63 kg (*pers obs*).

It has now been proposed on the basis of molecular studies to lump the 27 races of leopards found across its range from Africa to Asia into eight races (Miththapala *et al.* 1996). They have suggested that 3 of the races found in the Indian subcontinent, the Nepal leopard *Panthera pardus pernigra*, the Kashmir leopard *P.p. millardi* and the Indian leopard *P.p. fusca* be lumped into *P.p. fusca*.

1.2 Ecology and conservation status of the leopard

Cats exhibit a wide range of social grouping behaviour, ranging from the group living lions to the solitary leopard. Most species are markedly asocial (Kitchener 1991). Among the larger felids the lion is the most sociable. Both cheetahs (*Acinonyx jubatus*) and tigers are both considered more likely to be found in groups than the leopard (Bailey 1993).

Leopards have been found to be essentially solitary and territorial animals by Hamilton (1976), who found that they were most likely to socialize at the carcass of large prey. Ten per cent of his 122 sightings at baits were of two leopards. In Wilpattu, out of 96 sightings of leopards, 78 were of solitary animals, 10 were of adult male and adult female, presumably courting pairs, 4 were females with juveniles and four were unclassified. The only social groupings seen were thus mother with cubs and courting pairs (Eisenberg and Lockhart 1972). In Ruhuna National Park, also in Sri Lanka, Santiapillai *et al.* (1982) recorded 84.4% of his 32 observations as solitary, 6.3% as pairs, two observations of three and one observation of four animals together. The groups were of females with cubs. Schaller (1972) observed pairs in three instances out of a total of 155 observations, the rest of which were of solitary leopards. Bailey (1993) found that no interactions occurred between resident males in his study area and that most interactions that occurred between males and females were associated with courtship. The present study recorded four sightings of individual leopards and one sighting of a courting pair.

Communication among leopards has been speculated by Bailey (1993) to serve several functions, chief among which are to allow them to separate themselves in space and time, to attract the opposite sex during courtship, and to distinguish each other by age, sex and individual status. Scent marking is the primary mode of communication. This includes scraping, marking with faeces and spraying of urine. In tigers, these have been found to be used most often along trails and trail intersections that serve as common boundaries between territories (Smith *et al.* 1989).

In Nepal the leopard land tenure system was suggested as one in which the home range of a male enclosed the home ranges of many females (Seidensticker 1976). In Wilpattu, a male enclosed the home range of a single female (Muckenhirn and Eisenberg 1973). Rabinowitz (1989) in Thailand found that male leopards had slightly overlapping home-ranges of 27-37 km^2 enclosing female ranges of between 11-17 km^2.

Bailey (1993), in South Africa, found little spatial overlap between home ranges of adult male leopards, which decreased even further during the wet season. Female home ranges also overlapped a little, while male home ranges completely overlapped many female home ranges, as in the Nepal study. Female home ranges appeared to be related to availability of prey needed to successfully raise young ones. He visualised the land tenure system of leopards as a superimposition of three layers of mosaics. The first layer would be that of female home ranges with various degrees of overlap on which would be superimposed the second layer of male home ranges displaying little overlap amongst themselves but each male range covering the ranges of several females. A third layer would be that of the floaters or transients, mostly juvenile and nonresident individuals without territories. Eisenberg (1986) found that until the age of puberty juveniles were tolerated, after which they became transient until they could find a suitable undefended portion of habitat where they could establish and defend a territory.

In southern India leopards are thought to be more successful than dholes (*Cuon alpinus*) and tigers because of their ability to climb, cache their prey on trees, take small sized prey and be relatively independent of water (Johnsingh 1983). They have been shown to kill medium sized prey, mainly impala (*Aepyceros melampus*), but also take a very wide variety of small animals including hyrax, civet and mongoose in Kruger National Park in South Africa (Bailey 1993). Hoppe-Dominik (1984) found leopards eating a wide spectrum of the potential prey available in the Tai National Park, Ivory Coast, with about thirty species recorded. Hamilton (1976), in his pioneering study on leopards in Tsavo found that their diet consisted of a significant number of small prey. In the Kalahari desert leopards have been known to take small prey like Bat-eared fox (*Otocyon megalotis*), jackal (*Canis spp*), genet (*Genetta spp*), hare (*Lepus spp*), duiker (*Cephalopus spp*) and porcupine (*Hystrix spp*) (Bothma and Le Riche 1984). Bertram (1978) found that a sample of 150 kills comprised of over 30 different species in the Serengeti.

In Sri Lanka, based on a sample of 29 kills, attempted kills and evidence from scats, leopards took mainly chital and wild pig (*Sus scrofa*), but also sambar (*Cervus unicolor*), langur (*Presbytis entellus*), hare (*Lepus nigricollis*), porcupine (*Hystrix indica*) and domestic buffalo calves (Muckenhirn and Eisenberg 1973).

In Nepal, Seidensticker *et al.* (1990) found wild pig, sambar, chital, hog deer (*Axis porcinus*), barking deer (*Muntiacus muntjac*) and domestic cattle as part of the leopard's diet. Prey below 50 kg in weight made up the bulk of the diet. Outside the boundaries of Royal Chitawan National Park domestic livestock made up much of the diet and seemed to be sustaining the leopard population.

In the Pakistan Himalayas, Schaller (1977) found leopards preying mainly on wild goats (*Capra aegagrus*) but also on livestock, hare and porcupine. Few studies have found the leopard to be a major predator of arboreal prey (Bailey 1993). Struhsaker (1975) and Charles-Dominique (1977) found the leopard to be largely uninterested in primates. Struhsaker (1975) thought that they could not prey efficiently more than 10m above the ground. He also reports that primates may be less vulnerable to predation because of their arboreal habitat and social behaviour. However, Rabinowitz (1989) in Thailand found leopards preying on primates as did the rainforest leopards in the Tai National Park of the Ivory Coast (Jenny 1996). Ravi Chellam (1993) found leopards to be preying on langurs in Gir.

In the Himalayas, leopards have been known to take goral (*Nemorrhaedus goral*) (Charudutt Mishra *pers comm*). In the Shivalik hills of Rajaji National Park, analysis of scats has shown that leopards eat chital, sambar, barking deer, goral and livestock (A.J.T.Johnsingh *pers comm*). In Sariska Tiger Reserve a large proportion of leopard scats contained rodents (K Sankar unpublished data). The leopards on the Mundanthurai plateau were reported to be preying mainly on sambar (Sathyakumar 1992), while Johnsingh (1983) in Bandipur found that 66% of leopard kills were chital. Fifteen and a half per cent of the kills weighed more than 100 kg. Ravi Chellam (1993) found that of the 200 scats that he analyzed from Gir, 40% contained chital remains while langur remains were found in 25% of the scats.

The growing human population in the tropical regions of the world has resulted in extensive habitat loss for large predators, and poses the main threat to the conservation of wild cats (Kitchener 1991). In addition to this, the fur and body parts of many cat species have considerable value in the wildlife trade, encouraging poaching and endangering their continued survival (Fitzgerald 1989). All over its range, leopard populations have declined severely and predictions have been made that in another twenty years available range in sub-Saharan Africa will decline by half (Martin and de Meulenaer 1988). Opinion about its future in Africa outside protected areas has been pessimistic with Cobb (1981) saying that we must accept the fact that man will not coexist with leopards and continue to kill them. Habitat destruction, loss of wild prey, poaching for skins, bones and claws, and poisoning carcasses of livestock killed by leopards are significant threats to the animal (Nowell and Jackson 1996).

Strategies targeted at conservation of the leopard will need to take into account the fact that many leopards exist outside protected areas and close to human habitation. Any long-term strategy has to therefore have the involvement of the rural people (Anderson and Grove 1989). Amelioration of the conflict resulting from livestock killing and occasional man-eating is especially important in the

Indian context. Control of the illegal international market for skin and bones is also vital. Bailey (1993) suggests a three pronged strategy for conservation of the African leopard involving education and awareness programme for children, strengthening of protected areas, and utilization of leopards on a sustainable basis for the benefit of people living in and around leopard habitat.

India supports 13% of the world's livestock population, most of which depends on forests for its forage requirements (Lal 1989). Since leopards in India share their habitat with domestic livestock there is inevitably some level of predation on them. All the Project Tiger reserves record livestock predation by tiger and leopard regardless of the densities of wild prey available in them (Sawarkar 1986). Norton *et al.* (1986) however found that a negligible number of leopard scats examined contained remains of sheep or goat in areas with plentiful natural prey in Africa. A study on a ranch in Africa (Mizutami 1993) concluded that compared to total losses due to all causes, the proportion of livestock lost to leopards was small. Schaller (1967) thought that leopards on the periphery of Kanha Tiger Reserve subsisted almost entirely on livestock. The leopard's habit of breaking into sheds and living near villages makes it a greater potential threat to livestock than tigers. Leopards have also been known to turn to killing humans. The man-eater of Rudraprayag claimed about 125 victims before being shot (Corbett 1981). Between 1982-1989, 170 people were killed by leopards in India, the majority of them being in the Garhwal, Kumaon and Chamoli hill districts of Uttar Pradesh (Johnsingh *et al.* 1991).

The leopard has been documented to be adaptable with respect to its habitat and food requirements, being found in intensively cultivated and inhabited areas as well as in and around urban development (Nowell and Jackson 1996). The generalist nature of this species implies a wide variation in its ecology across its range. The food habits, land tenure systems, activity patterns and the nature of the leopard's interaction with humans and domestic animals in various types of ecosystems in India needs to be studied so as to formulate site-specific management strategies to ensure its conservation.

1.3 Background for the present study

The Sanjay Gandhi National Park (SGNP) is a habitat with low wild ungulate densities and high levels of disturbance. The Park is like a small island of forest surrounded by very dense human inhabitation. Encroachment by hutments is gradually decreasing the area of the Park available for wildlife despite the best efforts of the Maharashtra State Forest Department. Many people enter the Park every day and cut wood to meet their fuelwood needs (*pers obs*). Some illegal felling for teak (*Tectona grandis*) also takes place, especially on the northern boundary near the Vasai creek. Bailey (1993) avers that the extremely high densities of leopards speculated to occur within the city limits of Nairobi are probably atypical around developed areas. The SGNP is also atypical by this criterion. Small areas, low densities of wild prey and high biotic pressures by surrounding human inhabitation however are characteristics that are shared by many forest areas in India. By documenting the ecology of the leopard in these apparently marginal conditions, it is hoped that the study will supplement the available information on this charismatic large carnivore and enable informed management action for its conservation.

Objectives

The study began in December 1995 and field work continued till July 1996. The main objectives of this study were the following:

1. *To determine the diet of the leopards in SGNP.*

2. *To estimate the relative abundance of potential prey for leopards in selected areas in SGNP.*

3. *To relate vegetation characteristics, human disturbance and prey abundance to the intensity of habitat use by leopards.*

4. *To investigate spatial and temporal patterns in the occurrences of leopard-human conflict in and around SGNP.*

STUDY AREA

2.1 Location

The Sanjay Gandhi National Park (SGNP) lies between 19° 8'N, 72° 53' E and 19° 21'N, 72° 58'E. Earlier known as Borivli National Park, it extends over an area of 103 km^2, 8.5 km^2 of which is covered by lakes. SGNP lies partly in Thane and partly in the Mumbai Suburban district. For management purposes the Park has been classified into a core zone of 28.1 km^2, a buffer zone of 66.2 km^2 and a tourism zone of 8.6 km^2 (A.R. Bharati unpublished manuscript).

The eastern limit of the Park is bordered by the Yeur forest division, the west by the Krishnagiri Upvan plains and the suburb of Borivli, the north by the Nagla forest block and on the south by the Aarey Milk Colony in the suburb of Goregaon (see **Fig 1**). The National Highway 8, also known as the Western Express Highway runs south-north along the western border of the Park, connecting the city of Mumbai to Ahmedabad, while the Eastern Express Highway, running along the eastern border connects Mumbai to Nasik. The Park is about 40 km away from downtown Mumbai.

2.2 Geology and Terrain

The Park forms, geologically, a part of the 'Deccan trap'. Basic lava flows comprising of basalt rock are mainly seen. Ash beds are also found. At some places near Tulsi and Vihar lakes, volcanic breccia is found. Marine alluvium is found on the west on the plains towards the suburb of Borivli. The soil is quite shallow over most of the park, especially on hill sides (Rege 1974).

The topography is hilly and with only a few areas of plain terrain. In certain places the hills are steep, giving way to precipices and rocky outcrops. These constitute the edge of the Sahyadris and are oriented predominantly in the north-south direction. The plains rise from about 30 m above sea level to a series of peaks, the highest of which is 486 m, connected to each other by narrow plateaux.

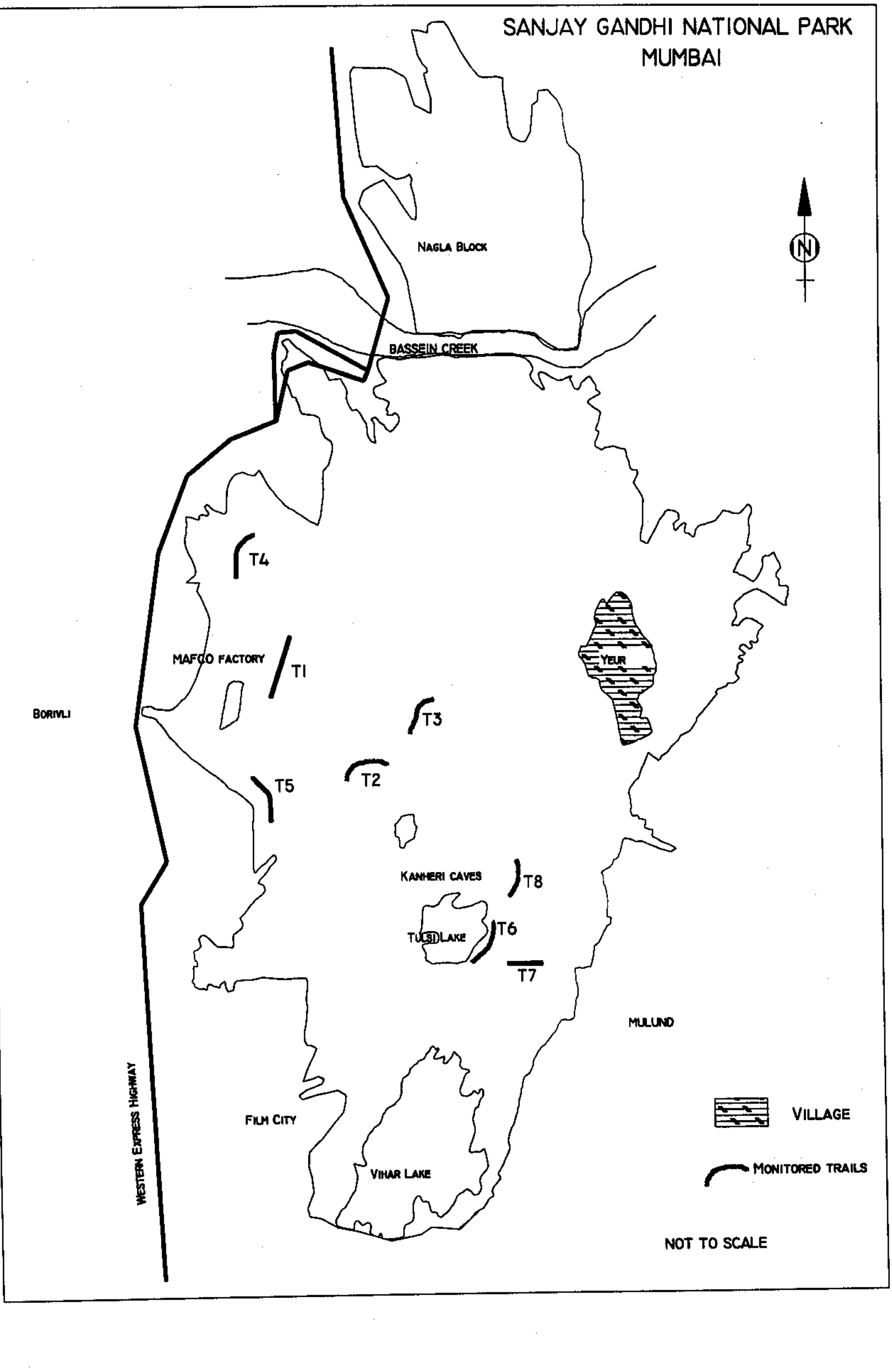
2.3 Climate

The mean annual temperature is 27° C, November to February is generally pleasant with nights tending to be cool, the temperature increasing from March with April, May and October quite warm and humid. The proximity of the Arabian Sea makes the climate equable. The south-west monsoon gives abundant rainfall to the region. The mean annual rainfall of about 2600 mm, concentrates itself from the middle of June to the end of September. The north-east monsoon usually gives a little rainfall of about 50 mm or less in November and December (Rege 1974).

2.4 Vegetation

The forest is mainly of the Southern Moist Deciduous type (Champion and Seth 1968). Santapau and Randeria (1955), in a survey of the flora of the Park found the top storey to consist of *Terminalia crenulata, Tectona grandis, Garuga pinnata, Bridelia retusa, Butea monosperma, Mallotus philippensis, Adina cordifolia, Bauhinia racemosa*. In areas of scanty soil species like *Sterculia urens, Nyctanthes arbor-tristis,*

FIG I. : MAP OF THE STUDY AREA AND LOCATION OF MONITORED TRAILS IN THE PARK



Holoptelia integrifolia, Hymenodictyon excelsum, Hymenodictyon obvatum and *Gardenia lucida* were seen. In some densely wooded areas, pockets of semi-evergreen forest are also found. Some teak plantations are also present as part of the improvement fellings silvicultural system followed in the past (Rege 1974). Mangrove forests of *Avicennia spp* are found along the tidal creeks and estuarine mudflats. In all around 320 genera of plants have been recorded in the Park (A.R. Bharati unpublished manuscript).

2.5 Fauna

The Park has a wide assemblage of fauna. An avifauna of at least 250 species belonging to 47 families is found (A.R Bharati unpublished manuscript). Thirty eight species of reptiles are also found. Among the mammals, blacknaped hare are commonly seen. The bonnet macaque (*Macaca radiata*) is found and so are a few introduced rhesus macaque (*Macaca mulatta*). Hanuman langurs are common in relatively undisturbed areas. Ungulates are represented by chital, sambar, barking deer, mouse deer (*Tragulus memmina*) and chowsingha (*Tetracerous quadricornis*). Small carnivores like the common mongoose (*Herpestes edwardsi*) can be spotted easily, whereas jackal (*Canis aureus*), jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosa*) and small Indian civet (*Viverricula indica*) are rarely seen, but do exist. The striped hyena (*Hyaena hyaena*) is also reported. Domestic dogs, owned by the people living in the Park as well as ownerless strays from Mumbai city are abundant and may be a significant cause of predation on small mammals and ungulates. The top predator in the park is the leopard.

2.6 The leopard population in SGNP

Despite the small size of the Park and its proximity to the densely populated urban Mumbai, the forest department census, using the pugmark technique, reckons a population of about 40 leopards (see **Table 1**).

Table 1. Census figures of leopard population in the SGNP

Source: Office of the SGNP, Maharashtra State Forest Department.

YEAR	MALE	FEMALE	UNKNOWN	CUBS	TOTAL
1988	15	15	0	5	35
1989	11	11	12	9	43
1990	15	16	3	13	47
1991	11	13	15	4	43
1992	14	16	2	13	45
1993	15	7	10	6	38
1994	12	19	5	5	41
1995	14	13	8	4	39
1996	18	17	0	5	40

An indication of the high densities of the leopard population in SGNP would be if the leopards here had small home ranges and large degrees of home range overlap. Research has shown that there is an enormous variation in home range size for a wide array of felids. This variation has been related to the temporal and spatial distribution of prey and the mean body size of the felid species (Eisenberg 1986). Large cats would thus have large home ranges, while abundant prey would tend to reduce home range size and thus increase densities of these predators. For example, the relatively small home ranges of tigers in Chitawan was associated with seasonally stable, evenly distributed prey populations (Sunquist 1981), while in Siberia, with very low densities of prey, home ranges of male tigers are in excess of 800 km^2 (Kitchener 1991).

In rainforests most of the productivity is locked up in tree crowns, making it inaccessible to terrestrial herbivores (Eisenberg 1980). The low densities of terrestrial herbivores would not be able to support high leopard densities in the rainforest. Leopard densities in these habitats have been opined not to exceed 1 per 10 km^2 and more likely to be around 1 per 30 km^2 by Bailey (1993). David Jenny (1996) concluded from his study that rainforests were not the 'tropical havens' for leopards and estimated densities of about 1 per 14 km^2 in the Tai National Park. Home range of a male leopard here was found to be 86 km^2, with partially overlapping female ranges which were up to three times smaller than the male home range. The highest densities recorded by Bailey (1993) in his woodland study area of Kruger were 1 per 3.3 km^2 where prey biomass varied from 2,932 to 6,186 kg/km^2, while Pienaar (1969) estimated a crude density of 1 per 29 km^2 for the whole park. For the Serengeti, Schaller (1972) guestimates that the density of leopards could be about 1 per 22 to 26.5 km^2. In Wilpattu National Park the estimated densities were 1 per 29 km^2 (Muckenhirn and Eisenberg 1973). Smith (1977) reported a maximum density of 1 per 4.5 km^2 in the Matopos National Park, Zimbabwe. In Wilpattu, home ranges of four leopards were recorded as between 8 and 10.5 km^2 (Muckenhirn and Eisenberg 1973). In Nepal Seidensticker (1976) found female home ranges between 6 and 13 km^2 in the Royal Chitawan National Park.

The number of wild ungulates in SGNP is low, despite a reintroduction of chital and sambar in 1971 (Rege 1974), (see **Table 2**).

Table 2. Census figures of ungulate population in the SGNP in 1996.

Source: Office of the SGNP, Maharashtra State Forest Department.

Species	Number
Chital	137
Sambar	33
Barking deer	21

That SGNP, with a land area of 95 km^2 may have a crude density of leopards as high as 1 per 2.4 km^2 is surprising in the light of figures for the available prey population. Leopards from SGNP also move outside the Park limits into the adjacent Aarey Milk Colony, which has habitats of scrub jungle characterised by high human disturbance and inhabitation. This spillover into the Aarey Milk Colony may reduce the density of the leopards inside SGNP.

Large cats are difficult to count. Various indirect methods have been used to estimate their populations. In Africa, Martin and de Meulenaer (1988) estimated leopard populations over Africa. They regressed estimates of 23 leopard populations from different countries in Africa given by various wildlife researchers with the annual rainfall in those places. They then extrapolated the results to the whole continent. The results have been criticised as being dependant on crude and unsubstantiated population estimates and being made on the basis of untested assumptions (Bailey 1993). In Kruger, Bailey (1993) extrapolated densities from his study sites, arrived at on the basis of his knowledge of radio-collared leopard home ranges, to areas with similar habitats and prey densities.

The pugmark technique (Panwar 1979) is used for tigers and leopards in India. For a short period of time forest officials make plaster casts or tracings of all the pugmarks found on suitable substrates. These are then compared assuming that each individual has a unique and distinguishable pugmark. This method has the advantage of being relatively cheap. It has been criticised as unreliable by Karanth (1987), who has instead suggested using intensive camera trapping coupled with mark-recapture methods for estimating tiger populations in the wild (Karanth 1995). Smallwood and Fitzhugh (1993) have distinguished individual pumas (*Felis concolor*) using discriminant function analysis on their pugmark measurements. Gore *et al.* (1993) have also suggested multivariate techniques for identification of tiger pugmarks. The addressing of more research to develop reliable methods to assess large cat populations is crucial so that basic demographic information is available for each species (Nowell and Jackson 1996).

The pugmark technique used in SGNP and all over India has been demonstrated to be of unreliable accuracy (Karanth 1987). The reliability of the census figure in SGNP therefore remains unknown in the absence of ancillary information on home range sizes and extent of their overlap.

The SGNP faces tremendous pressures due to the ever increasing population of Mumbai city. Slums have started encroaching into the park. A recent study based on remote sensing data put the loss in area of the park from 1990 to 1995 at 3.02 km^2 (Jadhav *et al.* 1995), gradually reducing the habitat available to wildlife. Between twenty and thirty lakh people are estimated to visit the Park annually (A.R. Bharati, unpublished manuscript), mainly visiting the tourism zone for recreation. Two fatal attacks by leopards on children in quick succession took place in May 1995. These have fuelled fears that the increasing potential for interaction with people, coupled with the lack of adequate natural prey, could intensify leopard-human conflict.

THE FOOD HABITS OF THE LEOPARD

Studies of feeding ecology of carnivores rely on one or a combination of many methods. These are: direct observations of incidences of hunting, finding kills made by the predator based on prey remains, or studying the remains of prey found in predator scats. The leopard hunts by stalking, taking prey opportunistically and hunting mostly at night, especially in places where they have been persecuted by man (Nowell and Jackson 1996). Since they are secretive and not easily seen, direct observation of prey capture is only rarely possible. For example only 3 of 64 hunting attempts witnessed by Bertram (1978) resulted in success. Most studies therefore rely on the indirect evidence from kills and scats.

An examination of 44 leopard scats by the forest department staff in SGNP over five years from 1989 to 1994 revealed the presence of hair of macaque, common langur, black naped hare and domestic dog (R.P. Barahate unpublished data). A meat processing factory is located inside the park (**Fig 1**) and the leopards may also scavenge off the waste from this factory (J.C. Daniel *pers comm*).

3.1 Methods

The food habits of the leopard were investigated by scat analysis. Eight dirt roads were monitored regularly in the Park for scats. Other areas in the Park were searched opportunistically. All scats found were put in paper bags and the locality and date were noted. Fresh scats were air dried before being bagged.

Analysis of the scats was done in the laboratory. The diameter of the scats was measured around the thickest portion in the laboratory with the help of vernier callipers. Scats were considered to be leopard scats if they had pointed ends and many lobes in relation to their size or if they were associated with pugmarks or scrapes. The scats were first divided into those that were definitely leopard scats on the basis of size, pointed ends, number of lobes and associated leopard signs, those that were most likely to be leopard scats, and those that could have belonged to other species like small cats, domestic dog or hyena. The last group of scats was discarded for the purpose of analysis.

Scats were teased apart with forceps to look for rodent jaw bones and claws of rodents and dogs. Samples of undigested hair from the prey remains found in the scat were taken and washed in water. They were then dried, washed in alcohol for 10 minutes, and then in xylene. The hair were then mounted on a slide in xylene and examined under a binocular microscope for characteristic medullary patterns. Prey hair was identified by comparison with a reference collection of mammalian hair maintained in the laboratory of the Wildlife Institute of India. Twenty randomly picked hair were examined from each scat (Mukherjee *et al.* 1994).

3.2 Sample size requirements for scats

Each scat yielded the remains of one or more species. The percentage of scats containing prey of various species was determined. It is necessary to know whether the number of scats analyzed reflect an accurate picture of the diet of the leopard.

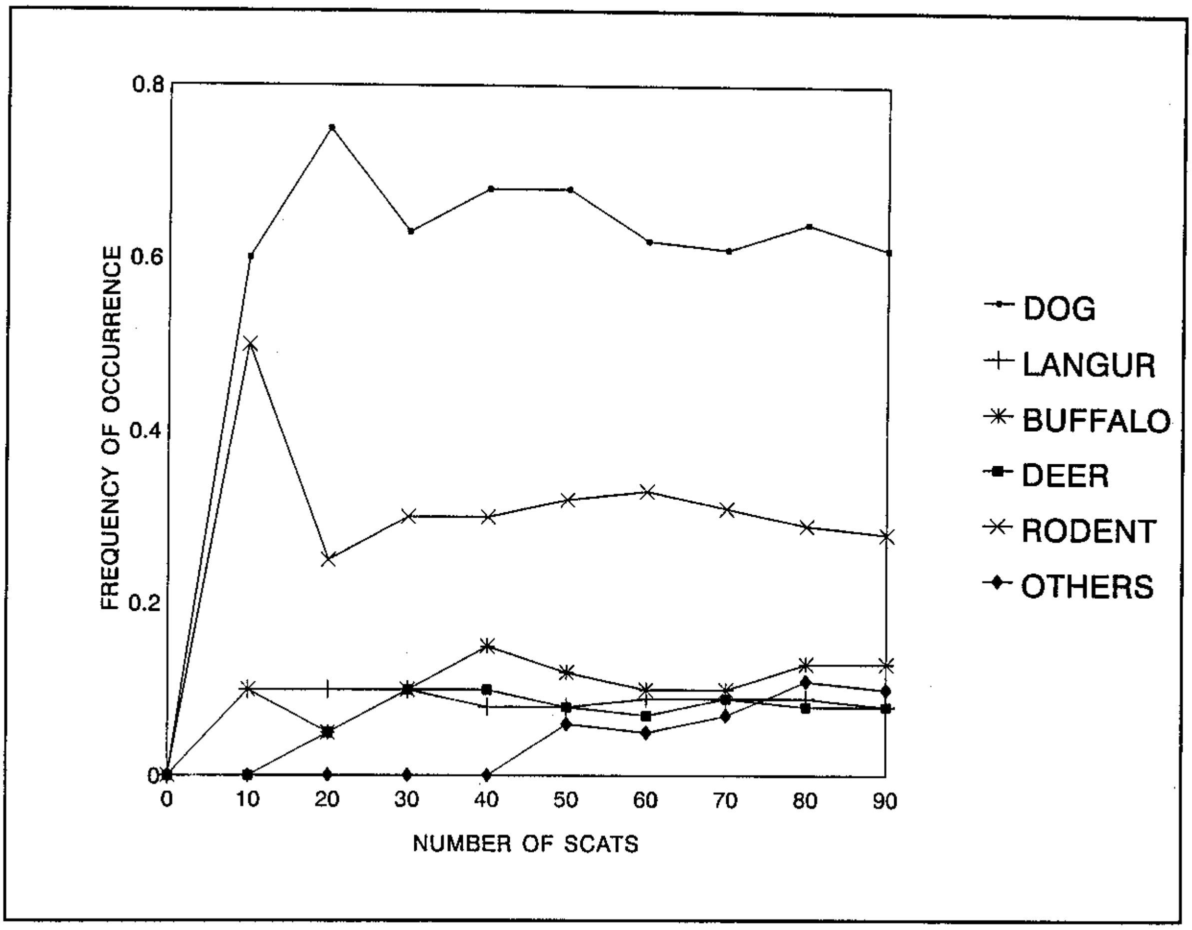


Figure 2: Observation-area curve to determine adequacy of sample size of scats for quantifying percentage of prey.

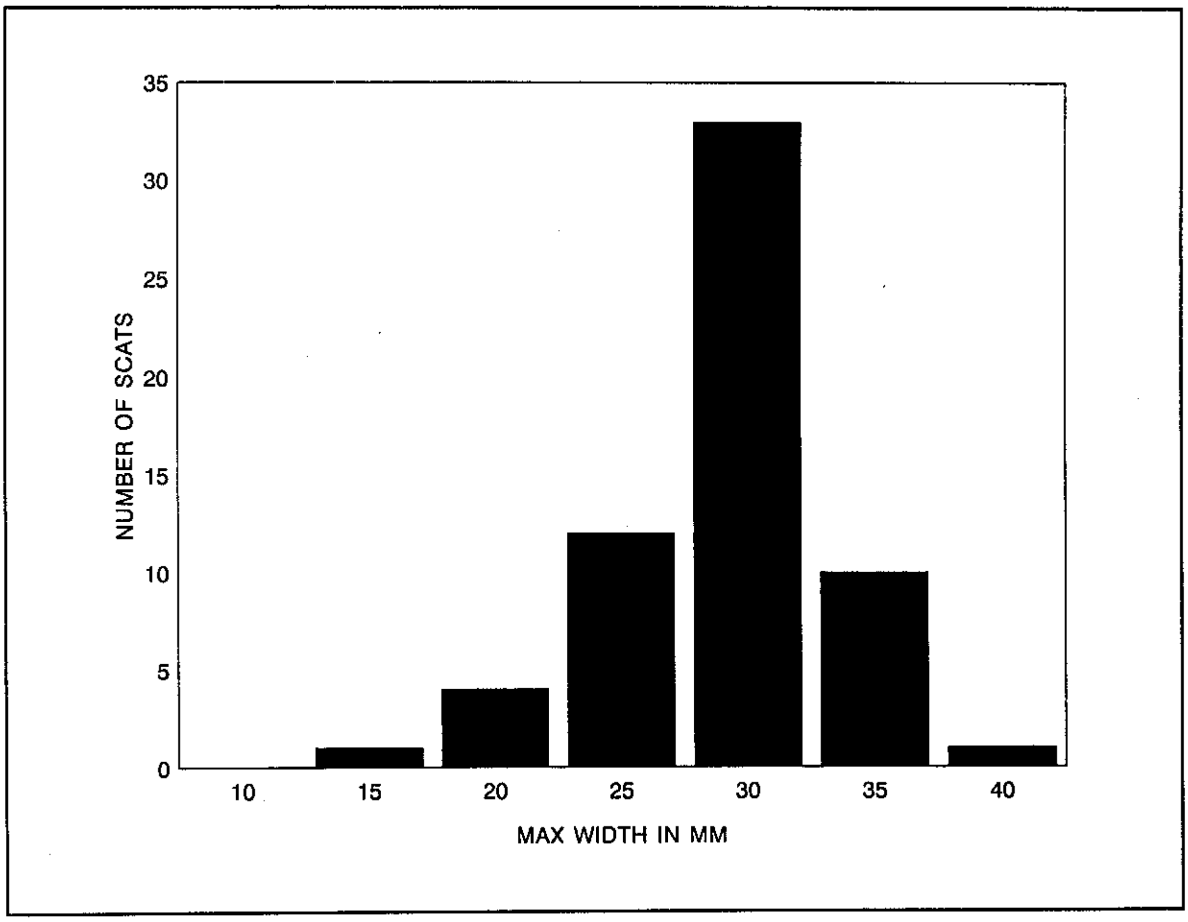


Figure 3: Frequency distribution of diameter of leopard scats measured around the thickest region in SGNP (n=61).

The following procedure was adopted to find out adequacy of sample size. After all the scats were analyzed, an observation- area curve (Odum and Keunzler 1955) i.e. a curve for the per cent frequency of occurrence of major species represented in the diet was calculated at an interval of every five scats, after randomising the order of the results obtained. After fifty five scats the curve flattened out for most prey species, the relative percentages of prey remained similar after this (see **Fig 2**). This indicated that a sample size of about fifty five scats was enough to obtain an accurate picture of the diet of leopards in SGNP. The actual sample size analyzed was 90 scats.

3.3 Scat measurement

The width of the scat was measured around the thickest part with the help of a vernier callipers for scats which were of distinct form. On an average(±SD) scats measured 26.5± 4.3 mm. The distribution of scat measurements is given in **Fig 3**.

3.4 Diet composition

Predator diets have been found to be more precisely studied by scat analysis as opposed to kills in forested habitats (Karanth and Sunquist 1995). Studies based on kills are biased towards large prey, the remains of which are more easily detected than those of small prey. Most scat analysis studies give a percentage frequency of occurrence of each prey type in the carnivore's diet. The relative biomass of prey eaten can be estimated using the regression model developed by Ackerman *et al.* (1984) for cougar.

The total sample of 90 scats was subjected to resampling to get variance and confidence limits on the mean percentage of prey in scats (Reynolds and Aebischer 1991). This involved iterating different subsamples of the same size 10000 times using the bootstrapping method using the computer programme SIMSTAT (Pélàdeau 1995). The mean percentage of various prey types, the variance and the 95% lower and upper confidence limits associated with the mean were calculated **(Table 3)**.

Table 3: Mean percentage frequency of prey types found by scat analysis, after bootstrapping simulation with 95% Confidence limits (see text).

Prey	Mean (%)	Lower Confidence Limit	Upper Confidence Limit
Domestic dog	63.7	52.3	72.7
Domestic buffalo	14.8	6.8	21.6
Rodents	26.1	17.0	36.4
Primates	11.4	5.7	19.3
Cervids	9.1	3.4	14.8
Others	5.7	1.1	11.4

It was seen that 77% of scats contained only one prey species, 21% of scats had two species and 2% had three species. Seventy seven per cent of multispecies scats had domestic dog as one of its constituents and 66% had rodent species
(Fig 4).

Frequencies of species found in scats sometimes give a misleading indication of the importance of the species in the leopard's diet, which is better described by the relative biomass contributed by each species. Ackerman *et al.* (1984) derived estimates of relative biomass of prey taken by mountain lions (*Felis concolor*), using feeding trials. The linear regression that he obtained has been used by Karanth and Sunquist (1995) for leopards and tigers.

The linear regression equation:

$$Y = 1.98 + 0.035X$$

(r= 0.77)

Where **X** is the average body weight of the prey species in kilograms gives a weight of prey per scat, Y, that is used to convert relative frequencies of various prey obtained in scats into relative biomass of prey species taken. The model assumes that there is only a single species per scat.

Reliable estimates for the relative biomass of prey taken by leopards in SGNP may be possible given fairly reliable estimates of mean weight of each prey type and the presence of a single prey item per scat. Both these conditions could not be satisfied. The applicability of an equation derived from mountain lions to leopards is also untested. Moreover, the prey of the mountain lion, living in colder climates, is likely to have more hair per unit of body weight and therefore more scats

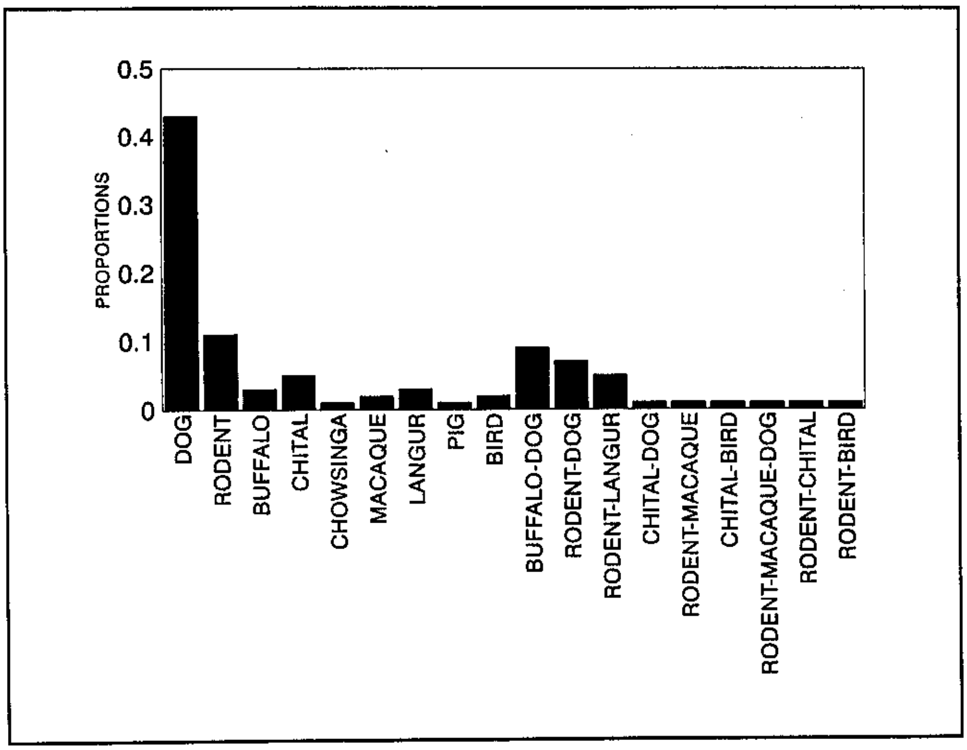


Figure 4: Proportions of various prey species combinations found in the sampled leopard scat.

may be produced per unit biomass consumed. Each leopard scat, consisting of less hairy prey might therefore represent more biomass eaten than in the case of the mountain lion. The relative biomass estimation was therefore not done.

Most studies on food habits in Africa and Asia have found ungulates to be the main prey species of the leopard (Bailey 1993). The present study seems to be one of the exceptions as the bulk of the diet comprises of domestic dogs. The leopard's fondness for domestic dogs as prey around villages and near inhabitation has been well documented in literature (e.g Daniel 1996). We find that ungulates and primates are not as important a component of the diet as domestic dogs, and while reasonable numbers of rodents are preyed upon, they are unlikely to contribute a significant biomass to the diet because of their low weight. Many studies have documented the opportunistic nature of the leopard's hunting pattern (e.g. Bothma and Le Riche 1984, Eisenberg 1986; Bailey 1993). Because of the occurrence of domestic dogs in the SGNP and the paucity of wild ungulates, the leopard seems to be largely surviving on small prey (less than 20 kg in weight). Schaller (1972) found that the leopard was mostly taking prey in the 20-70 kg class. Thirty six per cent of the leopards prey in Chitawan was less than 25 kg (Seidensticker *et al.* 1990) while 84% of scats analyzed in the present study contained prey (rodents, langur, macaque, birds and domestic dog) that could be considered as small (<20 kg). The leopard should have encountered a number of black naped hare as its presence and pellets were quite abundant (*pers obs*). The absence of remains of the black naped hare, quite easy to identify in scats because of its distinctive medullary pattern, comes as quite a surprise and remains unexplained. K. Sankar and S.Mukherjee (*pers comm*) also found little hare to be taken in Sariska, Ravi Chellam (1993) did not find much hare in leopard scats, while Karanth and Sunquist (1995) estimated that about 5% of the leopard's prey in Nagarhole comprised of hare.

Arboreal prey (birds and primates) comprised 12 per cent of total prey taken. Bird remains (in one case peafowl, *Pavo cristatus* and unidentified in two others) were found in three scats, and were only a minor component of the leopard's diet. Langur and macaque were also taken showing that the arboreal nature of prey does not necessarily preclude its exclusion from the leopard's diet. Seidensticker (1983) found that an abundant and diverse prey base in Chitawan meant that leopards took macaques and langur only occasionally, while Schaller (1967) found leopards to be killing langur frequently in Kanha Tiger Reserve, Madhya Pradesh.

Livestock has been recorded as a major component of the diet taken by leopards at the edge of Royal Chitawan National Park where the densities of domestic ungulates at the boundaries were far more than those of wild ungulates (Seidensticker *et al.* 1990). The proportion of scats in which domestic buffalo hair were found in the present study was a puzzling phenomenon. No records of buffalo killing could be found with the park authorities, who have a scheme for the compensation of livestock lost due to predation. The Park is contiguous with the Aarey Milk Colony in the south and leopards are regularly seen there. There are numerous buffalo *tabelas* (sheds) to be found in the suburb of Goregaon near the Aarey Milk Colony. A likely explanation could be that the leopards are scavenging off the carcasses of buffalos left lying near the edges of the Park by *tabela* owners unwilling to dispose off carcasses properly. A similar scavenging on buffalo has been observed in Majhatal Wildlife Sanctuary in Himachal Pradesh (Charudutt Mishra *pers comm*).

3.5 Regulation of Prey Populations

The impact of predation by large cats on the population of their prey is a little understood process in spite of much theoretical research into predator-prey relationships. Most work on predator impacts on prey populations has been done in aquatic systems with controlled populations of predator and prey. A notable exception has been the research into lynx (*Lynx* sp)- snowshoe hare population relationships (eg Boutin *et al.* 1986). Recently Palomares *et al.* (1995) have worked on the Iberian lynx (*Lynx pardinus*) in Spain and have reported to have found evidence of 'mesopredator release'in which the top predator, the lynx, kept down populations of mongooses, and therefore relieved predation pressure on small game species. The ecological role of a top predator in maintaining small animal diversity thus is seen as a possibility.

In order to answer the complex question on the impact that the leopard in SGNP has on the prey population, accurate data on several aspects of the population dynamics of predator and prey needs to be gathered. Leopards in SGNP prey mainly on domestic dogs, wild ungulates and primates. The extent of predation by dogs on the ungulates also needs to be studied. One of the authors (R.C.) saw an attempt at predation by domestic dogs on chital in the SGNP. Is the low density of cervids in the Park a result of combined predation by leopards and dogs on them? Do the leopards actually keep the dog population in check and so promote the continued existence of wild ungulates in the Park, a case of 'mesopredator release'? And is the heavy dependence on dogs by the leopards a typical case of a functional response to reduced wild ungulate prey density? The present study cannot answer these interesting questions.

THE LEOPARD'S HABITAT

4.1 Methods

The leopard's habitat was quantified in terms of tree density, abundance of potential prey, distance from habitation and stalking cover. Sampling was done along eight dirt roads (trails T1 to T8) in the park (**Fig 1**). A point on each of the trails was randomly chosen by generating a random number representing the distance of the point from the beginning of the trail. A pedometer was used to measure the distance. A 1 km long section beginning from the point was intensively monitored for leopard signs such as scats, pugmarks and scrapes. Tree density, stalking cover and relative abundance of prey were estimated along this part of the monitored trail.

4.2 Estimation of prey abundance

It was not possible to obtain absolute density estimates for the prey of the leopard because of their low numbers and infrequent sightings. An indirect relative estimate was therefore obtained by counting pellets along the trails. Rectangular plots of 10 X 2m were laid at 100m intervals on each side of the trail for quantifying pellets of prey species. The sampling was repeated five times for each trail during the course of the study. An encounter rate (no of sightings per km) was also calculated based on direct sightings of animals while monitoring the trails.

Pellet groups reflect both nocturnal and diurnal relative abundances while encounter rates were calculated on the basis of diurnal sightings. Since the leopard is primarily nocturnal, pellet groups would give a better indication of relative prey availability along trails. Pellets also persist on the forest floor for a long time, enabling detection. Pellet counts gave better results for assessing hare relative abundances while very few cervid pellet groups could be found. Livestock were sighted more on trails, compared to their dung. Encounter rates were therefore better suited for cervids and livestock (**Table 5**).

A very low density of pellet groups was encountered on all trails. Hare pellets were seen most often, especially on bare patches of rock without grass or litter. The only domestic livestock seen on trails were cows, mostly belonging to an ashram located above Kanheri caves.

4.3 Tree density and cover estimation

The density of trees along the trails was estimated using circular plots of 10 m radius at every 100 m on both sides of the 1 km section of trail. Twenty plots were thus laid for each trail, and all woody vegetation of more than 20 cm gbh was counted.

Stalking cover was estimated with the help of a cover board (e.g. Jones 1968). A cover board of 75 cm by 90 cm was constructed with twenty five alternating black and white rectangles. The cover board was held by an assistant at the centre of each plot and the number of rectangles visible from four points at 10 m distance from the board in different di-

Table 5: Number of pellet groups/dung per 20 m^2 (n=100/trail)(p.g) and encounter rates/km (e.r).

T. No.	Hare e.r	Hare p.g	Cervid e.r	Cervid p.g	Primate e.r	Primate p.g	Cow e.r	Cow p.g
T1	0.13	0.03	0.07	0.03	0.27	0.08	0.00	0.00
T2	0.00	0.19	0.40	0.00	0.40	0.09	0.20	0.04
T3	0.07	0.05	0.13	0.00	0.13	0.03	0.27	0.03
T4	0.07	0.35	0.07	0.00	0.00	0.00	0.07	0.05
T5	0.20	0.13	0.00	0.00	0.00	0.00	0.13	0.00
T6	0.00	0.10	0.33	0.08	0.25	0.14	0.00	0.00
T7	0.00	0.00	0.00	0.00	0.50	0.07	0.00	0.00
T8	0.00	0.10	0.00	0.05	0.42	0.05	0.00	0.00

rections were noted. The number of rectangles not visible due to obstruction caused by vegetation between the board and the observer was an index of stalking cover. A mean estimate of the stalking cover available to the leopard was thus obtained at each plot. Tree density and cover along the trails is given in **Table 6**.

4.4 Disturbance on trails

The measurements of human disturbance on the trails was initially attempted to be quantified by the number of cut trees in the vegetation plots. However there were too few cut trees in the plots. Distance from the nearest *pada*, a typical tribal hamlet found in the Park, was considered to be an index of disturbance along the trail (**Table 6**).

4.5 Relative use of trails by leopards

The index of use of trails by leopards was calculated as the proportion of walks in which leopard sign was seen on the trail. It reflects the relative degree to which the trails were being used by leopards. Indirect evidences of leopard use such as scats, pugmarks and scrapes were collected along the trails. An interval of at least a week was allowed to elapse before a trail was remonitored. Only the presence or absence of signs along the 1 km trail was considered each time the trail was monitored, and not the number of signs encountered. Although some data was lost by this method, the resulting sample could be considered independent in time and space. Care was taken to see that scrapes, which persisted for a long time, were not counted again when seen on subsequent visits to the trail.

Trails **2**, **5** and **7** seemed to be areas of intense leopard use, trail **4** had low levels of use and trails **1**, **3**, **6** and **8** had moderate levels of use (**Table 6**). Proximity to human settlements did not inhibit leopard use of the trails, as a moderately used and an intensely used trail were found quite close to habitation. The disturbance caused by human habitation is probably more than offset by the availability of domestic dogs in and around the *padas*. Degree of use of a trail by leopards was positively correlated with point

Table 6: Habitat measurements and index of leopard use along trails in SGNP (Jan to July '96).

Trail *	**Index of leopard use.**	**Dist. to *pada* (km)**	**Stalk ing Cover**	**Trees/ha±SD**
T1	0.7	0.5	3.2	665±144
T2	0.9	1.5	3.3	686±215
T3	0.7	3.5	7.0	723±264
T4	0.3	1.5	6.3	627±226
T5	1.0	1.0	4.6	709±235
T6	0.7	3.5	4.7	670±236
T7	1.0	2.5	3.0	743±229
T8	0.7	3.0	4.0	662±170

* *Trails T1 to T5 were walked 15 times each, while T6, T7 and T8 were walked 12 times each.*

estimates of density of trees along the trail (Spearman's rank correlation, $r=0.77$, $n=8$, $p=0.03$). However, the density of trees was not found to be different between the different trails (K-W ANOVA, $\chi^2=2.3$, $p=0.85$). Stalking cover along the low use trail was found to be significantly higher than the moderate (Mann-Whitney $U=658.5$, $p=0.0002$) and intense use trails (Mann-Whitney $U=834.0$, $p=0.0004$). Stalking cover between moderate and intense used trails was not significantly different (Mann-Whitney $U=2029.5$, $p=0.87$).

It can be concluded that the variables considered (cover, tree density, distance to *pada* and prey density) do not play much of a role in determining use of the habitat by leopards. This makes sense in the context of a small area with a high density of leopards, where the principal prey, domestic dog, is not randomly distributed but is found in and around human habitation.

LEOPARD-HUMAN CONFLICT IN SGNP

5.1 Introduction

When large cats live in proximity to humans, some amount of conflict between them is inevitable (Sawarkar 1986). This usually takes the form of livestock killing by the predators. Human casualties are rare and usually the result of accidental encounters. The occurrence of deliberate man-eating by leopards does take place at times however, and then the leopard is acknowledged to be more dangerous than the tiger because of its boldness and cunning in entering villages to kill human prey (Daniel 1996). The famous man-eating leopard of Rudraprayag claimed more than 125 victims from 1918 to 1925 before it was finally shot (Corbett 1981). Corbett's explanation for the leopards habit of turning to human prey was that when epidemics killed large numbers of people in the Himalayas the bodies were not cremated but simply pushed down into the valleys. The leopard, scavenging off human corpses soon acquired a taste for them and started man-eating at the end of the epidemic.

Sunquist and Sunquist (1990) say that small island-like preserves of ideal habitat may be recipes for creating man-eating tigers. These habitat patches would have females breeding successfully. The dispersing young adults, being pushed out of the prime habitat would encounter human habitation and may take to man-eating. In Gir, for example, there is a high density of lions inside the Protected Area and where the habitat quality is good. Outside the Protected Area, there is a matrix of agricultural fields and natural vegetation constituting a poorer quality habitat. It was the subadult lions, dispersing into these poorer habitats, which were found to be disproportionately involved in conflict situations (Saberwal *et al.* 1994).

5.2 Leopard-human conflict in SGNP

The Forest Department maintains records of reported cases of conflicts in and around the Park. This secondary data was collected from the SGNP Office and analyzed for patterns. SGNP is a small high density area for leopards, where an unquantified amount of breeding does take place. Leopards with cubs have been seen by many Forest Department staff (*pers comm*), and pugmarks of leopards with cubs at two places in the Park were also recorded (*pers obs*). The numerous instances of leopard sightings outside the Park, (**Table 7**) indicates the possibility of the area or habitat quality being insufficient for the population.

5.3 Management of problem leopards

Many leopards going outside SGNP or suspected of being involved in attacks on people have been captured by the Forest Department. Nineteen leopards have been translocated to other sanctuaries, most of them to the Tansa Sanctuary about 150 km away. Nineteen leopards have been translocated to areas inside the Park (**Table 8**). The Park fits the description of the 'recipe' given by Sunquist and Sunquist (1990), as a source for the dispersal of animals into areas of increased interactions with people. The potential for a large amount of leopard-human conflict certainly exists in the Park.

Table 7 Instances of leopard-human conflict in which human deaths, injuries and entering of leopards in human habitations occurred from 1986 to 1996.
Source: Office of the SGNP, Maharashtra Forest Department.

Year	Deaths	Injuries	Found in human habitation
1986	1	*	*
1987	1	*	*
1988	2	*	2
1989	0	*	1
1990	2	1	6
1991	0	4	12
1992	3	6	5
1993	1	2	3
1994	0	1	6
1995	2	0	0
1996	2	1	0

* *not recorded*

Table 8 Fate of leopards captured after being involved in different conflict situations in and around SGNP (1986-1996).
Source: Office of the SGNP, Maharashtra Forest Department

Nature of Conflict	Died during capture	Kept in captivity	Translocated
Attacks on humans	6	1	11
Found in human habitation	3	4	27

It is a testimony to the retiring and shy nature of the animal that there has been a low level of human casualties over the last ten years. The management's action of promptly attempting to capture leopards involved in injuring or killing humans and those that have been seen out of the Park must also be a contributing factor in mitigating conflict. The value of translocating leopards within SGNP itself is questionable. With a high density of leopards, it is unlikely that suitable habitat inside SGNP is not already occupied by resident leopards. Translocating new leopards into already occupied territories may destabilise the leopard's social system, and will not even achieve the desired objective of removing the problem leopard from in and around human inhabitation. Ross and Jalkotzy (1996) report that a male adult cougar travelled back to his home-range twice after being translocated 56 and 72 km away from it. An adult female cougar was found dead after translocation, possibly because of the social stress of being located into an already occupied habitat.

5.4 Spatio-temporality in conflict

Table 7 shows the number of human casualties and reported cases of leopard located in human inhabitations over the last 10 years. A significantly higher number of conflict situations have taken place in summer than in winter (χ^2 = 9.75, df=1).

Table 9 displays the number of deaths, injuries and cases of straying into human inhabitations in three different seasons. An explanation put forward to explain this pattern is that more people sleep outdoors in the Park in summer which thus accounts for more casualties. This does not however account for the casualties taking place during the monsoon and pre- winter period from July to October, when people do not sleep outside and which were not found to be significantly different from conflicts in summer (χ^2= 0.49, p>0.05). In Gir, Saberwal *et al.* (1994) found that more lion attacks took place in the monsoons. This pattern was explained by the researchers by the overlap in diel activity patterns between lions and humans in that season as well as an increase in grass cover obstructing visibility. This increased the probability of accidental encounters.

Most of the victims who died in SGNP were children (78.5%), the ages ranging from 9 months to 16 years (n=13). Only three adults have been killed. Most of the injured, however were adults (81.2%). The spatial distribution for instances of death and injury from 1986 to 1996 has been shown on the map (**Fig 5**). Attacks do not seem to be restricted to any part of the SGNP, but occur more towards the periphery (83%, n=24) than in the core area. A number of attacks have taken place near Yeur in Thane district to the north and near the Aarey Milk Colony in Goregaon to the south.

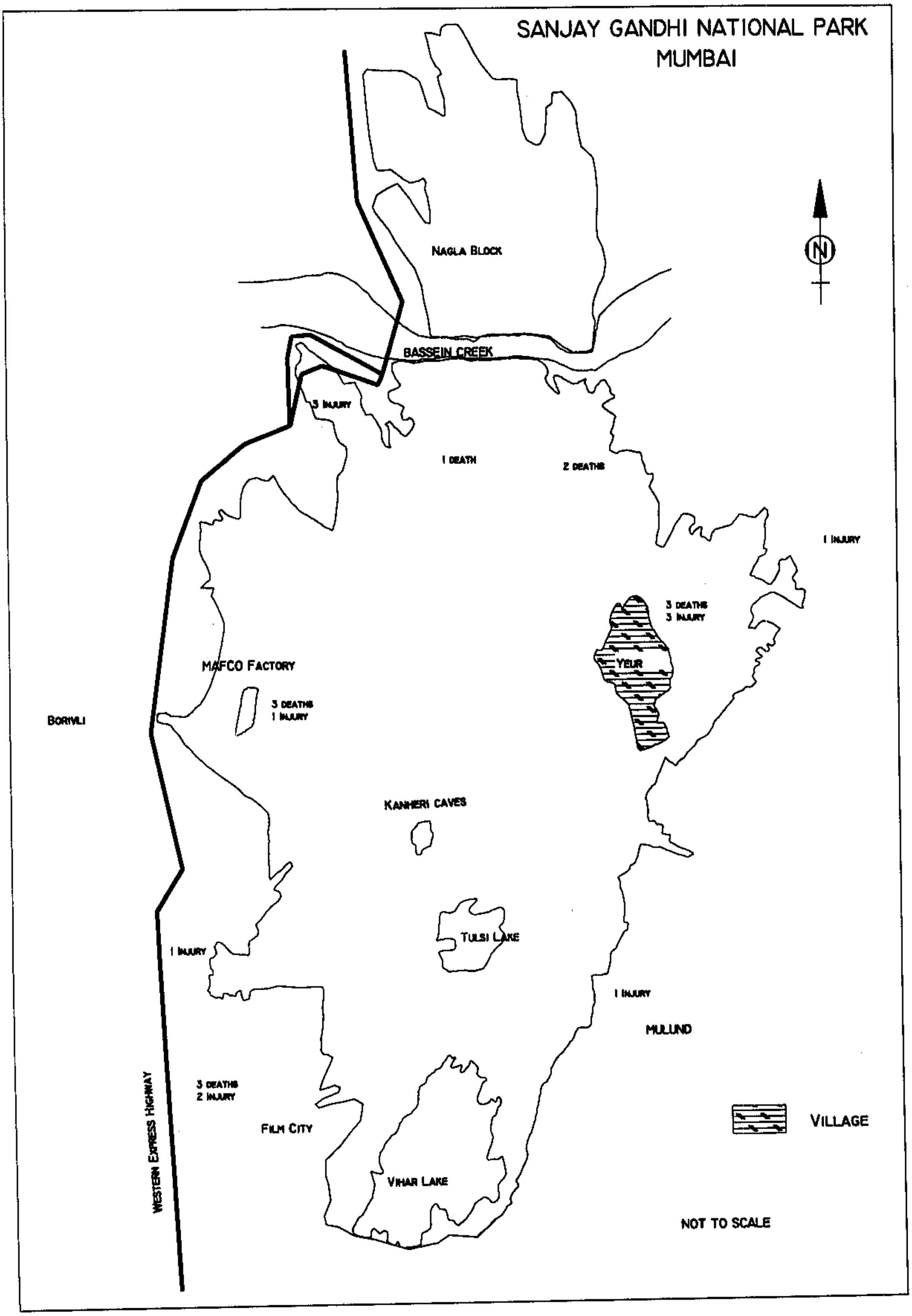
The amount of livestock killing taking place is not reflected accurately in the records of the Forest Department as a total of only 17 cases are on record from 1988 to 1996. People seem to be reluctant to inform the authorities in the case of loss of livestock to leopards (*pers obs*). The quantification of annual predation on livestock could not be done.

Table 9. Number of incidences of leopard-human conflict in SGNP in winter, summer and the monsoons from 1988 to 1996.

Source: Office of the SGNP, Maharashtra Forest Department

Type of Conflict	Winter (Nov-Feb)	Summer (Mar-June)	Monsoon (July-Oct)
Human deaths	0	10	3
Human injuries	1	5	9
Found in human habitation	8	13	11

FIG 5. : SPATIAL DISTRIBUTION OF ATTACKS ON HUMANS BY LEOPARDS IN THE PARK



ATTITUDES TOWARDS LEOPARD CONSERVATION IN SGNP

6.1 Introduction

Conservation of predators requires the cooperation and goodwill of the people living in and around their habitat. Since leopards tend to prey on livestock and sometimes attack humans, positive attitudes by the people living near them need to be inculcated and maintained by the Park management. It is not necessary that people living next to predators invariably have negative attitudes towards them. Respondents to a questionnaire in Alaska, for example, had the most positive perceptions of the wolf in a survey undertaken across various states in the USA (Kellert 1985), who also found that people with a positive attitude to predators indicated greater interest in protecting wildlife and natural habitats.

6.2 Methods

To investigate the levels of awareness about leopards and find out the attitudes of the people towards them, a questionnaire survey was undertaken. Representatives of 148 households in 10 *padas*, clusters of houses located in the Park, were asked questions. Information regarding their age, ethnic status, literacy, livestock holding, loss of livestock to predators and their knowledge about compensation of livestock kills was also gathered. Awareness scores were grouped as high, medium and low, while attitude scores were grouped as positive, neutral and negative.

6.3 Results

The age structure of the respondents is given in **Table 10**.

Table 10: The age structure of respondents to the questionnaires.

Age	Number of respondents
less than 20	0
21-30	66
31-40	46
41-50	29
more than 50	3

The results from the questionnaire were analyzed in the following way. Answers to questions testing 'awareness' were awarded between 1 and 3 points depending on the extent of knowledge displayed by the respondent. The points for the answers were summed to get an awareness score. Awareness scores were then ranked into high, medium and low for each respondent. A similar procedure was followed with attitude scores being ranked as positive, neutral and negative. Scores were compared using the Mann-Whitney U test and the number of respondents in the different categories were compared using the chi-square test.

Tribals comprised 67.5 per cent of respondents and 33.5% were non-tribals. Fewer tribals (29%) were literate compared to non-tribals (69%) (χ^2= 21.1, df=1). Greater literacy among non-tribals probably influenced their awareness about the leopard, because significantly higher number of non-tribals had a 'high' awareness score than tribals (χ^2 = 6.14, df=2). From the results of the questionnaire, it could be judged that 22% of all respondents had a negative attitude to leopards, 41% had a positive attitude while 36% did not display strong attitudes.

Did tribals have a more positive attitude? While tribals had significantly higher mean attitude scores than non-tribals (Mann- Whitney U= 1782, p=0.09), a chi-square test showed that there was no cause to reject the hypothesis that ethnicity and attitude towards leopards, generalised as positive, negative and neutral, were independent (χ^2= 6.14, df=2). Differences in both awareness (χ^2= 1.59, df=2, $p>0.05$) and attitude (χ^2= 3.14, df=2, $p>0.05$) between literate and illiterate persons could not be demonstrated. Mean scores of attitude (Mann-Whitney U= 2291.5, p=0.41) and awareness (Mann-Whitney U= 2402, p= 0.73) between literate and illiterate persons were also not significantly different.

There was a weak but significant positive correlation between awareness scores and attitude scores ($r = 0.39$, $p<0.01$, n=148) of all respondents. Kellert (1985) also found more positive feelings among people with a greater knowledge of animals. High awareness was therefore somewhat likely to be associated with positive attitudes towards leopards.

6.4 Compensation

There is a compensation scheme in the SGNP in which loss of livestock (except goats) is compensated by a cash payment after evaluation of the loss by the Forest Department. While 47% of the respondents knew about the existence of compensation, only 7% knew about the procedural details of availing it. It is important that people are made aware of the compensation scheme so that they can be quickly compensated for loss of livestock.

From 1988-1996 only 17 cases were recorded for compensation (Source: Office of the SGNP, Maharashtra Forest Dept.), while 11 respondents in the survey of 148 respondents (7.4%) stated that they had lost livestock to leopards. This implies that a number of households have not reported livestock losses to the Forest Department. Infield (1988) found that rural households experiencing the benefits of conservation areas had more positive attitudes than those who did not gain benefits. The lack of compensation could be a disincentive towards inculcating positive attitudes. A potential source of hostility of people to leopard conservation could be controlled if procedures for compensation were simplified.

MANAGEMENT OF THE LEOPARD IN SGNP

7.1 Introduction

Leopards, being generalists, can survive in a broad range of habitats. Large areas with sufficient medium sized prey, freedom from poaching and adequate cover are needed for a healthy leopard population.

According to Bailey (1993) maintaining genetically viable populations of leopards in small parks less than about 500 km^2 in area will be difficult over the long run. Leopards in small parks are often in conflict with the surrounding human population and under threat from encroachment and poaching. Confining leopards to small parks is also difficult and they are apt to go outside the boundaries of the protected area. SGNP is a very small area with an isolated population of leopards. It must therefore be managed intensively to promote the well being of its population over the long term.

The principal immediate threat to the leopard population in the Park is the loss of habitat due to encroachment of the forest. Other possible threats could be due to disease and increase in conflict with the people around the park. A long-term threat to the viability of the small population in the Park could be due to isolation and consequent inbreeding.

7.2 Loss of area in the Park

Jadhav *et al.* (1995) have quantified the extent of encroachment taking place on Park land using remote sensing methods. Fifty three hectares of forest was lost in 1994-95, and a total of 773 ha has been lost from the declared area of the Park. Extremely high land prices in Mumbai coupled with the increasing population has meant that encroachment will continue to be the principal threat to the survival of the Park in the foreseeable future. The ultimate fate of the leopard in the Park in such a scenario is grim. However the Park management has been taking active measures against encroachment and with long-term political support for such measures much of the danger to the leopard in SGNP could be staved off.

7.3 Paucity of wild prey

There is a paucity of medium sized wild ungulates in the Park. This does not seem to affect the leopard directly because of the availability of domestic dogs. There will always be stray dogs immigrating into the Park from urban Mumbai to augment their local population and the leopards are unlikely to ever face a shortage of this prey. This fact probably also accounts for their unusually high density. Restocking of the Park with chital and sambar procured from zoos may not help in establishing a wild prey base. Zoo animals are not as shy and their anti-predator responses are not as well developed as wild-caught ones. They are thus more likely to be preyed upon by the leopards and would also be susceptible to poaching before a breeding population establishes itself. Enhanced protection to the wild ungulates already present, coupled with some experimental introductions of wild-caught ungulate species into the Park may be a better strategy.

7.4 Monitoring disease

A consequence of the high dependence on domestic dogs by the leopards is the increased risk of disease. In the Serengeti in 1994 about 30% of the lion population was wiped out due to canine distemper. The epidemic was probably transmitted to the lions from the large population of domestic dogs found along the outskirts, which act as a permanent reservoir of the virus. Consequently a campaign for the vaccination of thousands of dogs has been initiated (Packer 1996). Such a campaign might not be cost efficient in SGNP. A leopard cub found abandoned in the Park during the study period died, and the autopsy revealed the cub probably died of rabies (R.P. Barahate *pers comm*).

The danger to the leopards from dog borne diseases should be recognised and a regular monitoring of dogs in SGNP for diseases should be done. Vaccinations of leopards by capturing them may be considered if increased incidence of disease or mortality in leopards is seen.

7.5 Mitigation of conflict

The leopards going outside the SGNP are animals that come into direct conflict with humans. They are either being pushed out to peripheral areas by resident leopards or are going out in search of prey. Their capture and subsequent release back into SGNP does not address the root cause of the problem. The behaviour is therefore likely to recur and be a source of danger to humans living outside the Park.

Release of leopards into territories already occupied by other resident leopards is also fraught with risk to the introduced animal. Such releases should not be done. Translocation to other protected areas with a low density of leopards may be explored only if there is suitable unoccupied habitat and adequate prey available in these areas. Translocation or reintroduction of leopards involved in human casualties should not be done. Such leopards should be put into captivity permanently or eliminated if there is no demand for them from zoos.

7.6 Maintenance of long term viability

It has been suggested that at least 50 randomly breeding individuals are needed to protect a population from going extinct due to random fluctuations in birth and death rates, or demographic stochasticity (Shaffer 1981). Excessive inbreeding would lead to a decline in genetic diversity and possible maladaptive effects (Simberloff 1988). Inbreeding in male Ngorongoro lions has been associated with a high percentage of sperm abnormalities (Packer *et al.* 1991).

SGNP does not possess the minimum numbers thought to be necessary for the long-term viability of populations. In the absence of natural immigration of leopards through dispersal, it will be desirable to introduce male leopards from other areas to ensure genetic flow into SGNP. It will be mandatory to remove the resident male from the area by capturing it before releasing the new leopard to make sure that no social conflicts arise between the introduced and the resident leopards. The frequency of such artificial immigrations will have to be decided after studies determining the extent of inbreeding already present have been done. It may be worthwhile to study the percentage of abnormal sperm in a few leopards in the Park and compare it with leopards from a bigger protected area with a larger population to decide whether an in-depth study on this aspect is needed.

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