

**ECOLOGY OF LEOPARD IN SANJAY
GANDHI NATIONAL PARK, MAHARASHTRA WITH
SPECIAL REFERENCE TO ITS ABUNDANCE, PREY
SELECTION AND FOOD HABITS**



a report *by*
Nikit Surve

under the supervision of
Dr. S. Sathyakumar
Dr. K. Sankar
Dr. Vidya Athreya



भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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FOREWORD

The Sanjay Gandhi National Park is a unique protected area within a megapolis of a size of Mumbai. The National Park is home to number of free ranging leopards. The rich biodiversity and its location in the heart of cityscape make it one of its own kinds in the world. The presence of leopards in SGNP surrounded by high rises and human habitations from all sides often give rise to incidents of human- leopard conflict. To mitigate such incidents, it was felt to conduct a study to understand the ecology of leopards in Sanjay Gandhi National Park and this gave way to the present study answering basic questions about the leopards as to what densities do they exist inside the park and as to what do they feed on.

This is a first ever comprehensive study of leopards conducted in the entire Sanjay Gandhi National Park in a systematic way. It was a six month long project which was carried out by Nikit Surve a Masters student from the Wildlife Institute of India, Dehradun under the supervision of Dr. S. Sathyakumar and Dr. K. Sankar of Wildlife Institute of India and noted wildlife Conservationist Dr. Vidya Athreya. This project had full-time involvement of the ground staff from Sanjay Gandhi National Park who were trained sufficiently to carry out modern census techniques such as camera trapping. The study revealed the leopard densities along with other baseline data. I congratulate Nikit Surve and his mentors as well as all others including SGNP field staff and officials who were part of this study for coming out with an excellent report. It will become the base line data for all future reports to be generated and will help the park authorities in devising management strategies for conservation and management of leopards in Sanjay Gandhi National Park.

Vikas Gupta
CCF & Director,
Sanjay Gandhi National Park, Mumbai.

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Executive Summary

Though information is available on the leopard's ecology from natural habitats, very less information is available on the ecology of leopards from human-dominated habitats in India. Hence the study was conducted at Sanjay Gandhi National Park (SGNP), Mumbai where leopard was found to be the apex predator. The total area of SGNP is 104 sq.km. It is covered by human habitations on all the sides leaving just a narrow tip on the northern side. Camera traps were deployed in a systematic manner covering the entire study area of approximately 140 sq. km. to get leopard images. Leopard density of 21.55 ± 4.6 (SE) per 100 km² at 95% confidence interval was calculated in the study area using Spatially Explicit Capture Recapture models. The wild prey densities were estimated inside SGNP using Distance sampling with the help of line transects. The maximum density amongst ungulates was shown by chital (14.49 ± 5.2 [SE] per km²) followed by sambar (7.52 ± 1.7 [SE] per km²). Among primates, maximum density was shown by common langur (48.04 ± 8 [SE] per km²) followed by bonnet macaque (30.78 ± 12 [SE] per km²). Density for other prey species encountered on line transects like wild pig and barking deer were not estimated as they were sighted only twice on the line transects. Dog density on the periphery of SGNP was calculated to be 17.26 ± 0.69 (SE) per km² using mark-recapture technique. Food habits of leopards were studied by conducting dietary analysis using leopard scat. The high density of dogs in the periphery of the National Park also reflected in the leopard's diet. Dogs alone contributed 24.46 % of the total biomass consumed in leopard's diet. Domestic prey contributed to 43% whereas wild prey contributed to 57 % of leopard's diet in terms of relative biomass consumed. The study suggests that the leopards are dependent on both wild as well as domestic prey in the study area. Leopards can share spaces with humans even amidst urban environs as long as prey population (both domestic and wild) remain sufficient and their habitat is protected.

1. Introduction

The Leopard (*Panthera pardus fusca*, Meyer, 1794) in India, is listed in Schedule I of the Indian Wildlife (Protection) Act. (Anon 1972) under the highest level of protection. Leopard falls under the near threatened category of IUCN (IUCN 2014). The leopard remains in the Appendix 1 of CITES. Leopard has a pan India distribution except for desert areas and mangroves.

1.1 Leopards in human-dominated areas.

A few studies on ecology of leopards in human-dominated landscapes are available from Maharashtra (Edgaonkar and Chellam 1998; Athreya *et. al.*, 2007) and Uttarakhand (Chauhan 2007). These studies show the dependency of leopards on domestic prey. Studies from Mumbai include Edgaonkar and Chellam (1998) who conducted a preliminary study on leopard ecology in Sanjay Gandhi National Park. In Mumbai, the immense amount of garbage available attracts a lot of domestic dogs which in turn attract leopards (Edgaonkar 2002). Bhale *et. al.*, (2005) conducted a short study and gave a concise report on the Sanjay Gandhi National Park. Tiwari and Apte (2006, 2008) from the Bombay Natural History Society (BNHS) also conducted surveys on leopard conflict and conducted awareness campaigns in and around the park and produced city forest reports in 2006 and 2008 and this also includes a preliminary study on diet composition of leopards in Sanjay Gandhi National Park (Tiwari and Prasad 2009). (Mirza *et. al.*, 2013) gave a report on minimum number of leopards based on their opportunistic camera trapping in SGNP.

1.2 Rationale

Leopard is an animal which has acquired a bad name in India as far as conflict is concerned. Conflict usually involves cattle depredation or human killing. Leopard attacks on human have also been reported from Sanjay Gandhi National Park in Mumbai, Maharashtra. As urbanization is increasing habitats are shrinking day by day (same is the case with the forests in Mumbai). Every conflict situation is a unique one and needs to be handled and resolved in a specific manner. As Sanjay Gandhi National Park is one of the few protected areas within the city limits of a metropolis in India, there is a need for a better understanding of the leopard's ecology in this area.

1.3 Objectives

The present study has the following objectives

1. To estimate the density of leopard in Sanjay Gandhi NP.
2. To estimate the density of wild and domestic prey in the study area.
3. To determine food habits of leopard.

2. Study Area

The Sanjay Gandhi National Park (SGNP), also known as the Borivali National Park, extends over an area of 104 km² and spread across some portions of the Mumbai Suburban and Thane districts (19° 8' N, 72° 53' E and 19° 21' N, 72° 58' E) (Figure 1). The Vihar Lake forms the southern boundary of the SGNP. The townships of Bhandup, Mulund, Thane (Plate 3) and Goregao, Malad, Kandivali, Borivali (Plate 2) form the eastern and the western boundary respectively. The northern boundary extends beyond the Bassein creek and includes the Nagla forest block (Plate 1). About 8.5 km² of the total National Park area is covered by lakes. The Tulsi and Vihar lakes have a combined water spread area of about 8.62 km².

For management purposes, the SGNP has been classified into a core zone of 28.1 km², a buffer zone of 66.2 km² and a tourism zone of 8.6 km². The National Park is divided into three ranges i.e. Tulsi, Yeur, and Krishnagiri Upvan. NH-8 the western express highway runs parallel to the park on the western side whereas the Eastern express highway runs on the eastern side connecting Mumbai to Nashik.

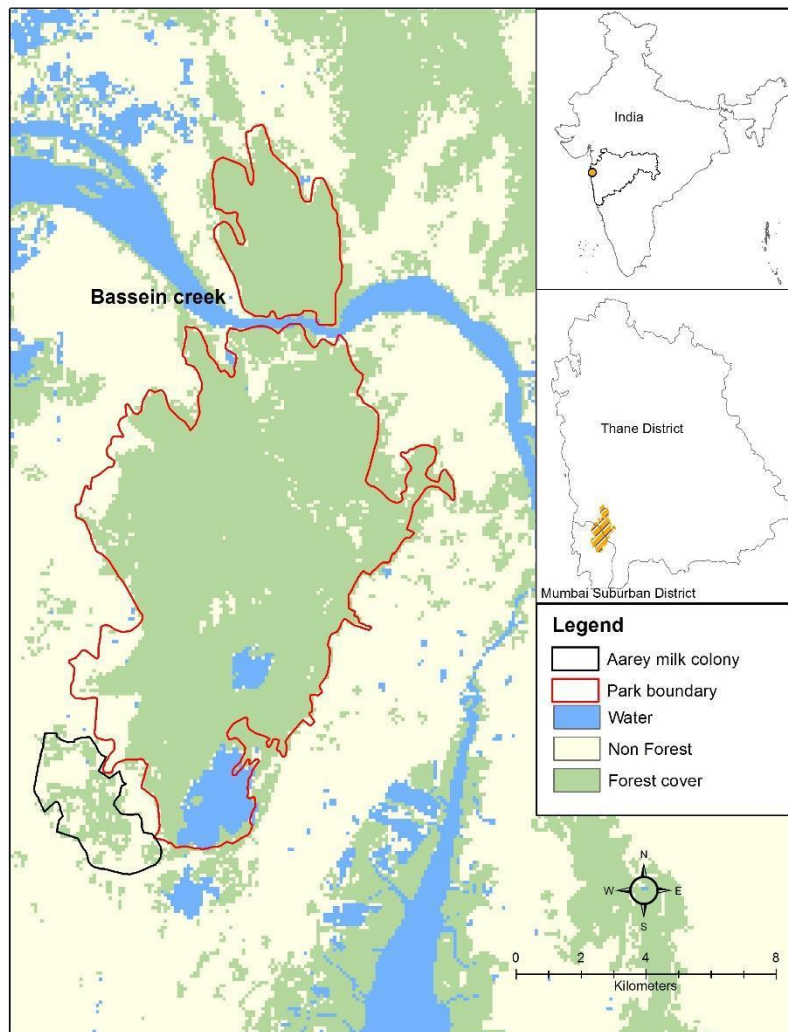


Figure 1. Location of Sanjay Gandhi National Park.

2.1 Geology

The park exhibits a diversity of terrain from 30 to 466 m above sea level. The topography is hilly with only a few plain areas. The hills are steep at certain places, giving way to precipices and rocky outcrops. The park is semi-mountainous; the level ground being between Tulsi and Vihar lakes, the lower westerly reaches of Krishnagiri Upawan and the northern end of Chena forest. These hills are regarded as the outer spurs of the Sahyadris (Western Ghats).

2.2 Climate

The mean annual temperature is 27° C, November to February is generally pleasant with nights tending to be cool, and temperature starts increasing from March and continues to increase till May. These months are quite warm and humid. The proximity of Arabian Sea makes the climate equable. The southwest monsoon gives abundant rainfall to the region. The mean annual rainfall is 2600 mm. The north-east monsoon usually gives a little rainfall of about 50 mm or less in November and December.

2.3 Vegetation

The forest is mainly of the Southern moist deciduous type (Champion and Seth 1968). Due to its proximity to the coast, numerous water courses and hilly terrain, the flora too presents a very diverse picture, ranging from dry and moist deciduous to semi-evergreen, open scrub and halophytes. The major tree species found are: *Tectona grandis* (Teak), *Terminalia tomentosa* (Ain), *Bombax malabaricum* (Red silk cotton tree), *Adina cordifolia* (Kadamba), *Butea monosperma* (Flame of the forest) and *Pterocarpus marsupium* (Bibla). In some densely wooded areas, pockets of semi-evergreen forest are also found. Some Teak plantations are also present as a part of the improvement fellings and silviculture system followed in the past (Rege 1974). Mangrove forests comprising of *Avicennia* sp. are also found along the tidal creeks and estuarine mudflats.

2.4 Fauna

Leopard (*Panthera pardus*) is the top carnivore in the park. Other meso-predators and omnivores found in the study area are jungle cat (*Felis chaus*), rusty spotted cat (*Prionailurus rubiginosus*), Asian palm civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*), Indian Grey mongoose (*Herpestes edwardsii*), and ruddy mongoose (*Herpestes smithii*). The wild prey species found in the study area are spotted deer (*Axis axis*), sambar (*Rusa unicolor*), common langur (*Semnopithecus entellus*), wild pig (*Sus scrofa*), bonnet macaque (*Macaca radiata*), rhesus macaque (*Macaca mullata*), barking deer (*Muntiacus muntjak*), mouse deer (*Tragulus memmina*), Indian porcupine (*Hystrix indica*) and black naped hare (*Lepus nigricolis nigricolis*) (Edgaonkar and Chellam 1998; Pradhan 2002). Domestic prey species such as cattle, buffaloes, goats, pigs, dogs are also found in the study area and adjoining areas (<http://dairy.maharashtra.gov.in/>).

2.5 Human dimension

Sanjay Gandhi National Park is one of the most highly visited protected areas in the country (approx. 2 million visitors per year). Most of them visit the Krishnagiri Upwan sector which comprises the recreation zone comprised of a mini train, nature trails, lion safari, tiger safari, lawns, and paddle boating (on an artificially made lake on Dahisar river). People also visit the Kanheri caves in huge numbers. These caves were built by Buddhist monks over 2000 years ago. This site is managed by the Archaeological survey of India. There exists an Air force communication base inside the NP at the highest point in the National Park. The state electricity board also has a unit within the park boundaries. Bombay Municipal Corporation (BMC) has their water purification plants inside as well as on the periphery of the National Park as the lakes are managed by BMC. There are about 43 *padas* (Hamlets) inside the National Park boundary. Some have access to electricity. Yeur and Chena are two tribal villages within the National Park boundary. Some of the people living in these Padas practice agriculture. But majorly these people work as laborers or go outside the park on a daily basis for jobs. There is no pressure from livestock grazing on the National Park. People are majorly dependent on the forest for firewood. Collection of non-timber forest products takes place but on a very minor scale mainly of fruits.

2.6 Aarey Milk Colony (AMC)

The Aarey Milk Colony (AMC) located in Goregaon East covers an area of 12.8 km² and the Film City are located to the southern border of the Sanjay Gandhi National Park. The vegetation of AMC is heavily human-modified which includes remnant patches of southern moist deciduous forest. Human-modified vegetation includes scrub forest and understory shrubbery composed of jujube (*Zizyphus mauritiana*), Lantana (*Lantana camara*), and plantations of exotic tree species as Gliricidia (*Gliricidia sepium*) and forest red gum (*Eucalyptus sp.*) (Punjabi et. al 2012). As these places have much altered forest and scrub patches that are contiguous to SGNP, they were also be included in the study area. The AMC consists of more than 30 cattle production units with a total capacity of over 15,000 head of cattle (Punjabi et. al., 2012). On an average, 16,000 cattle mainly buffaloes are reared on 1,287 hectares of land, and 32 cattle farms (<http://dairy.maharashtra.gov.in/>). The AMC holds domestic prey in the form of feral dogs and pigs, and waste generated from the cattle farms in the form of carcasses.

Plate 1. Bassein creek which lies on the northern side of the park separating Nagla block from the National Park



Plate 2. Old (non-functional) stone quarry area on the western side of Sanjay Gandhi National Park.



Plate 3. *Mama Bhanja Durgah* on the mountain top and the city on the eastern side of Sanjay Gandhi National Park.



3. Study Period

The study was carried out from 5th December 2014 to 15th April 2015.

The first twenty days of the study period were spent in conducting reconnaissance survey in the study area. The forest beats were walked along with the beat guards covering all the ranges and all possible information on leopard and prey base distribution available was gathered. Using a Global positioning system (GPS), leopard locations were noted down which would serve useful while conducting camera trapping. Available roads and trails inside SGNP were also mapped for further use to conduct field surveys. A motorcycle was used wherever possible. We had three official training session on camera trapping and line transects for the field staff at SGNP and hands on experience was gathered when on filed.

4. Methodology

4.1. To estimate the density of leopards in Sanjay Gandhi National Park

The entire study area (~ 140 sq. km.) was divided into grids of 2x2 kms (Figure 2). A preliminary survey was carried out throughout the study area along with the concerned beat guards to identify probable camera trap sites based on sign surveys for leopard (scats, tracks and others). This being a human dominated area the cameras were not set to function for 24 hours. Cameras were set only from 5pm in the evening to 7am in the morning. This was done to avoid theft of the cameras and loss of data. This involved a lot of effort and the entire study area could not be covered at one go. Hence the entire study area was divided in three blocks and block-wise camera trapping was carried out. Each of these three blocks consisted of 9, 10 and 12 camera trap locations. The cameras in each block were functional for fifteen days except for the last block where they were functional for fourteen days only. Thereby, the total sampling period amounted for 44 days. Some cameras were not functional on particular days at particular sites. Therefore the total sampling effort after considering all the functional cameras was 422 trap nights. A pair of camera traps was placed at each camera trap location for effective sampling and getting images of both the flanks of individual leopards. The camera traps used (Cuddeback attack and Cuddeback color C1) had built in motion and heat sensors to detect any animal movement. As each leopard individual has a unique rosette pattern (Plate 4) it can be used for individual identification. All Statistical analysis was done in programme R (R development core team 2014).



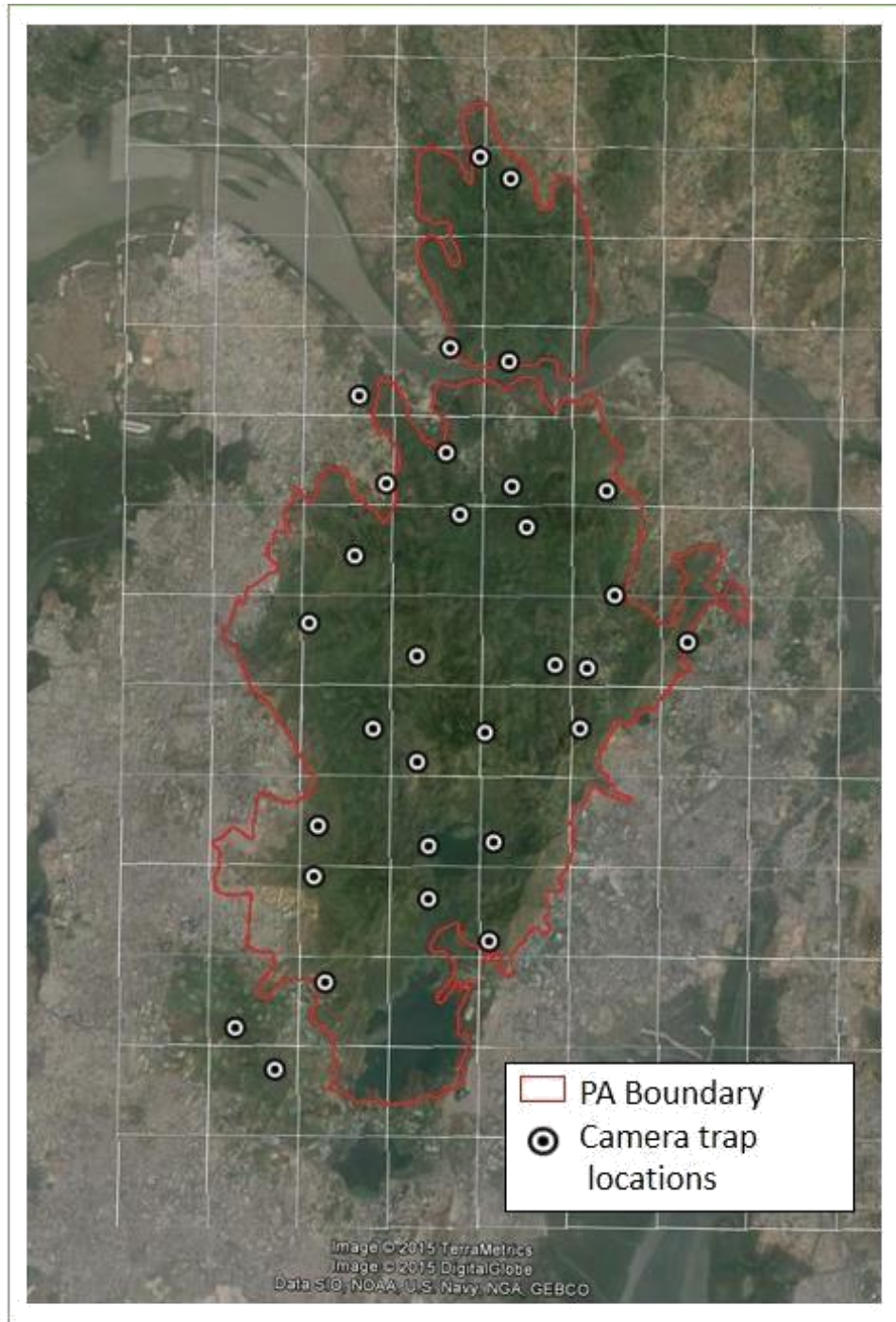
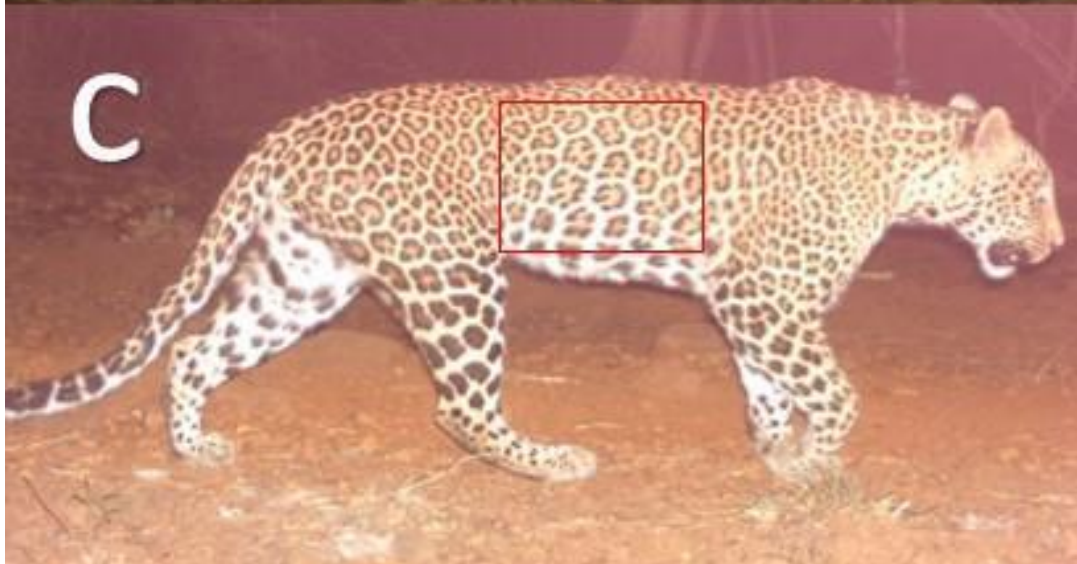
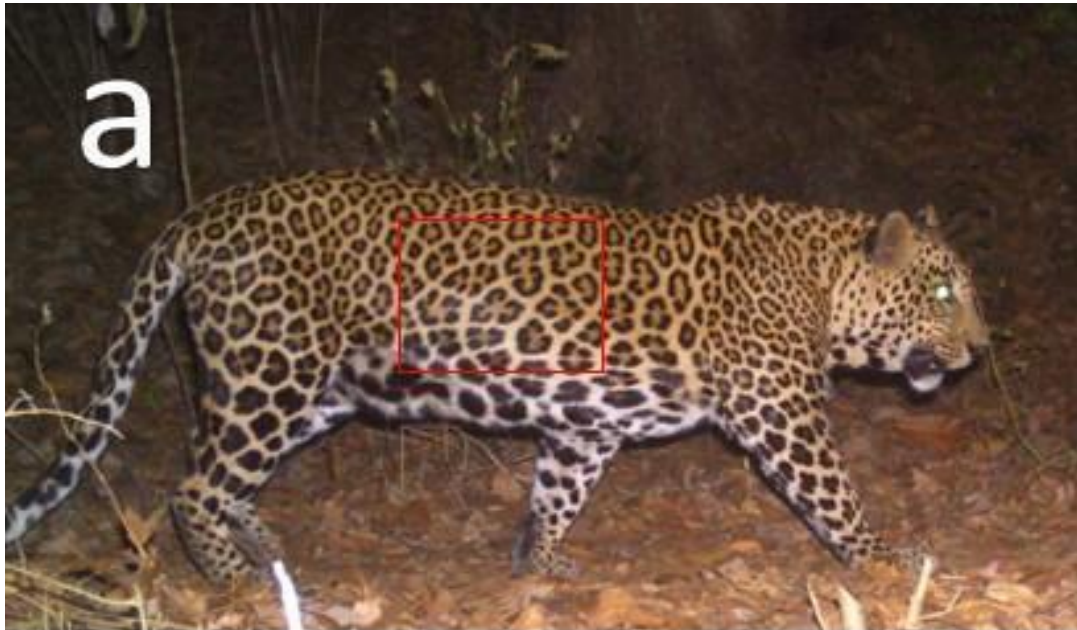


Figure 2. Camera trap locations in Sanjay Gandhi National Park (December 2014–April 2015).

Plate 4. Three unique individuals (a,b,c) identified based on their unique rosette pattern.



4.2. To estimate the density of wild and domestic prey in the study area.

The variable distance line transect method was used to estimate prey density in the study area. Sixteen line transects were initially marked on a map of SGNP covering major habitat and terrain types. These were marked taking into consideration the accessibility to the start points. Later the line transects were actually laid and marked on field (Figure 3) using a GPS device to get the exact location, a Sunto compass was used to check the line bearing, and a rope to measure the line length. Transects were cut in an appropriate manner so as to facilitate movement of two people without making much noise. All the line transects were marked and numbered using red paint, the paint was applied at least 6 feet above the ground. Each transect was walked 3 times in the morning and 2 times in the evening making a total of 5 replicates during the study period. Transects were walked with the help of trained forest staff and volunteers. The length of the line transects varied from a minimum of 1km to a maximum of 2 km. A total effort of 120kms was put into walking the line transects. While walking on a transect the bearing at which the animal was sighted and its ocular distance was noted down using a Sunto compass and a Hawk Range finder respectively. This data was noted down in a datasheet which was made in two languages i.e. English and Marathi for convenience of the local staff. The data collected was analysed in the software DISTANCE.

Domestic prey

The entire survey to estimate dog populations was conducted at three different locations which were spatially separated from each other (Figure 4). Ensuring geographic closure was the most important criteria while selecting these areas. The three dog survey locations selected i.e. Aarey milk colony, Kashmirira and Yeur village had areas such as 9.31 km², 1.64 km² and 1.69 km² respectively. Initially I surveyed all the three locations on a motorbike to identify certain fixed points where dogs were observed either in groups or singly. GPS locations were taken for all these points. The points selected were usually near garbage dumping sites, water bodies, feeding sites, human settlements and carcass dumping sites, if available. The points were spaced in a manner such that the area covered was large and that the perimeter to area ratio was small, so as to avoid violation of the assumption of geographic closure. In total Aarey milk colony, Kashmirira and Yeur had 50, 10 and 10 points respectively. Majority of the dogs were stray and some were classified as semi-owned but this had no change in the movement of dogs. Dogs were marked using the natural markings on their body even mono-coloured dogs were marked as each and every dog had some marking pattern which was unique to that particular individual. Mark-Recapture method was used to estimate dog numbers in the study area. Peak activity hours in each of these areas were identified by an initial survey during the first two days. The surveys were carried out during the morning hours from 10 am to 12 am at Aarey milk colony and Kashmirira whereas at Yeur the survey was carried out from 5pm to 7pm. During each survey the observer along with a volunteer would cover all the fixed points at a location in a unidirectional way on a motorbike. At each point five minutes were spent and dogs present in 30-50 meter radius from the point were photographed so as to get good pictures of both the body sides and any distinct patch on their body. This was repeated for three days at Aarey milk colony and four days each at Kashmirira and Yeur. Each day was used as an occasion while analyzing the data in the software Mark.

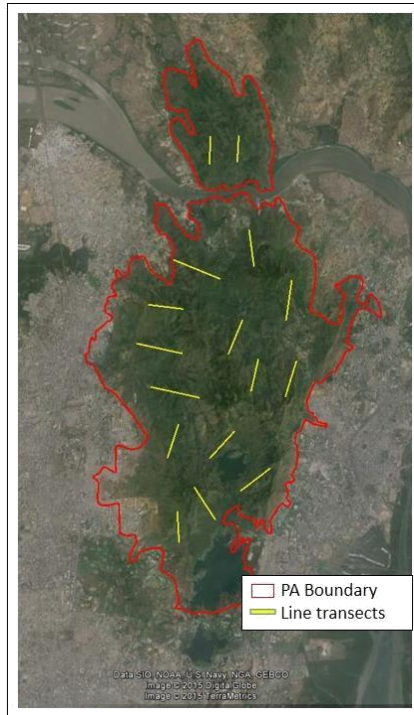


Figure 3. Line transects in Sanjay Gandhi National Park (December 2014- April 2015).

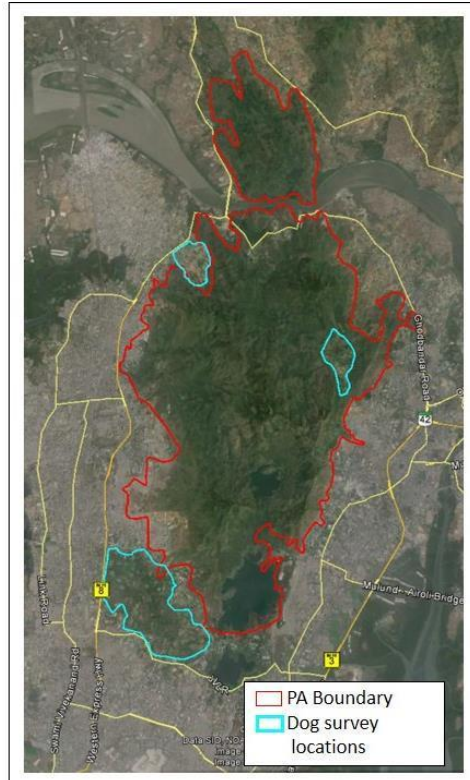


Figure 4. Dog survey locations in Sanjay Gandhi National Park (December 2014- April 2015).

4.3 To determine food habits of leopard.

Diet analysis was conducted using undigested material from leopard scats. Leopard scats were collected systematically along the identified roads and trails (n=25). Trails were walked twice a month. Only confirmed leopard scats were selected for the analysis based on their size, shape and secondary evidences such as scrape marks and pug marks. A total of 103 scats were collected out of which 97 were used for analysis. Scats were collected and stored in zip lock plastic bags with appropriate labels. These scats were sun-dried and then washed in running water (Plate 5). Undigested material like hair, nails and claws were collected from each scat sample. These were again sundried. Individual prey species were identified based on the medullary patterns of the hair and the same was compared with available reference slides. The data obtained was analyzed to calculate relative frequencies of occurrence of individual prey in leopard's diet.

Plate 5. Leopard scat being washed in running water.



5. Results

5.1 Estimation of population of leopards

Camera trapping resulted in a total of 88 photographs of leopards. Using their unique rosette patterns 31 leopard individuals (10 males, 16 females & 5 individuals of unknown sex) were identified. Spatially explicit capture-recapture analysis was carried out using secr package 2.9.4 in the software R programming. The leopard density calculated was $21.55 \pm 4.6(\text{SE})$ per 100 km^2 at a confidence interval of 95%. The leopard abundance was calculated to be $35.59 \pm 0.51(\text{SE})$ at a confidence interval of 95%.

Photo capture rates

To obtain the photo capture rates for all the species captured in the camera traps the photo capture events for each species was divided by the total number of trap nights i.e. 422. This helped in deriving a crude index of trapping and visitation rate for other species, for which rigorous capture-recapture sampling analysis was not possible.

Table 1. Photo capture rates for all the species being captured in the camera traps (February 2015 – April 2015 between 17:00 hours and 7:00 hours) at the Sanjay Gandhi National Park.

Sr. No	Species	Photo capture events	No. of captures /100 trap nights
1	Human being	123	29.15
2	Leopard	92	21.80
3	Wild pig	43	10.19
4	Sambar	41	9.72
5	Domestic Dog	29	6.87
6	Chital	15	3.55
7	House cat	10	2.37
8	Small Indian civet	9	2.13
9	Cattle	9	2.13
10	Black naped hare	8	1.90
11	Palm civet	6	1.42
12	Bonnet macaque	5	1.18
13	Barking deer	4	0.95
14	Jungle cat	3	0.71
15	Mouse deer	1	0.24
16	Rusty spotted cat	1	0.24

5.2 Wild and domestic prey densities inside Sanjay Gandhi National Park

The density of all prey species was calculated using the program DISTANCE. In total 8 potential leopard prey species were encountered on line transects viz., chital, sambar, barking deer, wild pig, common langur, bonnet macaque, grey jungle fowl and red spur fowl. Densities were calculated only for chital, sambar, common langur and bonnet macaque as rest of the species did not have enough number of sightings to be analysed in the program DISTANCE.

Table 2. Individual and group densities of major wild prey species of leopards estimated in Sanjay Gandhi National Park, Mumbai, Maharashtra.

Species	No. of groups (n)	Model	Min AIC	D	SE	DS	SE	MCS	SE
Chital	38	Half Normal Cosine	111.15	14.49	5.2	4.83	1.67	3.15	0.75
Sambar	40	Half Normal Cosine	56.07	7.52	1.7	4.28	0.86	2.07	0.29
Bonnet macaque	26	Half Normal Hermite	74.71	30.78	12	3.68	1.23	8.35	1.44
Common langur	92	Half Normal Hermite	130.15	48.04	8	13.07	1.86	3.66	0.29

n : Number of groups
 Min AIC : Minimum Akaike Information Criteria value
 D : Individual density
 DS : Group density
 SE : Standard error
 MCS : Mean cluster size

The highest density found was of common langur followed by bonnet macaque, chital and sambar (Table 2). Mouse deer was captured on one occasion in one of the camera traps on the north eastern side of the park. Rhesus macaque and mouse deer were not encountered on the line transects although they occur in the study area.

Density of Dogs

Dogs were identified based on the natural markings present on their body. The number of dogs identified in each of the three locations is provided in table 3.

Table 3. Summary of captures of dogs in three dog locations.

Location	No. of dogs identified	Area (sq.km)	Occasions
Aarey Milk colony	274	9.31	3
Kashimira	61	1.64	4
Yeur	53	1.69	4

The Huggins closed captures model was used to estimate dog abundance using the Program MARK.

Table 4. Abundance of dogs at three different locations.

Area	Abundance	se	lcl	ucl
Aarey milk colony	280.66	2.89	276.96	289.02
Kashimira	61.49	0.79	61.05	65.51
Yeur	56.04	2.06	53.91	63.16

Maximum density of dogs was found at Aarey milk colony i.e. 20.22 ± 5.28 (SE) per km. sq. followed by Kashmirira i.e. 16.1 ± 8 (SE) per km. sq. and Yeur 14.4 ± 7.1 per km. sq. (SE) respectively. A weighted mean of the densities from three areas was calculated for further analysis. The mean dog density calculated was 17.26 ± 0.69 (SE) per km. sq.

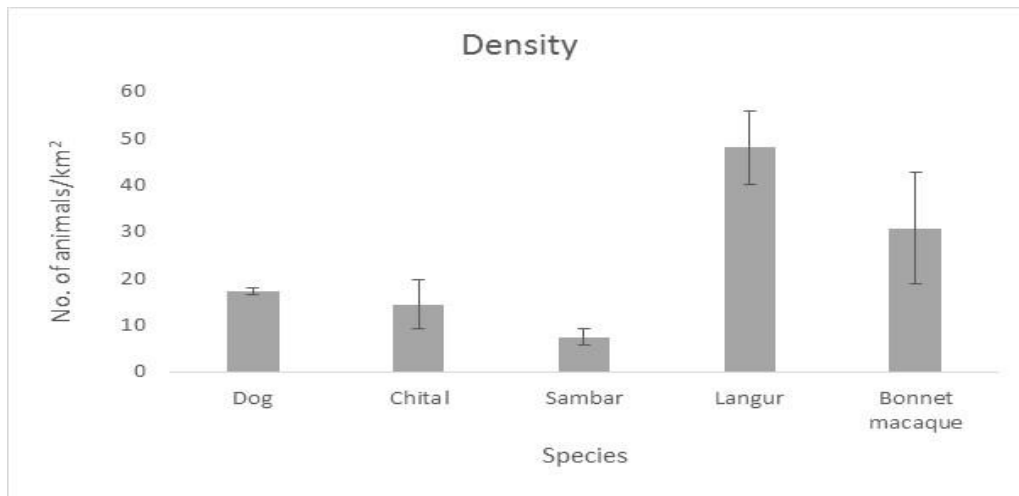


Figure 5. Densities of domestic and wild prey for leopards in and around Sanjay Gandhi National Park.

5.3 Leopard's diet composition

Altogether 133 remains from 13 prey species were found in 97 leopard scats. Sixty-six percent of leopard scats contained single prey species and 34 percent contained two prey species. Domestic prey contributed to 43% of leopard's diet whereas wild prey contributed to 57 % of it in terms of relative biomass consumed calculated using Ackerman's equation (Ackerman *et. al.*, 1984). To check the adequacy of sample size an observation-area curve was calculated. 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 randomizing the order of the results obtained (Figure 6).

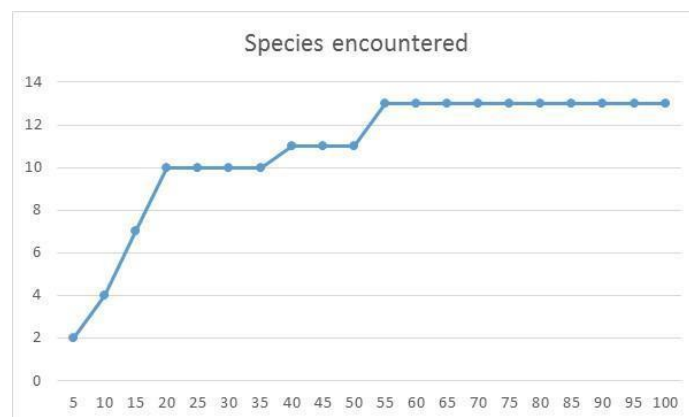


Figure 6. Observation-area curve for determining adequacy of sample size to determine leopard food habits based on scat analysis.

After analysing 60 leopard scats the curve flattened out as there was no more increment in the number of prey species encountered. This indicates that a sample size of 60 leopard scats were adequate to represent the diet spectrum of leopards in Sanjay Gandhi National Park.

Table 5. Frequency of occurrence of prey in leopard scats.

Prey species	Prey Species remains (f=113)	Average body weight (X)	Whole collectable scat (W=97)	Frequency of occurrence (F)	Relative frequency of occurrence
Dog	36	18	27	37.11	27.07
Chital	20	30	16	20.62	15.04
Rodent	21	0.5	9	21.65	15.79
Common langur	19	7	16	19.59	14.29
Cat	12	2	9	12.37	9.02
Sambar	5	200	5	5.15	3.76
Cattle	3	175	2	3.09	2.26
Bonnet macaque	3	6	3	3.09	2.26
Wild pig	6	47	5	6.19	4.51
Domestic fowl	4	2	2	4.12	3.01
Goat	2	30	1	2.06	1.50
Black-naped Hare	1	4	1	1.03	0.75
Bird	1	2	1	1.03	0.75

Although the frequency of occurrence of dogs was shown to be highest among all other prey species we cannot conclude about the contribution of dogs in leopard's diet (Table 5). The reason for this being, frequencies of the identifiable prey remains in the scat do not tell us about the actual proportion of prey type eaten. This is more so when the prey items vary in size to a considerable degree. Smaller prey species have more undigested material (hair) due to higher body surface to mass ratio.

Table. 6 Total biomass consumed for each prey in Sanjay Gandhi National Park.

Prey species	Biomass consumed/collectable scat ($Y=1.98+0.035X$)	Prey biomass consumed ($B=Y \times W$)	Relative biomass consumed
Dog	2.61	70.47	24.46
Chital	3.03	48.48	16.83
Sambar	8.98	44.9	15.59
Langur	2.23	35.6	12.36
Cat	2.05	18.45	6.4
Wild pig	3.63	18.13	6.29
Rodent	2	17.98	6.24
Cattle	8.11	16.21	5.63
Bonnet macaque	2.19	6.57	2.28
Domestic fowl	2.05	4.1	1.42
Goat	3.03	3.03	1.05
Black-naped Hare	2.12	2.12	0.74
Bird	2.05	2.05	0.71

Ivlev's index

It was found that domestic dogs were the most utilized prey species by leopards. Sambar deer was less utilized by leopards (figure 7). Only four prey species were taken for comparison as densities could not be estimated for other prey species and these were the major contributors in the leopard's diet in terms of biomass (table 6).

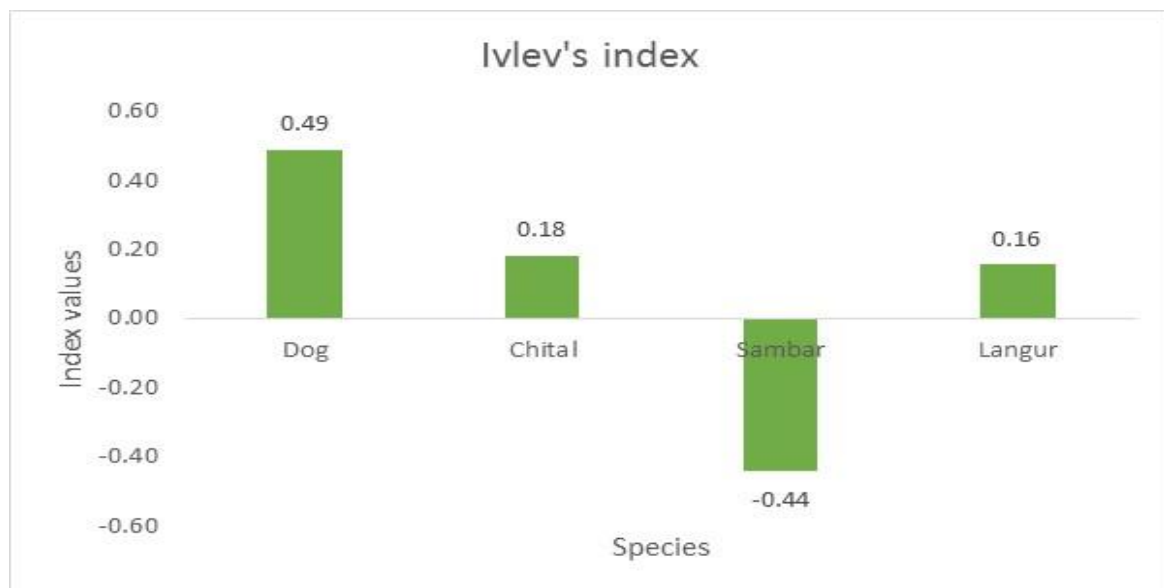


Figure 7. Ivlev's index for major prey species of leopards in Sanjay Gandhi National Park

6. Discussion

6.1 Leopard population

Sanjay Gandhi National Park located in Mumbai is one of the few Protected Areas in the country which falls within the municipal limits of a metropolis. The National Park has human pressure from all four sides leaving a small window on the northern tip. The minimum human density on the periphery of the park is about 20,000 people per sq.km. The encounter rate as given in table 1. also indicated the high usage of the National Park by humans. Even though the camera traps were set only during the night hours, the photo capture rates shown by humans was higher than any other wild or domestic prey species captured. This situation is perhaps unique in the world where such a high density of a large cat is sharing space with extremely high density of humans. When seen in context of attacks on people it is extremely interesting as there were no attacks on people reported since October 2013 (Forest Department records). Sanjay Gandhi National Park shows a leopard density of 21.55 ± 4.6 (SE)/100 sq.km based on the present study which, has one of the highest density of leopards found anywhere.

This study is the first to obtain density estimates of leopards from Sanjay Gandhi National Park using the spatially explicit capture recapture method. The only existing leopard numbers available from Sanjay Gandhi National Park are those from the total counts done by the Forest Department on a yearly basis. This was based on counting individual leopards at different water holes at the same time which may not give reliable estimates of leopard population due to untested assumptions involved in it. Another study which was conducted in Sanjay Gandhi National Park (Mirza *et. al.*, 2013) also gave a minimum number of 21 leopards present in the park using camera trapping. Results from this study could not be compared due to difference in methodology Camera trapping also revealed territorial overlap of a few leopards to a certain extent in the present study. On many occasions leopards have been reported and observed in the periphery of the buildings present on the boundary of the National Park. Many apartments on the periphery of the park which have CCTV cameras installed have recorded leopards in their vicinity.

6.2 Prey population

There were only two sightings of wild pigs on the line transects as they were majorly found to be nocturnal based on the camera trap data (Table 1). A pair of mouse deer was also photo-captured in one of the camera traps during the camera trapping conducted for leopards. After discussions with *Van Majurs* I got to know about presence of mouse deers in certain pockets of Sanjay Gandhi National Park such as Chena and Goregao areas. The high densities of primates inside the park could be due to garbage generated through tourism activities. Even though dogs are present inside the park their numbers are quite low as people staying inside the park usually avoid keeping dogs in order to avoid leopards. But dogs are present in good numbers on the periphery of the park at a density of 17.26 ± 0.69 (SE) per km. sq. High dog densities on the periphery of the park can be explained by the presence of humans and immense amount of garbage.

6.3 Leopard's diet.

The generalist behavior of leopards is clearly reflected in the present study. On the basis of scat analysis the leopard was observed to be feeding over a range of prey items varying in weight from 0.5 kg to 200 kg. The presence of dog, cat, domestic fowl, cattle, goat remains in the leopard's scat can be justified on the basis of the human settlements on the periphery of the park. Dog was observed to be the principal prey species for leopards in Sanjay Gandhi National Park. Primates including bonnet macaques and common langurs have good densities in the study area. As these are arboreal animals they are not easily accessible to leopards hence they were not adequately represented in leopard's diet. There are cattle sheds present on the southern and north-eastern sides of the park. Once cattle is dead the general practice followed by the cattle owners is to dump the carcass. So there might be a possibility of a scavenging occurrence on dead livestock which was discarded. Otherwise Forest Department does not have any records of livestock depredation (Forest Department records). Biomass contribution of dogs from the present study is 24.26% in the leopard's diet. The present study had considerable contribution from wild ungulates and primates in the leopard's diet in terms of biomass. On comparison with previous studies (Edgaonkar and Chellam, 2002; Tiwari and Prasad, 2009) from Sanjay Gandhi National Park on food habits of leopard, both the studies showed dog as the principal prey for leopards in their results. But there was a significant difference in the present study and the past two studies in representation of cervids in the leopard's diet. The present study showed about 16.83 and 15.59 percent of contribution in terms of biomass from chital and sambar in leopard's diet respectively. Whereas the previous studies showed a very minimal presence of cervids in leopard's diet. The present study just highlights the already existing fact about importance of dogs in leopard's diet.

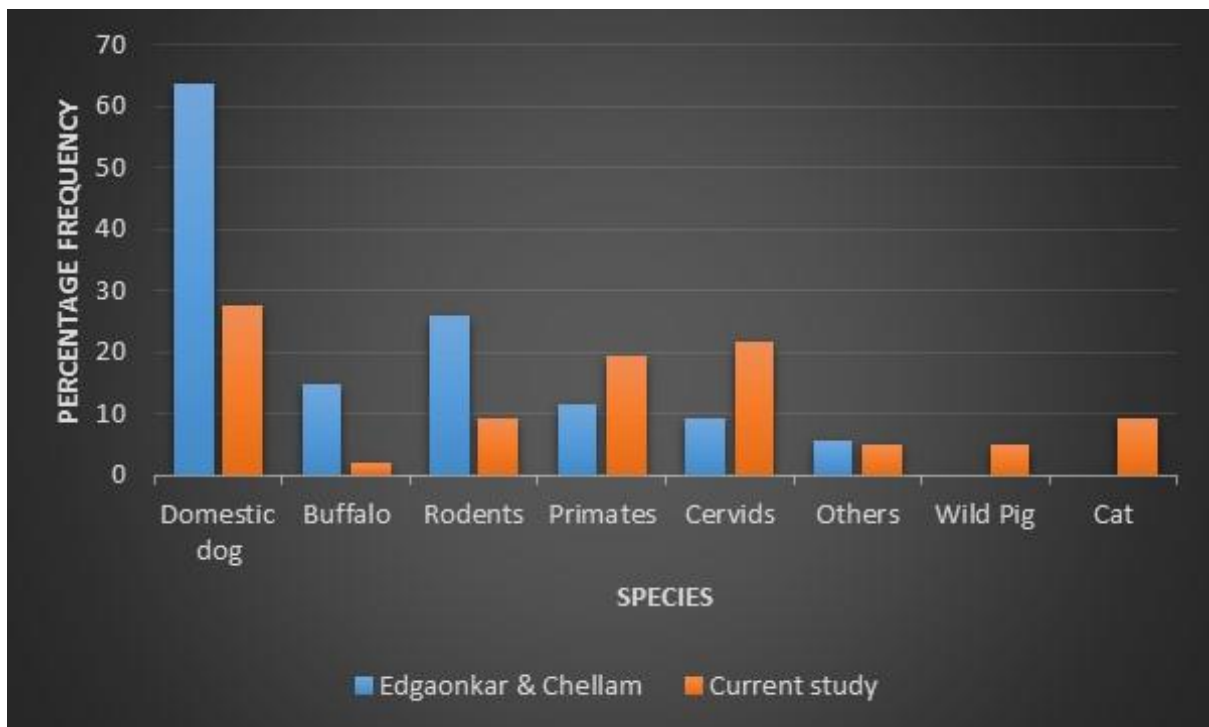


Figure 8. Comparison of leopard's diet between current study and Edgaonkar and Chellam, 2002 study.

7. Conclusion

The study suggests that the leopard is dependent on both wild as well as domestic prey. This in turn is responsible for the high density of leopards shown in the study area.

8. Management of leopards in Sanjay Gandhi National Park.

The leopards in Sanjay Gandhi National Park provide us a unique opportunity to understand large cat ecology where they share space with extremely high density of humans. Our study finds extremely high density of leopards as well and no reports of attacks on humans in the period of the study which indicates that conflict is not related to density of the large cat or the density of the people. However, given the past experience where serious conflict (large number of attacks on people) was not uncommon, it is extremely important to regularly monitor the leopards so that the Park Authorities have a baseline information base to prevent conflict from happening.

Although National Parks are meant to be inviolate, the history of SGNP has led to people living inside as well as a large number of people using the Park. This would require innovative ways to manage this Park which is situated in the metropolis of Mumbai.

Leopards are large ranging animals and there are often reports of them in the human use areas near SGNP, especially in the night when they are caught in CCTV cameras while hunting dogs. For Park management we recommend that GPS collaring of leopards be carried out so that we understand their movement and can devise mitigation measures to minimise problems to people around the Park.

Leopards have lived in and around SGNP for a very long time, and the resilience of this species, as well as their interaction with the humans is a unique situation rarely seen anywhere else in the world. It is recommended that this aspect be utilised as an opportunity to show case the adaptability of this cat as well as the way people interact with the leopards in media and other awareness materials created in India as well as worldwide.

9. References

- Anonymous, 1972. The Wild Life (Protection) Act 1972. Natraj Publishers, Dehra dun.
- Athreya, V., Thakur S., Chaudhari S., & Belsare A. 2007. Leopards in human dominated areas: a spill over from sustained translocations into nearby forests. J Bombay Nat Hist. Soc., 104:13–18.
- Bhale, P., Bhatti, I., & Maye, R. 2005. A commissioned report on Sanjay Gandhi National Park. Maharashtra Forest Department.
- Champion, S. H., & Seth, S. K. 1968. A revised survey of the forest types of India.
- Chauhan, D. S. 2007. Status and ecology of leopard: Ranging patterns and reproductive biology of leopard (*Panthera pardus*) in Pauri Garhwal, Himalayas. Dehradun: Wildlife Institute of India.
- Edgaonkar, A., & Chellam R. 1998. A preliminary study on the ecology of the leopard (*Panthera pardus fusca*) in the Sanjay Gandhi National Park, Maharashtra. RR-98/002. Wildlife Institute of India, Dehra Dun, p 33.
- Edgaonkar, A., & Chellam R. 2002. Food habit of the leopard (*Panthera pardus*) in Sanjay Gandhi National Park, Maharashtra, India. Mammalia, 2002:353–360.
- Mirza, Z., Sanap, R.V., & Shah, V. 2013. Camera trapping: Leopards of SGNP, Mumbai. A Mumbaikars for SGNP project report #1. Submitted to the SGNP Forest Department. Mumbai. Maharashtra.
- Pradhan, M. S. 2002. Common vertebrate species of Sanjay Gandhi National Park, Borivali, Mumbai, Fauna of Conservation series-12: i-v, 1-56 pp (Published-Director, ZSI, Kolkata).
- Punjabi, G. A., Athreya, V., & Linnell, J. D. 2012. Using natural marks to estimate free-ranging dog *Canis familiaris* abundance in a MARK-RESIGHT framework in suburban Mumbai, India. Tropical Conservation Science, 5(4), 510-520.
- Rege, L.B.A. 1974. Management Plan for Nature Reserve. Borivali National Park.
- Tiwari, K., & Apte, D. 2006. City forests, Bombay Natural History Society. Mumbai.
- Tiwari, K., & Apte, D. 2008. City forests, Bombay Natural History Society. Mumbai.
- Tiwari, K., & Prasad, K. 2009. Preliminary study on the diet composition of the leopard (*Panthera pardus fusca*) in Sanjay Gandhi National Park. Bombay Natural History Society. Mumbai.

10. Appendix

Setting camera traps in the study area.



Right and left flank images of leopards



L1 – male



L3 – male



L4 – female



L5 – female



L6 – male



L8 – female



L11 – male



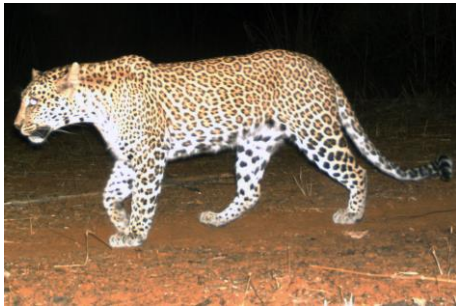
L15 – female



L16 – male



L17 – male



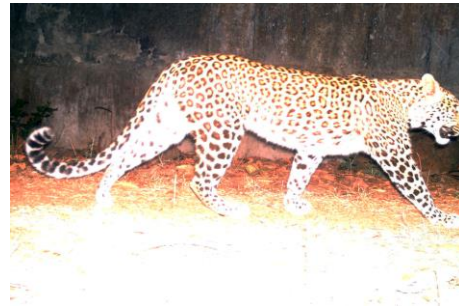
L18 – sex unknown



L19 – female



L20 – female



L21 – female



L23 – female



L24 – male



L25 – male



L26 – sex unknown



L28 – female



L29 – male



L30 – sex unknown



L31 – female



L32 – female

Right flank images of leopards



L2 – female



L7 – sex unknown



L9 – female



L22 – sex unknown



L27 – female



L34 – sex unknown



L35 – female

Left flank images of leopards



L10 – sex unknown



L12 – male



L13 – female



L14 – female

Other (Few of them) animals photo-captured during the study



Rusty spotted cat



Jungle cat with kittens



Mouse deer



Black naped hare



Small Indian civet



Palm civet