Monitoring of Re-Introduced Tigers (*Panthera tigris tigris*)

SARISKA TIGER RESERVE RAJASTHAN

Phase II

FINAL REPORT

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Rajasthan Forest Department

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CHAPTER 1
INTRODUCTION

1.1 Introduction

The Indian sub-continent is home to 60% of the global tiger population with a diverse array of large, meso and small carnivores occurring across diverse habitats. These habitats are compacted in 2% of the global landmass that harbors approximately 18% of the global human population. This high density of human population has an ever-increasing demand for land and other natural resources. Moreover, poor land-use policies coupled with socio-economic necessities and political reasons has resulted in protected areas becoming increasingly porous, fragmented, isolated with high anthropogenic pressures. One such protected area is Sariska Tiger Reserve (STR) situated in the semi-arid landscape of western India along the Aravalli ranges that are the oldest hill ranges in the world. Sariska Tiger Reserve lost its connectivity with Ranthambore Tiger Reserve quite recently and is now an isolated reserve with sharp boundaries and human habitation. There are 29 villages inside Sariska and about 170 villages within 3 kilometers of the reserve boundary. There are two highways which dissect the reserve. Sariska harbors fairly good population of large carnivores including the tiger, leopard and striped hyena. However, conserving large carnivores among human habitation has been a daunting task for managers and conservationists. Since, village relocation from inside the reserve is resource intensive contentious issue; identifying ecological requirements such as suitable breeding sites of large carnivores and protecting them from an ever-increasing human pressure has been the primary concern.

1.2 Reintroduction Efforts (2008 to 2018)

After the extermination of tigers in Sariska Tiger Reserve (STR) in 2004, the Wildlife Institute of India's report on `Status of tiger in Sariska' suggested building up of tiger population in Sariska through reintroduction (Sankar et al., 2005). A suggestion to translocate initial population of five tigers (two males and three females) from Ranthambhore Tiger Reserve (RTR) was made, with a supplementation of three tigers (one male and two females) every two years for a period of six years. The Population Viability Analysis (PVA) showed the probability of tiger survival as 0.9380 (0.0108 SE) in Sariska. Accordingly, in December 2005 a `Species Recovery Plan for Tigers' in Sariska was prepared. Following this scientific plan, three adult tigers (male) and five adult tigresses (female) were reintroduced from Ranthambhore Tiger Reserve and Keoladeo National Park, Bharatpur to build a self-sustaining population. These animals were fitted with radio-collars and translocated to Sariska between June 2008 and January 2013. The details are provided in Table 1.1.

Table 1.1: Details of Reintroduction of Tigers in Sariska Tiger Reserve

S. No.	Tiger ID.	Sex	Date of Reintroduction (Soft Release)	Date of Release in the Wild
1	ST1	Male	28.06.2008	06.07.2008
2	ST2	Female	04.07.2008	08.07.2008
3	ST3	Male	25.02.2009	27.02.2009
4	ST4	Male	20.07.2010	27.07.2010
5	ST5	Female	28.07.2010	01.08.2010
6	ST6	Male	23.02.2011	27.02.2011
7	ST9	Female	22.01.2013	28.01.2013
8	ST10	Female	23.01.2013	28.01.2013

The reintroduction being an intensive process required timely scientific inputs. The Wildlife Institute of India was bestowed with a responsibility of monitoring the reintroduced population with support of the National Tiger Conservation Authority since reintroduction. The animals gradually settled in Sariska, however did not breed for the first four years probably due to high stress levels and lack of inviolate space (Sankar et al., 2013). High stress levels among the reintroduced tigers was observed due to the prevailing disturbance in Sariska (Bhattacharjee et al., 2013). The first record of animal breeding was of ST2 in 2012.

Village relocation process to create inviolate space for tiger breeding was also initiated simultaneously. A total of 565 Gujjar pastoralist families were relocated from six villages.

The reintroduced population was continuously monitored over the years as part of the collaborative initiative between Rajasthan Forest Department, Wildlife Institute of India and National Tiger Conservation Authority. The report of the Phase I (2008-13) and the extended period (2013-15) were duly submitted.

The Phase II of the project was initiated in 2015 to primarily study the response of reintroduced tigers and their prey to village relocation efforts and to explore the future population management.
The objective of the Phase II were as follows:

- **i.** To study the home range and dispersal patterns of the re-introduced tigers and cubs with respect to relocated villages
- **ii.** To assess the habitat use by the re-introduced tigers and cubs with respect to relocated villages
- **iii.** To study the food habits of the re-introduced tigers
- **iv.** To estimate the population of the prey species
- **v.** To suggest management recommendations for effective conservation of tigers in the Tiger Reserve

The findings of the influence of village relocation on tiger and prey population, and future management scope have been provided in the Annual Progress Report (2015 – 16). Findings on the ranging pattern of tigers, factors influencing breeding of tigers, diet, temporal activity, and an update on the age-sex pattern of the tiger population for active population management in Sariska were presented in the annual report (2016 – 17). Here, we summarize our project findings to formulate conservation strategies for long term survival of Sariska's tiger population.

CHAPTER 2
STUDY AREA

Sariska Tiger Reserve (STR), an isolated reserve situated in Aravalli hills in Alwar district of north western Indian state of Rajasthan between Longitude: 79° 17' to 76°34'N and Latitude: 27° 5' to 27° 33'E (Fig 2.1). The reserve presently encompasses an area of 1200 km^2 and includes 881.11 km^2core and 383.11 km^2 buffer (TCP, 2016).

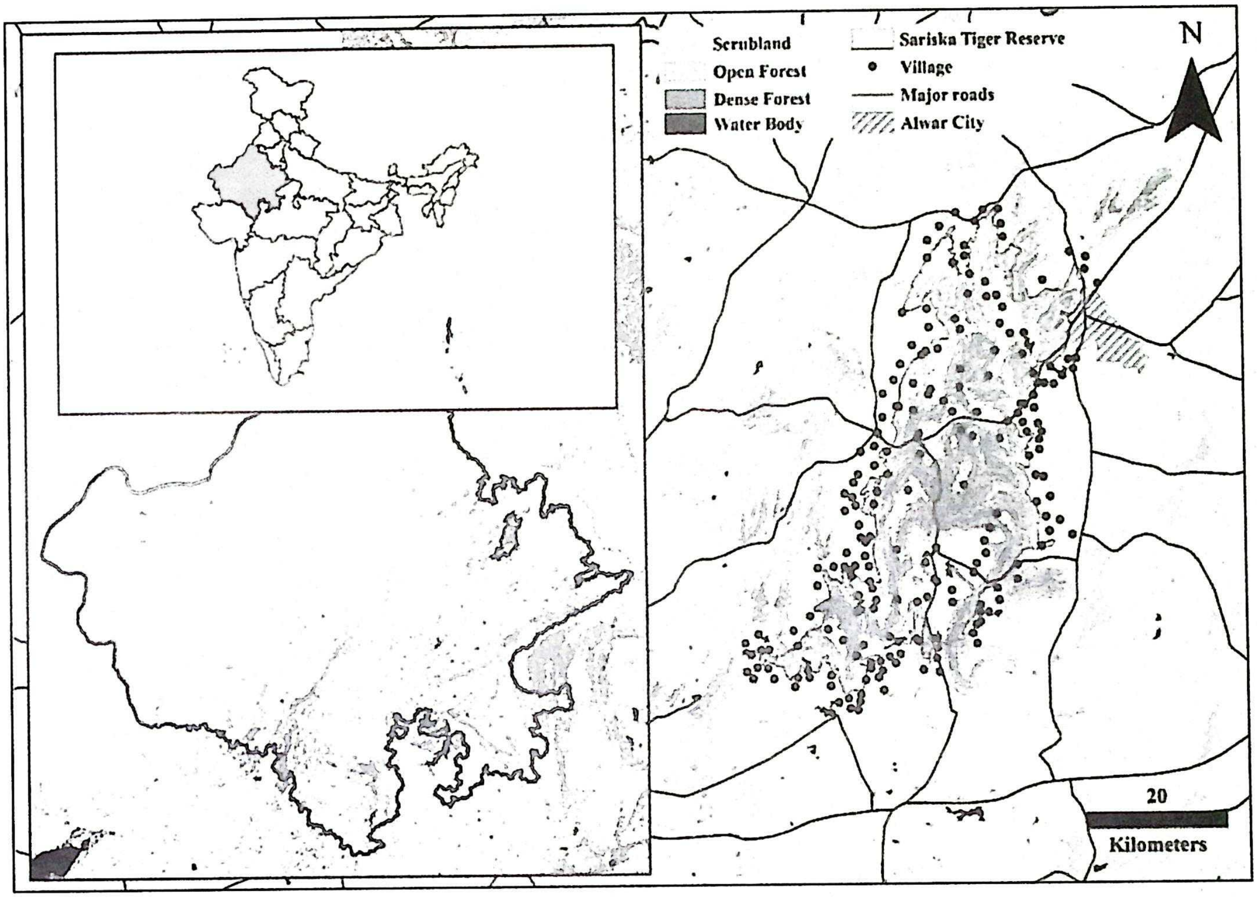


Figure 2.1: Location of Sariska Tiger Reserve with villages inside and at the periphery (within 3 km)

2.1. Climate

The climate is subtropical, characterized by a distinct winter, summer and monsoon. Winter commences from November with the temperature going as low as 3° C. Summer commences from mid-March and continues till end of June and followed by monsoons from south west in July and August. The study area also receives occasional winter and summer rains. Average annual rainfall recorded is 650 mm (Sankar, 1994).

2.2. History and Archaeological Richness

STR was was declared as the 11th Project Tiger Reserve by Govt. of India in 1978. In the pre-independence period, the forests within the Reserve were a part of the erstwhile Alwar State and maintained as a hunting preserve for the royalty (Johari, 2003). After independence, Sariska was declared as a Wild Life Reserve on 7th November, 1955, under the Rajasthan Wild animals and Birds Protection Act, 1951. The Reserve status was upgraded to that of a Sanctuary in 1958. STR was included in the list of Tiger Reserves by Government of India in 1978 as the 11th Tiger Reserve. In 1982, an area of 274 km² was declared as Sariska National Park vide Preliminary Notification *NO. F11 (22) Raj-8/78 Jaipur Dated 27 August 1982 under Wild Life Protection Act 1972 (Central Act No. 53) section 35 (1)*.

2.3. Major Vegetation Types

The vegetation of STR correspond to (1) Northern tropical dry deciduous forests (sub groups 5B; 5/E1 and 5/E2) and Northern Tropical Thorn forest (subgroup 6B) (Champion and Seth, 1968). *Anogeissus pendula* is the dominant tree species covering over 40 per cent area of the forest (Sankar, 1994). *Boswellia serreta* and *Lannea coromandelica* grow on rocky patches. *Acacia catechu* and bamboo are common in the valleys. Some valleys support *Butea monosperma* and *Zizyphus mauritiana*. *Dendrocalamus strictus* is extremely limited in distribution and is found along well drained reaches of the streams and moist and cooler parts of the hills. *Albizia lebbeck, Diospyros melanoxylon, Holoptepia integrifolia* and *Ficus spp.* are found in moist localities (Sankar, 1994). Parmar (1985) and Rodgers (1991) have classified vegetation of Sariska as follows:

1. *Anogeissus pendula* forest
2. *Boswellia serrata* forest
3. *Acaccia catechu* forest and
4. *Miscellaneous forest,* which can be further sub-divided into three categories viz.
   a) *Butea monosperma* forest
   b) Forest along nallas and
   c) Scrub land

Nine different vegetation and land cover categories have been delineated in STR (Sankar et. al. 2008). They are *Anogeissus* dominated forest, *Boswellia* dominated forest, *Butea* dominated forest, *Acacia* mixed forest, *Zizyphus* mixed forest, Scrubland, Agricultural land, Water body and Barren land.

2.4. Terrain

The major part of the area is occupied by rocks of the Delhi system and Aravalli system comprising of quartzite, conglomerates, grits, limestone, phyllite, granites and schist (Pascoe, 1950; Sankar, 1994). STR is characterized by rugged terrain, valleys and plateau with the altitudinal variation from 340 m to 777 m (Fig 2.2). The two main plateaus are Kankawadi (524 m above mean sea level) and Kiraska (592 m above the mean sea level). The most remarkable characteristics of the hills are their homo-genetic regularity of height, level summits and uniform appearance, stretching out from northeast to south-west, in more or less parallel lines (Soni, 2000). The depth of soil layer is more than 1 m in valleys, whereas it is only a few centimeters deep on the hill slopes. The soil is sandy loam and alkaline with pH varying from 7.25 to 8.00 (Yadav and Gupta, 2006).

2.5. Co-predators and Prey

Large carnivores found are leopard (*Panthera pardus*), striped hyaena *(Hyaena hyaena)*, and reintroduced tigers (*Panthera tigris*). STR sustains comparatively higher density of leopard (6.0±0.5 individuals/ 100 km^2, Mondal et al., 2012) and striped hyena (15.1±6.2 individuals/ 100 km^2, Gupta et al., 2009). Small carnivores are caracal (*Caracal caracal*), jungle cat (*Felis chaus*), common mongoose *(Herpestes edwardsi*), small Indian mongoose (*H. auropunctatus*), ruddy mongoose (*H. smithi*), palm civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*) and ratel (*Mellivora capensis*). Ratel density was 6.43 ± 2.79 animals/100 km^2 (Gupta et al., 2012).

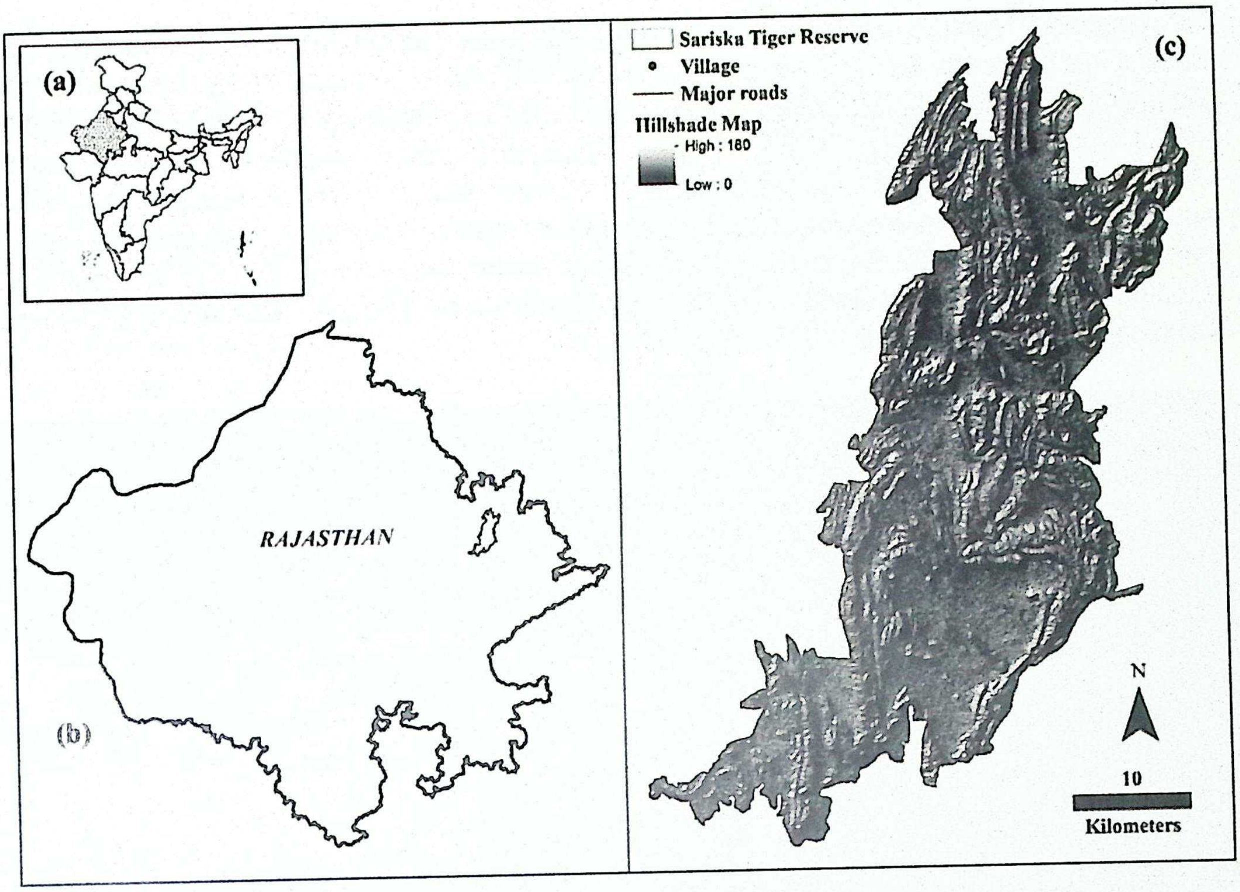
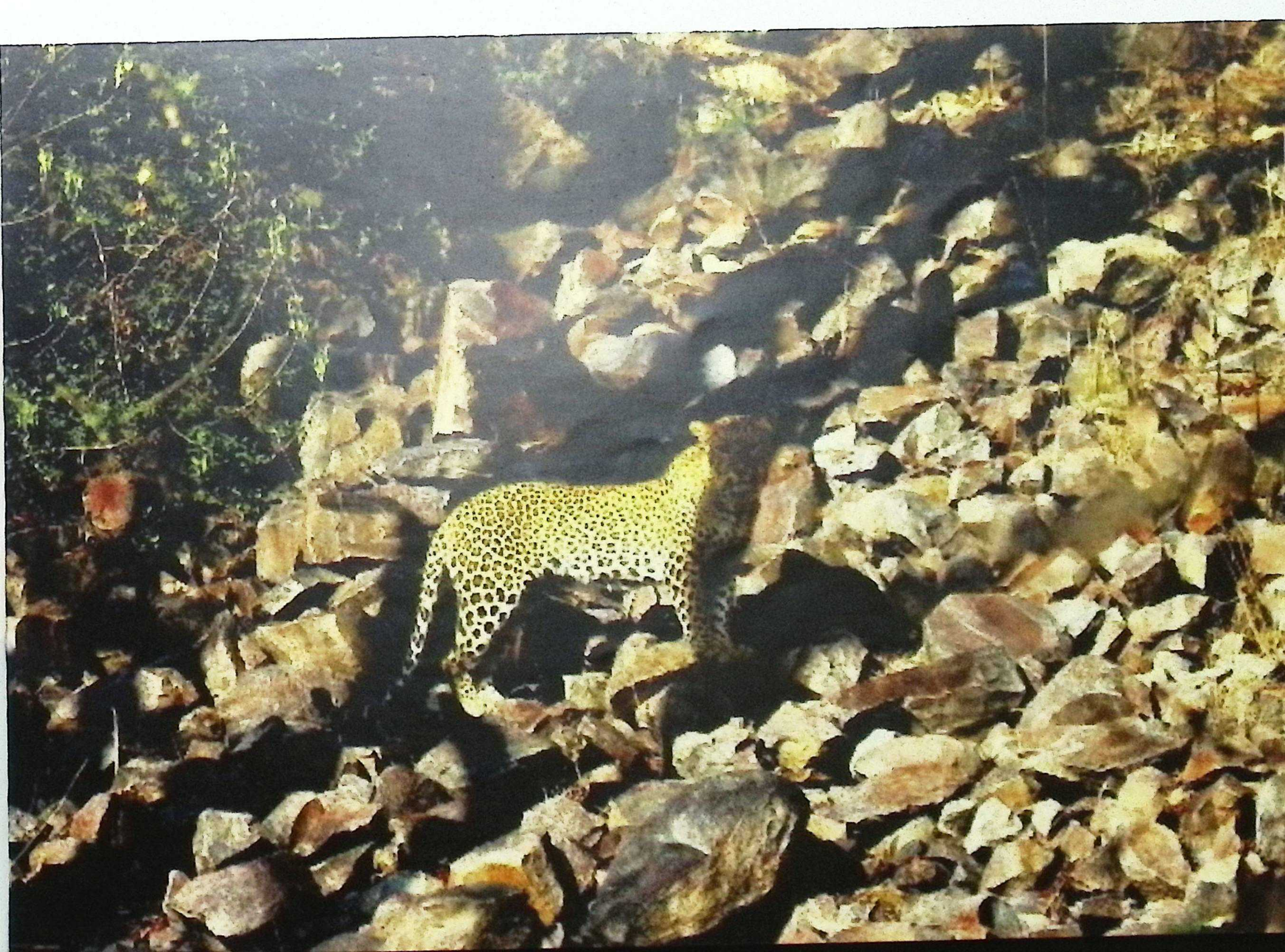


Figure 2.2: Hill shade map of Sariska Tiger Reserve showing terrain complexity



Wild ungulates found in Sariska include chital (*Axis axis*), sambar (*Rusa unicolor*), and nilgai (*Boselaphus tragocamelus*), and wild pig (*Sus scorfa*). STR sustains comparatively higher density of wild prey and livestock. Wild ungulate density of STR is 54.49 individuals/ km^2 and livestock density is 69.31 individuals/ km^2 (Table 2.1.). Rhesus macaque (*Macaca mulatta*) and common langur (*Seminopithecus entellus*) are the two primates found here. Procupine (*Hystrix indica*), rufous tailed hare (*Lepus nigricollis ruficaudatus*). and 11 species of rodents have been recorded. The overall rodent density was 22.92 ±4.65 (SE) animals/ha in winter, and 7.81 ±2.25 (SE) animals/ha in summer. The overall rodent density was 16.15 ±2.76 animals/ha, and their estimated total biomass was 612.9 gm/ha (Gupta et al., 2013).

The most abundant galliform species was the Indian peafowl *Pavo cristatus* with an estimated density of 53.1 ± 5.6 individuals per km^2. Densities were also estimated for grey francolin *Francolinus pondicerianus* (21.6 ± 4.8 individuals per km^2), quail species (4.3 ± 1.40 individuals per km^2) and painted spurfowl *Galloperdix lunulata* (2.5 ± 0.9 individuals per km^2) in STR (Kidwai et al., 2011). Prey availability in the study area is given in Table 2.1.

Table 2.1: Availability of wild and domestic prey (Density estimates) in Sariska Tiger Reserve

Prey Species	Density (No./km²)	Source
Wild Ungulates	54.49	Bhattacharjee, 2013
Chital (*Axis axis*)	16.25 ± 3.00	Bhattacharjee, 2013
Sambar (*Rusa unicolor)*	6.94 ± 1.27	Bhattacharjee, 2013
Nilgai (*Boselaphus tragocamelus*)	19.66 ± 1.85	Bhattacharjee, 2013
Wild Pig (*Sus scrofa*)	11.64 ± 2.11	Bhattacharjee, 2013
Medium and small sized mammal prey		
Common Langur (*Seminopithecus entellus)*	15.30 ± 2.90	Bhattacharjee, 2013
Rufous tailed hare (*Lepus nigricollis ruficaudatus*)	1.92 ± 0.4	Bhattacharjee, 2013
Rodent	0.16 ± 0.027	Gupta et al., 2013
Birds	74.7	Kidwai et al., 2011
Indian peafowl (*Pavo cristatus)*	53.1 ± 5.6	Kidwai et al., 2011
Grey francolin *Francolinus pondicerianus*	21.6 ± 4.8	Kidwai et al., 2011
Livestock	69.31	Bhattacharjee, 2013
Buffalo (*Bubalus bubalis*)	28.3 ± 4.68	Bhattacharjee, 2013
Cattle (*Bos taurus*)	41.01 ± 6.58	Bhattacharjee, 2013

2.6. Villages and Livestock

There were 29 villages within the Tiger Reserve boundary. Twelve villages are situated in the notified National Park and are due for relocation since 1984. Of these, Bhagani village was relocated during November 2007, Umri village during March 2012 and Rotkala village in March 2013.

The local communities residing within the reserve depend on the livestock for their existence while residing in the buffer are primarily engaged in agricultural sector. Large number of buffaloes and goats, cattle, sheep and a few camels are kept in the villages with the livestock density of 69.31 individuals/ km^2 (Bhattacharjee, 2013). The human population is over 8500 in the villages of Sariska TR. Additionally, there are approximately 170 villages in the periphery (within 3 km) of the reserve. These villagers depend totally on forests for their livelihood. The people inhabiting these villages are traditionally pastoralist and their main source of income is selling milk and its products like "Mawa and Ghee".

The Alwar Thanagazi-Jaipur State Highway passes through the reserve and more than 4000 vehicles ply on it every day). Another main road passes through the reserve is Sariska- Kalighati- Pandupole road which is 20 km and along the wildlife rich valley of the reserve.

CHAPTER 3
HOME RANGE AND DISPERSAL PATTERN

3.1 Introduction

The home range of an animal is defined as the area traversed by the animal in its normal activities of gathering food, caring for young and mating (Burt, 1943). The range must satisfy the energy needs of the animal (Gittleman and Harvey, 1982) and use of the range can provide information regarding the distribution, importance and accessibility of important resource (Henschel, 1986). Though tigers are generalists (Sunquist et al., 1999), they still are vulnerable to habitat loss and fragmentation. Defining the size, shape and pattern of utilization of an animal's home range is important for studying habitat selection and spacing of individuals (Katajisto and Moilanen, 2006).

3.2 Method

Home range, daily and seasonal movement of the reintroduced tigers was determined by employing radio-telemetry. Radio locations of each animal were determined by "Homing in" and "Triangulation" from three to four known reference points (White and Garrot, 1990). Coordinates of these reference points were taken with the help of Global Positioning System (GPS). For estimating home ranges, two to three locations every day per collared animal was recorded. The movement pattern of each collared individual was monitored continuously for a week every month. Home range estimations were carried out using appropriate software like CALHOME (Kie, 1994). Two methods such as 100% minimum convex polygon (Mohr, 1947) and Kernel method (Katajisto and Moilanen, 2006; Kernohan et al., 1998) was used to analyze the home range of the tigers. The harmonic mean method (Dixon and Chapman, 1980) was used to find centers of activity and range shifts between seasons. A digital terrain model in conjunction with satellite imagery was used for estimating home range size in undulating terrain to consider the factor of the topography.

3.3 Results

3.3.1 Home Range (2014-15)

A total of 378, 409, 345, 382, 437, 359, 271, 213 and 402 locations were recorded respectively of ST2, ST3, ST4, ST5, ST6, ST7, ST8, ST9 and ST10 between April 2014 to March 2015. The annual home ranges were estimated respectively as 53.51, 125.44, 367.16, 79.20, 196.57, 39.13, 49.32, 46.98 and 111.00 sq. km. for all nine tigers in an order from ST2 to ST10. (Fig. 3.1). The information serves as a link between the Phase I and Phase II of the project, hence included in the report.

3.3.2 Home Range (2015-16)

A total of 494, 346, 501, 458, 498, 445, 267, 271 and 378 locations were recorded respectively of ST2, ST3, ST4, ST5, ST6, ST7, ST8, ST9 and ST10 between April 2015 to March 2016. The annual home ranges were estimated respectively as 47.24, 103.07, 322.75, 67.52, 213.7, 30.82, 40.15, 76.39 and 80.29 sq. km for all the nine individuals (Fig. 3 and 4). The average annual home range for adult male tiger was 268±56 (SD) sq. km and for adult female tiger was 64±24 (SD) sq. km. (Fig.3.2).

3.3.3 Home Range (2016-17)

A total of 316, 365, 450, 376, 461, 360, 301, 382, 401, 151, 116, 248 and 197 locations were recorded respectively of ST2, ST3, ST4, ST5, ST6, ST7, ST8, ST9, ST10, ST11, ST12, ST13 and ST14 between April 2016 to March 2017. Additionally, 124 locations were recorded for the cub of ST9. The annual home ranges were estimated respectively as 20.3, 128, 470, 115.40, 274, 33, 53.40, 96.20, 123.23, 520.12, 87.05, 1240 and 70 sq. km. for all 13 adult tigers in an order from ST2 to ST14 (Fig. 5 & 6). Average annual home range for adult male tiger was 626.25±183.07 (SE) sq. km and for adult female tiger was 80.30±11.10 (SE) sq. km. Estimated home range for ST9 cub was 76.38 sq. km. As ST13 (male cub) was not established and was dispersing, no home range map was prepared for it (Fig 3.3).

3.3.4 Home Range 2017-18

A total of 252, 305, 321, 268, 328, 244, 231, 265, 271, 274, 187, 261, 170 and 180 locations were recorded respectively of ST2, ST3, ST4, ST5, ST6, ST7, ST8, ST9, ST10, ST11, ST12, ST13, ST14 and ST15 during the study period. The annual home range were estimated respectively as 24.08, 103.5, 236.92, 64.73, 138.55, 32.45, 39.39, 80.08, 79.14, 163.31, 31.8, 976.12, 35.79 and 32.98 sq. km. (Fig. 7 & 8). Average annual home range for adult male tiger was 1547.88 ± 8.63 sq. km. And for adult female tiger it was 54.55 ± 1.19 sq. km. (Fig 3.4)

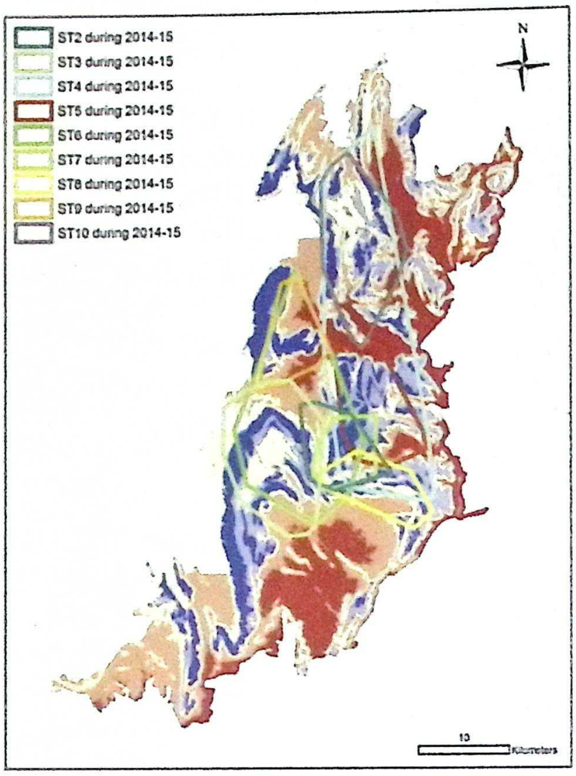


Fig. 3.1: Map showing the Home Range of tigers during 2014-15

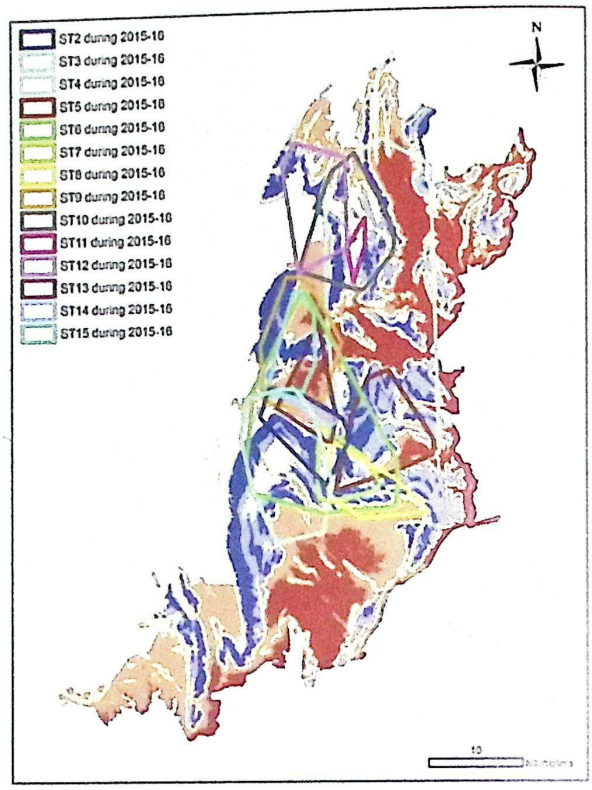


Fig. 3.2: Map showing the annual home range of tigers during 2015-16

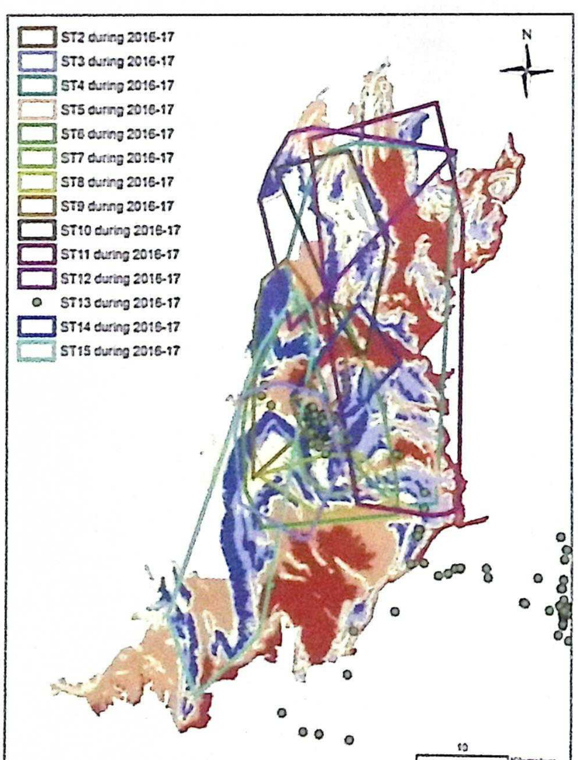


Fig. 3.3: Map showing the annual home range of tigers during 2016-17

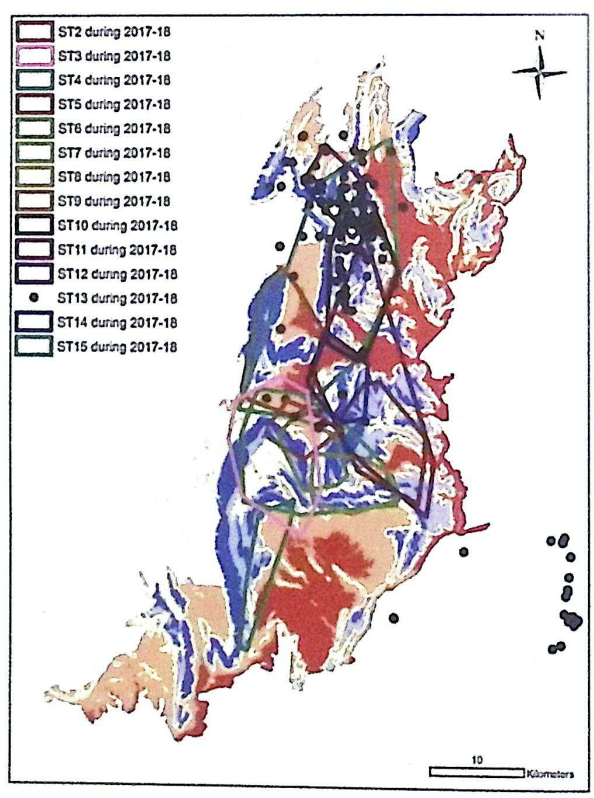


Fig. 3.4: Map showing the annual home range of tigers during 2017-18

3.3.5 Year wise comparison of the home range of tigers between 2014-18

Overall, a total of 1440, 1425, 1617, 1484, 1724, 1408, 1070, 1131, 1452, 425, 303, 509, 367 and 304 locations were recorded for ST2, ST3, ST4, ST5, ST6, ST7, ST8, ST9, ST10, ST11, ST12, ST13, ST14 and ST15 respectively during 2014-18. The comparison of home ranges of tigers over the period of 2014-18 are shown in Fig. 3.1.

Table 3.1: Comparison of home ranges from 2014-18

Tigers	Home range (100% MCP) estimation in sq. km (2014-18)			
	2014-15	**2015-16**	**2016-17**	**2017-18**
ST2 (Female)	53.51	47.24	20.3	24.08
ST3 (Female)	125.44	103.07	128	103.5
ST4 (Male)	367.16	322.75	470	236.92
ST5 (Female)	79.2	67.52	115.4	64.73
ST6 (Male)	196.57	213.7	274	138.55
ST7 (Female)	39.13	30.82	33	32.45
ST8 (Female)	49.32	40.15	53.4	39.39
ST9 (Female)	46.98	76.39	96.2	80.08
ST10 (Female)	111	80.29	123.23	79.14
ST11 (Male)	NA	NA	521	163.31
ST12 (Female)	NA	NA	NA	31.8
ST13 (Male)	NA	NA	NA	976.12
ST14 (Female)	NA	NA	NA	35.79
ST15 (Male)	NA	NA	76.38	32.98

During the study period (2015-18), ST2 was observed to be occupying areas of Karnakawaas-Tarunda-Haripura beats along with her cubs. First litters of ST2 tigress, *i.e* ST7 and ST8 tigress which attained adulthood, were observed occupying areas of Slopka-Kalighati-Karnakawaas-Umri and Jahaz-Slopka-Kalighati-Bhesota-Deori-Pandupol beats respectively. ST3 tigress was observed occupying areas of Ghanka -Richunda-Kharika-Bhagani-Sadar-Kankwari-Garh-Rajor. The male ST4 was observed occupying areas of Lodge-Panidhal-Umri-Pandupol-Bhatela-Slopka-Sukola-Binak-Umri-Sadar-Ganeshpura-Indok-Haripura beats and another male ST6 was observed occupying areasof Karnakawas-Haripura-Tarunda-Kalighati-Sadar-Pandupol-Slopka-Kankwari-Jahaz-Bhagani beats. The female ST5 was observed occupying areas of Sukola-Umri-Pandupole-Rotkala-Bhatyala-Kiraska beats. The tigresses ST9 and ST10 occupied Northern areas of Sariska Tiger reserve falling in Akbarpur and Talvriksha Ranges. Tigress ST9 occupied North-western areas of Berawas-Indok beats whereas, ST10 tigress occupied the North-eastern areas of Panidhal-Lodge-Rampur II-Rampur III-Binak-Lekhri beats along with her cubs. ST11 was observed to be using Umri-Rotkyala-Sukola-Kiraska-Ghamodi-Lilunda-Deori beats. ST12 uses the area of ST10. ST13 was observed to use the natal area (Karnakawas) initially, and further moved out in the territorial division at Rajgarh. The animals were captured and shifted to the tiger enclosure (Naya Pani). The animal following released got established in Panidhal-Lodge-Rampur II- Rampur III-Binak-Lekhri beats. ST14 was observed to be using Sukola-Kiraska-Ghamodi-Lilunda beats. ST15, the male cub of ST9 tigress, initially used the natal are before it moved out to Ajabgarh range and occupied Rajor-Garh-Bhagani-Bhangarh-Dighota beats. Individual year-wise home range of tigers in Sariska TR is provided in Fig. 3.5 – 3.18.

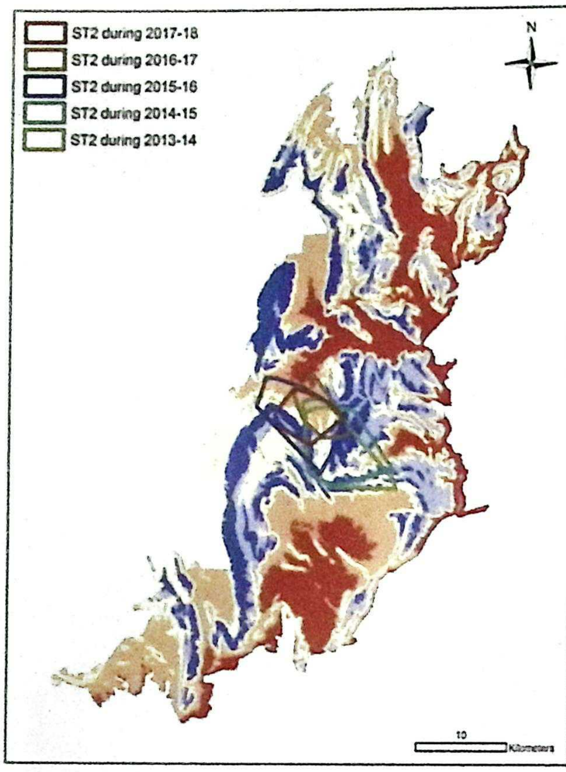


Fig. 3.5: Home range of ST2 during 2013-18

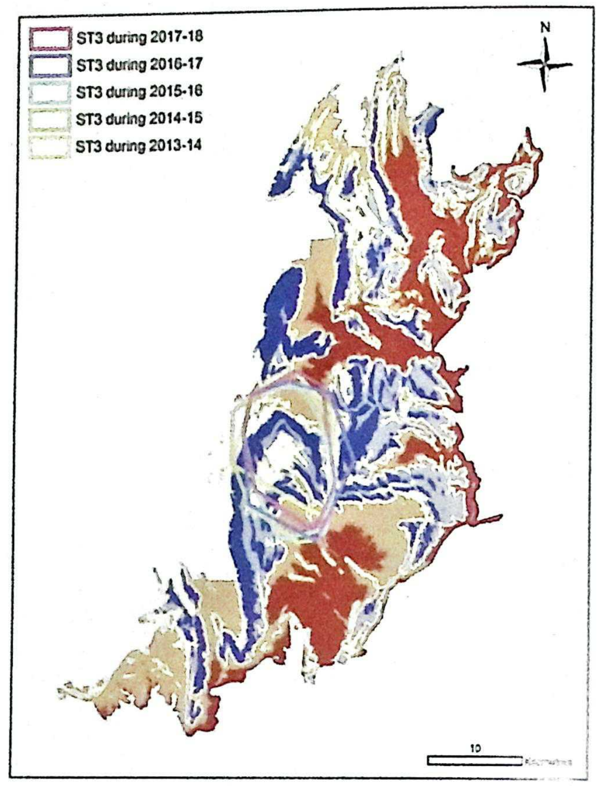


Fig. 3.6: Home range of ST3 during 2013-18

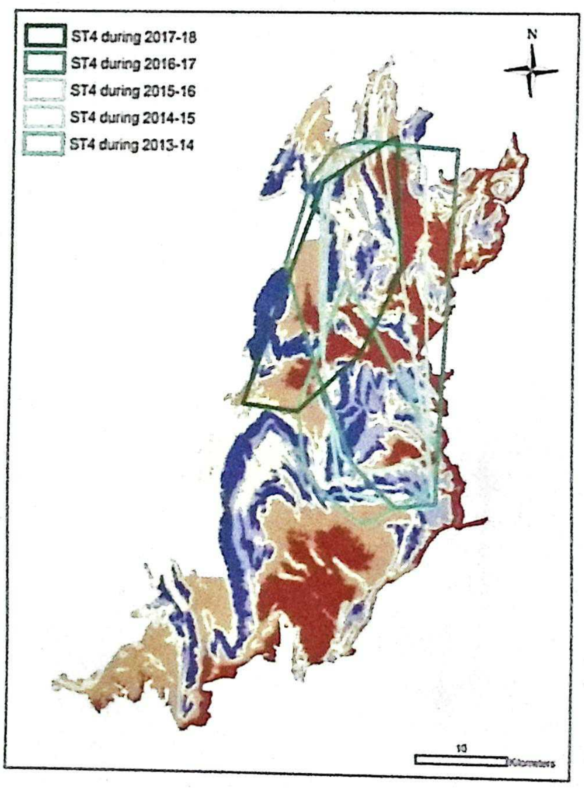


Fig. 3.7: Home range of ST4 during 2013-18

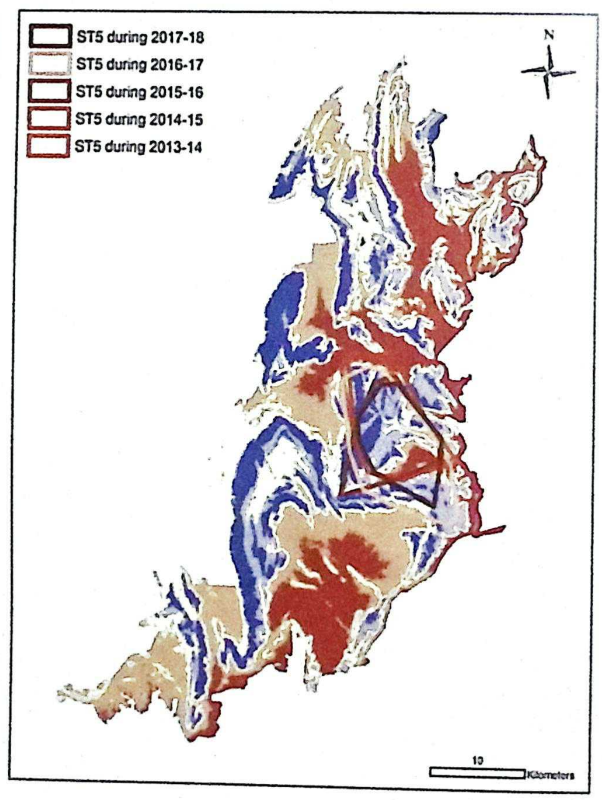


Fig. 3.8: Home range of ST5 during 2013-18

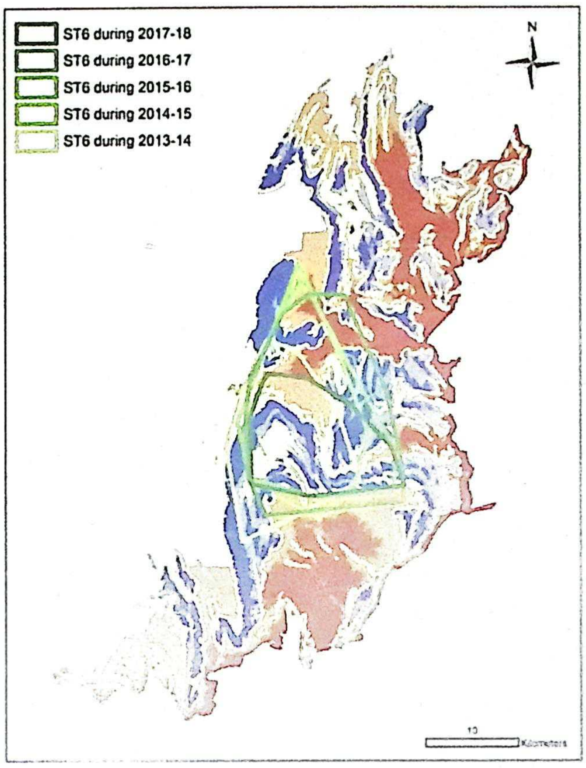


Fig. 3.9: Home range of ST6 during 2013-18

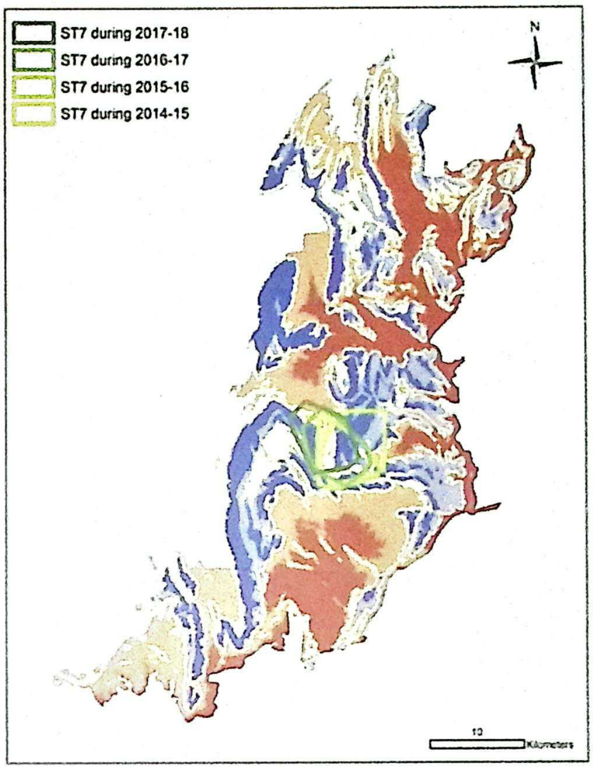


Fig. 3.10: Home range of ST7 during 2014-18

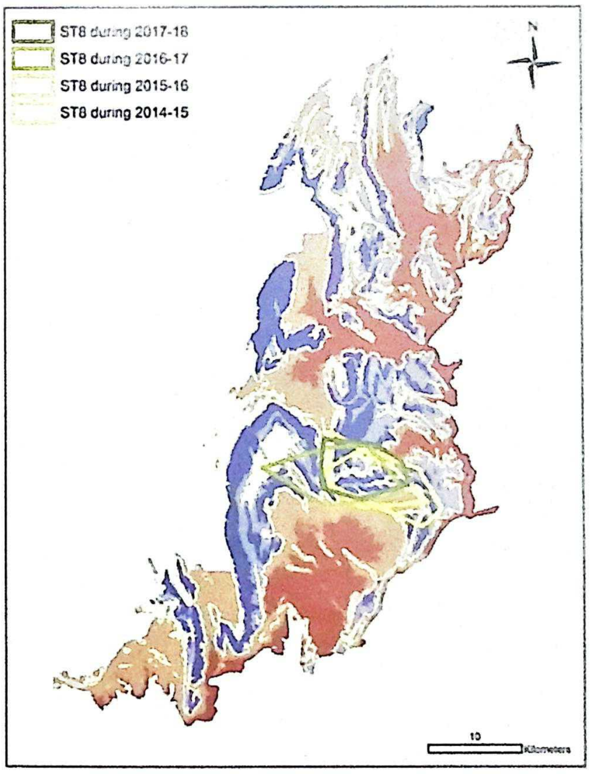


Fig. 3.11: Home range of ST8 during 2014-18

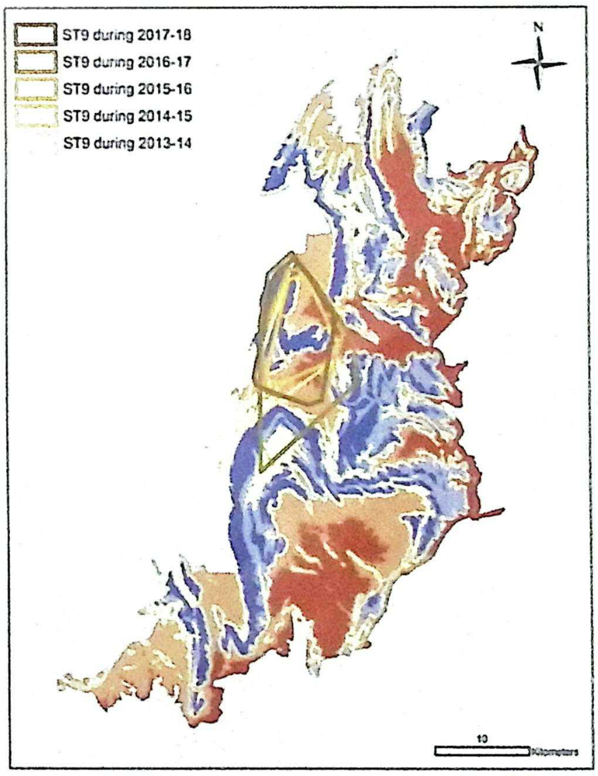


Fig. 3.12: Home range of ST9 during 2013-18

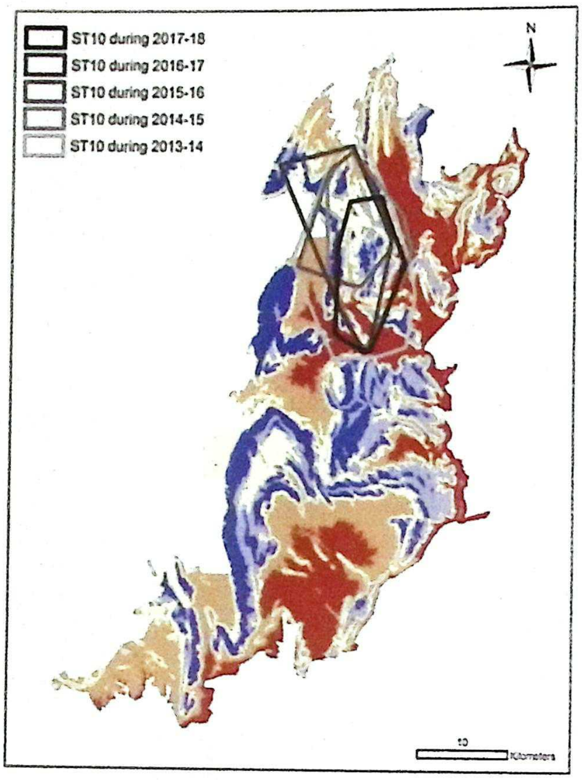


Fig. 3.13: Home range of ST10 during 2013-18

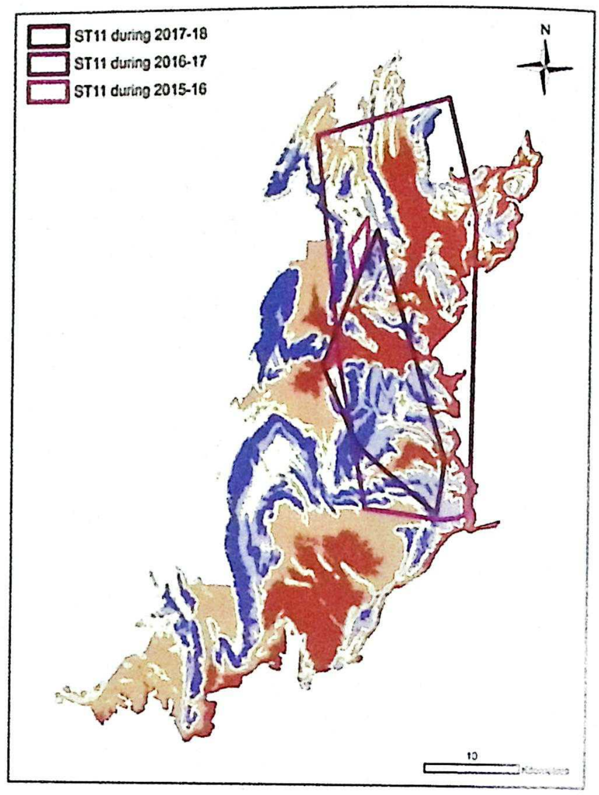


Fig. 3.14: Home range of ST11 during 2015-18

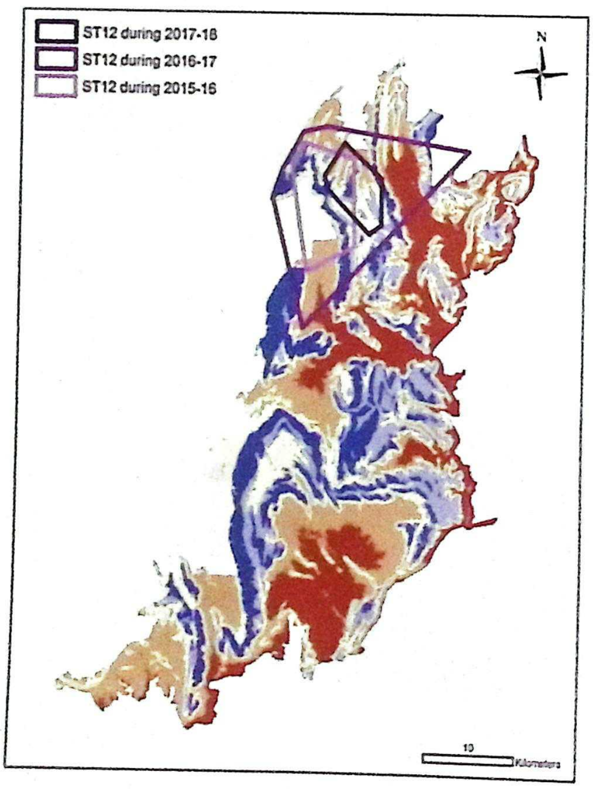


Fig. 3.15: Home range of ST12 during 2015-18

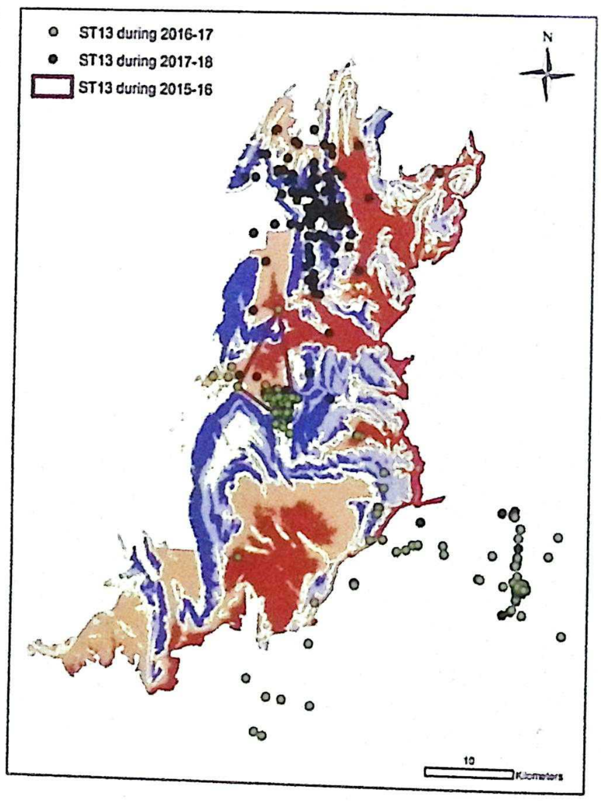


Fig. 3.16: Home range of ST13 during 2015-18

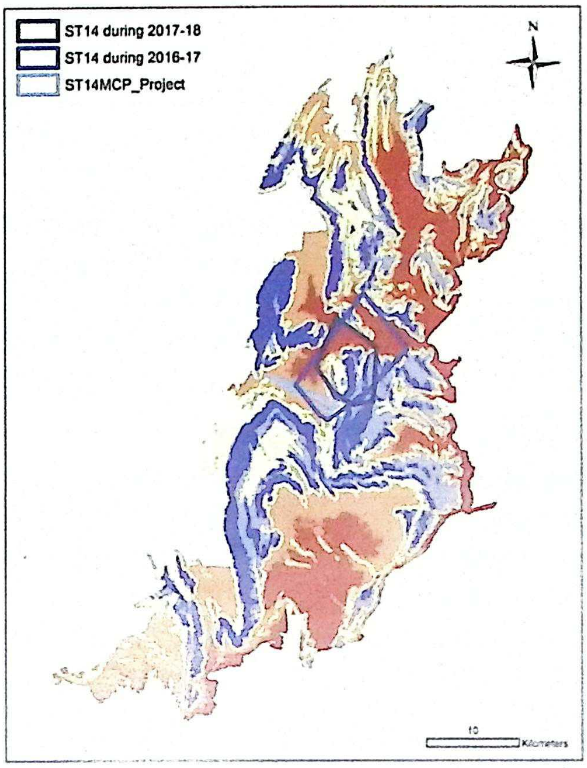


Fig. 3.17: Home range of ST14 during 2015-18

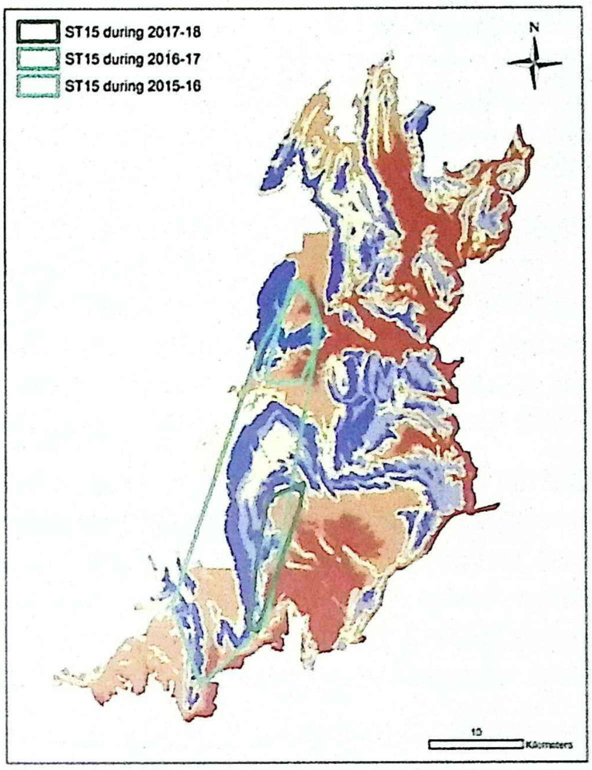
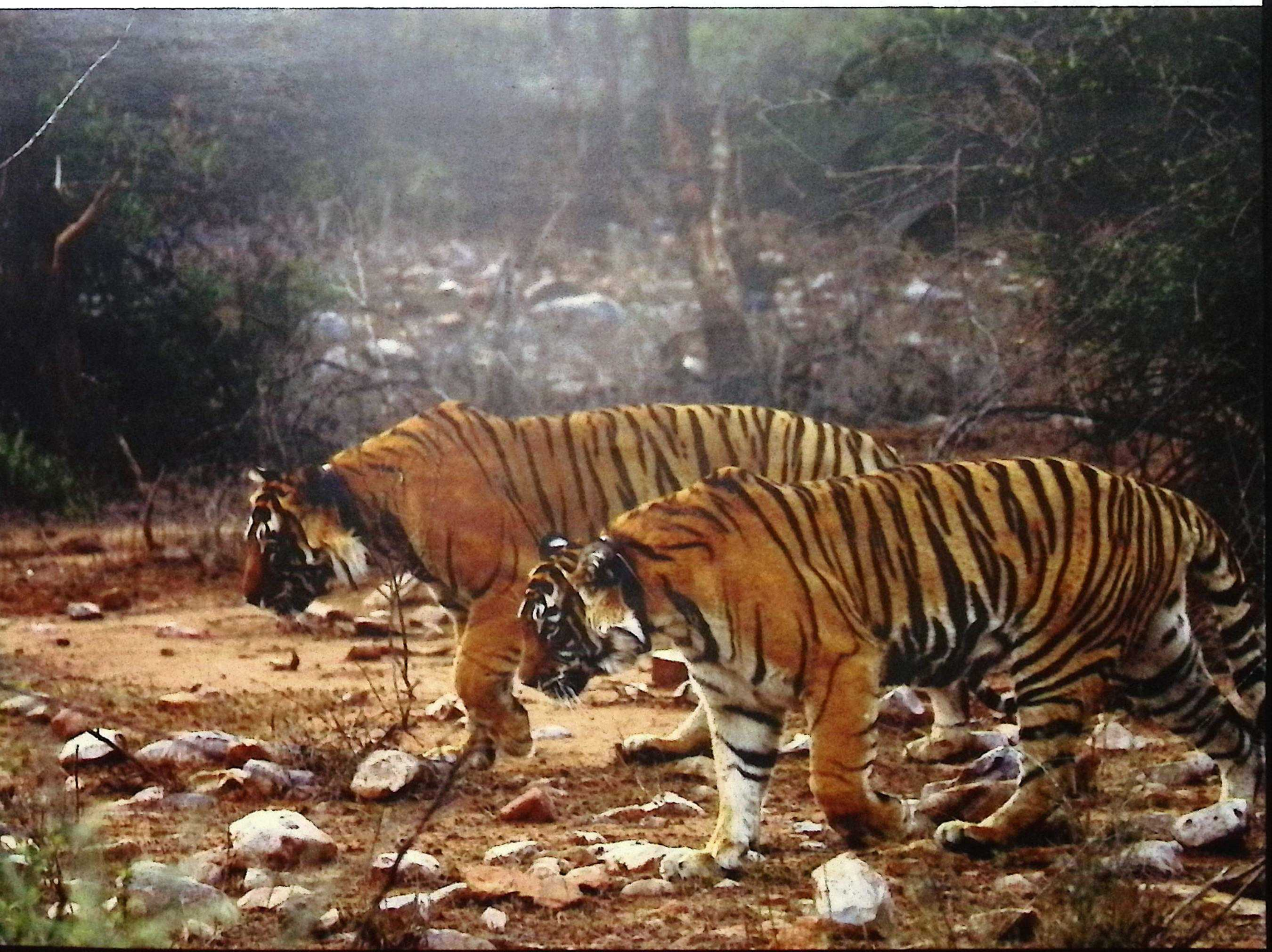


Fig. 3.18: Home range of ST15 during 2015-18



CHAPTER 4
PREY STATUS & DISTRIBUTION

4.1 Introduction

The primary reason for the unprecedented decline in tiger population are prey depletion, habitat loss and poaching is now a well-known fact (Sankar et al., 2009). Models based on tiger population dynamics have indicated that many of the fragmented tiger populations were unable to sustain poaching pressures despite high fecundity (Chapron et al., 2008) and large prey base. In fact, two tiger populations in India –Sariska TR and Panna TR, lost their tiger populations due to poaching despite having good prey base (Sankar et al., 2009, 2010).

After the reintroduction, high stress levels among the reintroduced tigers was observed due to the prevailing disturbance in Sariska. Reintroduced tigers didn't litter for first four years due to high stress levels and lack of inviolate space. However, village relocation process was also ongoing to create inviolate space for tiger breeding. 565 Gujjar pastoralist families have also been relocated from 6 villages till 2013. In this context, it was imperative to understand the response of prey population to village relocation and explore future population management scopes.

In this study, we estimated wild ungulate density and livestock density over three years (2013 – 2016) to understand the response of wild ungulates and change in livestock population following resettlement of 565 families.

4.2 Methods

4.2.1 Population estimation of principal prey species and livestock

Prey and livestock density were estimated through line transects under distance sampling framework using three years data collected from 2013 – 2016 (Buckland et al., 1993). A total of 38 line transects of 1.4 to 2 km each was laid randomly across 800 sq. km covering the tiger occupied area in Sariska which was representative of major terrain, habitat types. Each line transect was walked every dry and wet season thrice during the study period. Total effort was 1005.50 km during the study period. We recorded species, group size, age–sex composition, sighting angle measured using a hand held compass (KB 20, Suunto, Vantaa, Finland), and sighting distance measured by a laser range finder (Yardage Pro 400, Bushnell, Overland Park, Kansas, USA) on every walk. We recorded age and sex compositions when possible and classified animals as males, females, or fawns.

To model detection functions, we examined the data for each species/survey year for signs of evasive movement and peaking at a great distance from the line transect. Following this, the data was either truncated at great distances or reclassed so as to ensure a reliable fit of key functions and adjustment terms to the data. Akaike Information Criterion (AIC) and goodness-of-fit (GOF-p) tests were used to judge the fit of the model. We only considered models with values more than 0.70 in the goodness of fit (GOF-p) test. Using the selected model, estimates of group density (Dg), group size (GS), and individual density (Di) were derived. To test for significance between age and sex ratios across years, we computed 95% bootstrap confidence intervals (Hilborn and Mangel, 1997) as the data did not conform to the assumptions of normality.

4.3 Results

We estimated density of four principal prey species (Sambar, Chital, Nilgai and Wild Pig) out of total eight prey species detected on transects and livestock across three survey years. Total annual effort was 338.4 km. during the study period. Present study recorded a 40% increase in the wild ungulate density in Sariska over three years following relocation of 565 families from the reserve. Wild ungulate density increased from 46.8 ungulates/ km^2 in 2013 – 14 to 64.2 ungulates/ km^2 in 2015 – 16. Proportion of fawns increased over three years for both Sambar and Chital. Livestock density in the study area remained fairly stable across three years.

Table 4.1: Details of density estimates of principal prey species

Species	2013-14		2014-15		2015-16	
	Density	SE	Density	SE	Density	SE
Sambar	9.13	2.3	10.48	3.20	16.1	4.49
Chital	12.4	3.4	11.38	3.16	24.33	7.85
Wild Pig	9.1	2.5	4.15	1.76	8.12	3.18
Nilgai	16.2	2.6	15.59	2.59	13.69	2.00

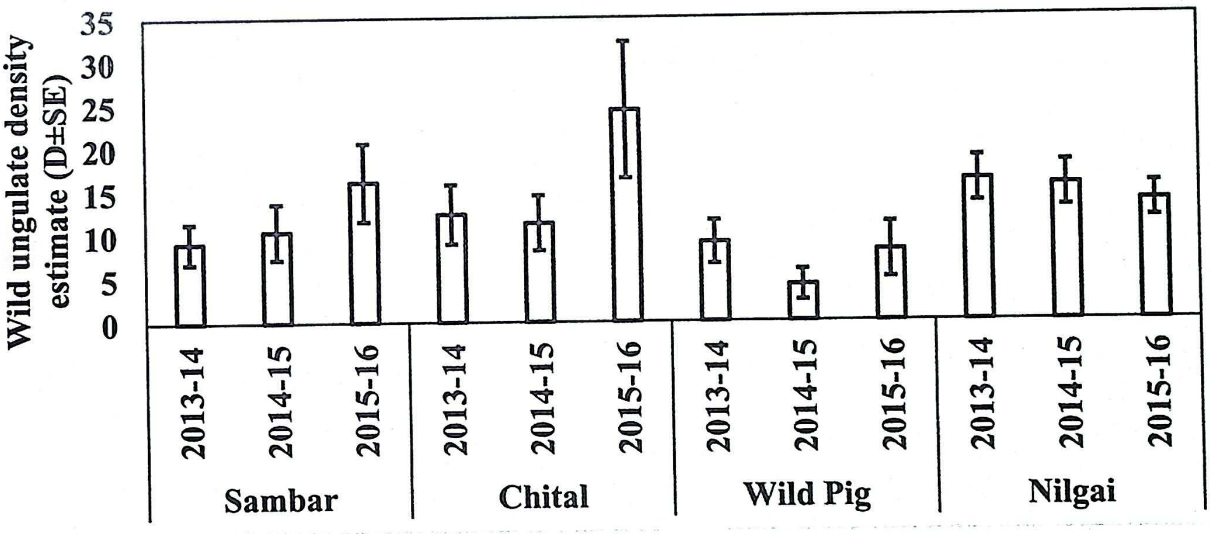


Figure 4.1: Details of density estimates of prey species during 2013 – 16 in Sariska

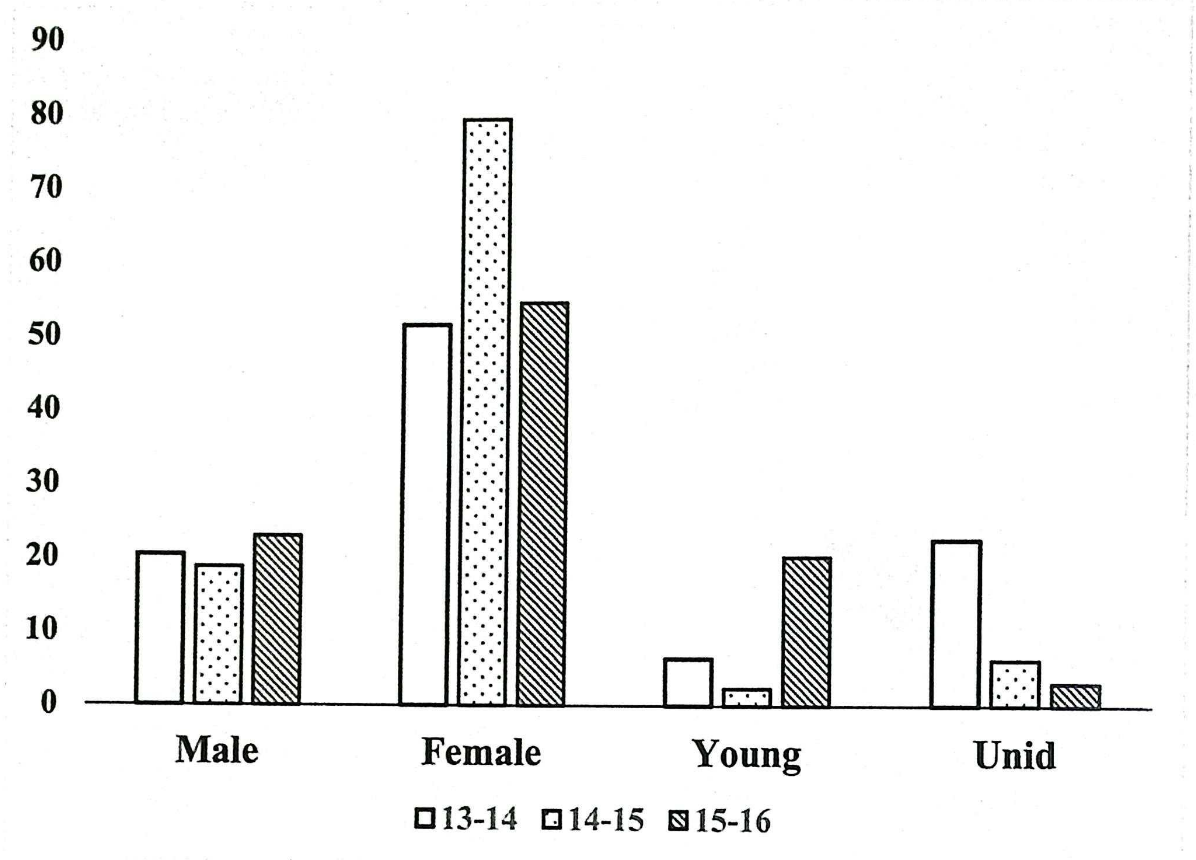


Figure 4.2: Composition (proportional) of adult males, adult females and young (up to yearling) for Sambar across three years

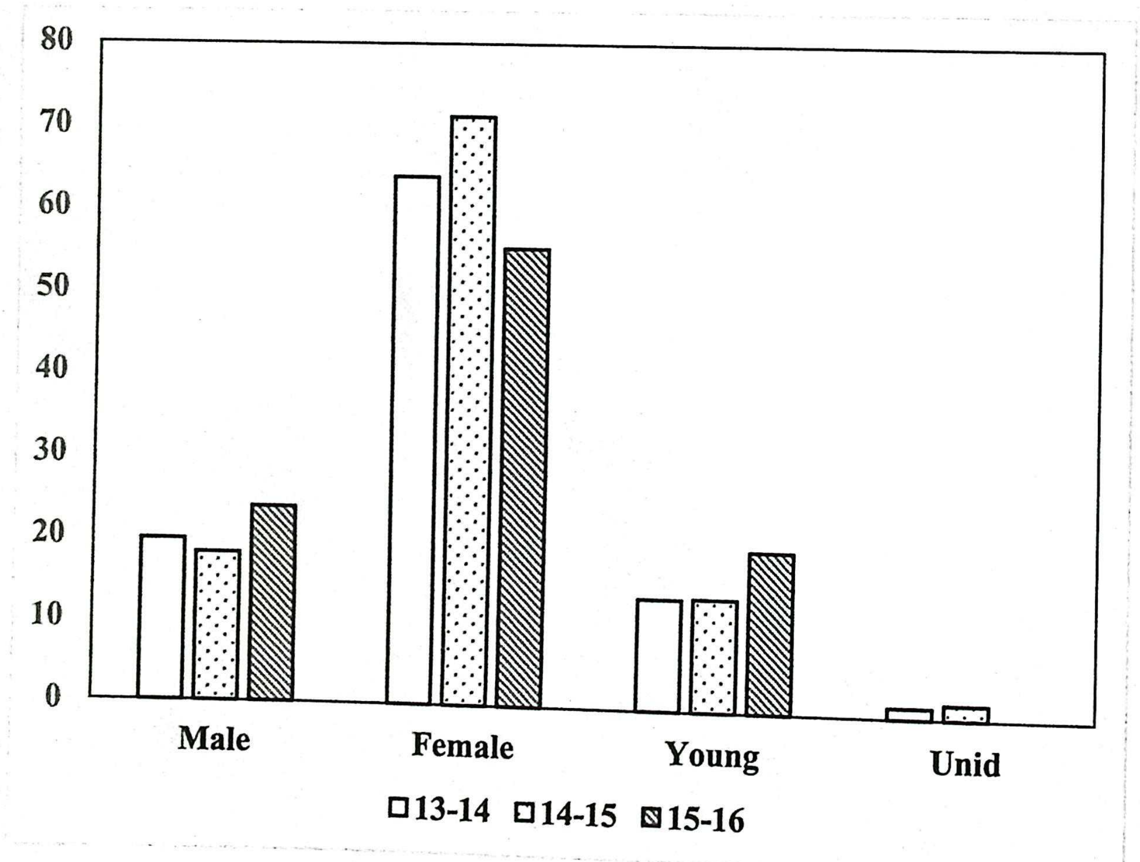


Figure 4.3: Composition (proportional) of adult males, adult females and young (up to yearling) for Chital across three years

Additionally, we also estimated prey and livestock population density of entire Sariska Tiger Reserve (1200 sq. km) during 2017 – 18 using the above-mentioned methods. However, the result of the same is presented separately as spatial coverage used to study response of wild ungulates and change in livestock population following resettlement of 565 families (800 sq. km) was different from the current study (2017 – 18, 1200 sq. km.).

Table 4.1. Details of density estimates of principal prey species & Livestock during 2017 - 18

Prey Species	Density of individuals	Standard Error
Sambar	9.07	3.81
Chital	17.1	9.09
Wild Pig	8.72	4.24
Nilgai	9.93	3.42
Livestock	69.41	25.07

4.4 Discussion

Our study presents evidence of the effectiveness of village relocation regarding prey population recovery following village relocation. Harihar (2009) documented tiger and prey population recovery in northern Indian protected area of Rajaji Tiger Reserve following Gujjar relocation. Madhusudan (2004) recorded recovery of ruminant grazers such as gaur and chital following 49% decline in livestock population. We observed approximately 25% increase in chital and sambar density following 44% decrease in livestock population, while nilgai and wild pig density decreased over three years. Proportion of fawns in the both the population increased also. Out of the various plant species collected by local people for fuel wood, *Anogeissus pendula* was most preferred (95%) followed by *Acasia leucophloea* and *Zizyphus mauritiana* forming the remaining smaller percentage. In addition, *Phoenix sylvestris* and *Butea monosperma* trees were heavily lopped and grass species such as *Apluda mutica, Heteropogon contortus* and *Chloris dolichostachya* are extracted for stall feeding of livestock. All these above mentioned vegetation forms food sources for wild ungulates (Sankar 1994). Resource extraction coupled with livestock grazing creates heavy competition for wild ungulates. Present livestock density (66.84±11.15 (SE)/ km^2) is much lower than the livestock density estimate (221.33/ km^2) assessed before tiger reintroduction in 2007 in STR, which is attributed to the fact that 565 families have been resettled outside STR. This remarkable decrease in livestock density reduced pressures for ruminant grazers like chital. Hence, the population is recovering. Sambar density increase is probably because of the reduction in resource extraction such as *Anogeissus, Apluda etc* coupled with reduced livestock grazing. Nilgai and wild pig prefer degraded habitat (Sankar, 1994). Reduction in their number is likely the indication of habitat quality improvement.

CHAPTER 5
PREY SELECTION AND FOOD HABITS

5.1 Introduction

Tigers (*Panthera tigris*) are obligate carnivores that occur sympatrically with leopards (*Panthera pardus*) in most of their range. These wide ranging congeneric mammalian carnivores differing in size (tiger: 120-270 kg, leopard: 30-90 kg) largely prey on ungulates such as Cervids, Bovids and Suids (Schaller, 1967; Seidensticker, 1976; Johnsingh, 1983; Karanth and Sunquist, 1995, 2000; Bagchi et. al., 2003; Andheria et. al., 2007). Previous studies on the food habits of sympatric leopards and tigers have shown that their diets are very similar when prey is abundant (Schaller, 1967; Johnsingh, 1983; Karanth and Sunquist, 1995; Bagchi et. al., 2003; Andheria et al., 2007). However, under deteriorating habitat conditions leopards may not be as adversely affected as tigers due to their ability to shift towards smaller prey (Ramakrishnan et al., 1999). Therefore, studies assessing the food habits of sympatric carnivores not only aid in our understanding of factors influencing their ecological segregation but may also serve as an indicator of change in habitat quality (Ramakrishnan et al., 1999).

5.2 Methodology

Diet and food preference of tiger were estimated from the scat analysis as well as from the kills (Reynolds and Aebischer, 1991; Mukherjee et al., 1994; Biswas and Sankar; 2002, Sankar and Johnsingh 2002; Bagchi et al., 2003). Scats were collected from all the locations used by the tiger throughout the year. All the collected scats were sun dried and preserved for future analysis. The micro-histological structure of the hairs used to identify the prey species. A total of 78 scats were collected from Sariska Tiger Reserve during 2017-18.

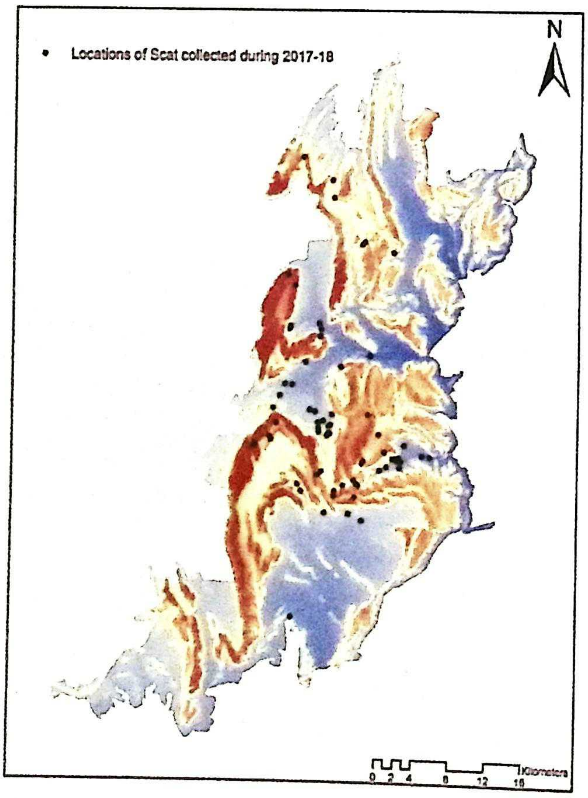


Figure 5.1: Map showing the locations of scat collected during April 2017- March 2018 in Sariska Tiger Reserve

5.3 Result

A total of eight species were identified in the collected tiger scats namely, Sambar, Chital, Nilgai, Wildpig, Buffalo, Cattle, Goat and Hare. Of these Sambar contributed the maximum in tiger's diet (33.63%) followed by Chital (30%), Cattle (17.27), Nilgai (7.27%), Buffalo (6.36%), Hare (2.72%), Goat (1.81%) and Wildpig (0.90%). Sambar as the main prey species for tiger in the study area has been re-established, as had been the trend throughout the study period 2008-13 (Sankar et al., 2013). The percentage of occurrence of prey species found in the scats of tigers during April 2017-March 2018 is shown in Fig 5.2.

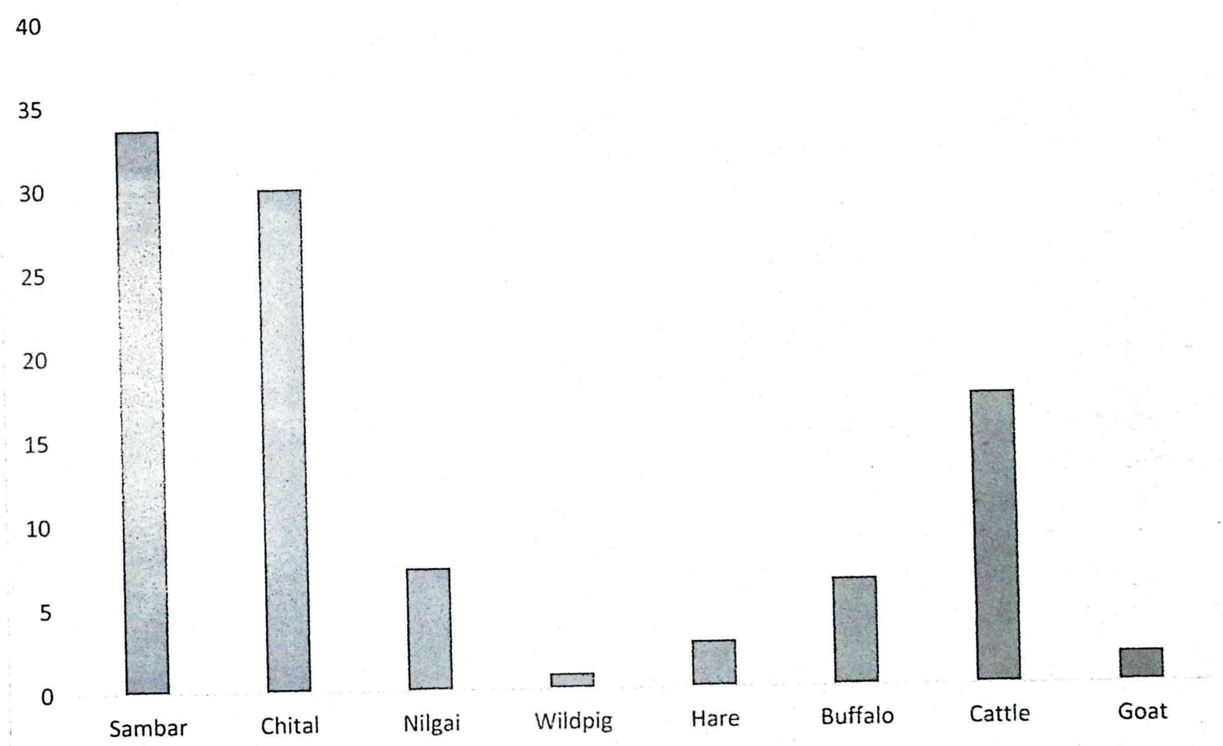


Figure 5.2: Percentage occurrence of prey species found in the scats of tigers during April 2017 to March 2018

5.4 Discussion

Sambar was observed to be the principle prey species for tigers followed by chital and cattle as inferred from the percentage occurrence of prey remains in tiger scats. Sambar's preference by tiger could be attributed to the larger body weight and wide distribution of sambar across the study area. Similar results were obtained by other studies in the country (Karanth and Sunquist 1995; Biswas and Sankar, 2002).

CHAPTER 6
POPULATION STATUS OF CO-PREDATORS

6.1 Introduction

Estimates of abundance of carnivores are necessary for conservation and management implications. However, abundance estimation of carnivores is difficult due to their elusive nature and nocturnal behaviour, large albeit patchy distribution. It is also important to understand the co-existence of different sympatric carnivores in a forested area for our better knowledge and management practices. Generally, coexistence in carnivores appears to be facilitated by differences in body size (Kiltie, 1984; Rosenzweig, 1966). Since predator body size is usually correlated with the size of prey utilized (Hespenheide, 1973; MacDonald, 1980; McNab, 1971; Rosenzweig, 1966), body size differences often result in the segregation of predators along a continuous prey size resource axis. As tertiary consumer, predator plays an important role in regulating prey species such as herbivores and omnivores (Carbone et al., 1999). Such predator-prey dynamics maintain the health and balance of ecosystems.

While, considerable conservation attention and investment is primarily focused towards the conservation of tiger population (Dinerstein et al., 2007) in Indian sub-continent, our understanding about the conservation status and ecology on the entire carnivore community remains poor. Leopard (*Panthera pardus*) and striped hyena (*Hyaena hyaena*) are largely coexisting with tiger in most of its distribution range in Indian sub-continent. Leopard population has also declined due to continual loss of habitat, poaching for illegal trade in body parts (Environmental Investigation Agency (EIA) and Wildlife Protection Society of India (WPSI), 2006) and human-leopard conflict. Data on Leopard abundance and ecology from India are also limited. Leopard populations have become heavily fragmented and isolated (Uphyrkina et al., 2001) and loss of habitat is the most serious long-term threat to leopard and their prey. Increasing human population, changing land use practices, soaring demands from our urban population and more recently fast expanding economic activity have started straining the delicate balance at which tiger and leopard survive (Wickramanayake et al., 1998). Mills and Hofer (1998) estimated the population of striped hyena to be over 1000 within India which was a gross under estimate and suggested that striped hyena population is declining as a result of global population decline of other sympatric carnivores due to decrease in natural sources of carnivores. Here, we estimate the population status of leopard and striped hyena and compared our results with long term population monitoring data to understand the trend of population of these two co-predators.

6.2 Methods

6.2.1 Field data collection methods

We used a grid-based sampling approach to photograph leopard and striped hyenas within the study area and used Spatially explicit capture-recapture models (SECR, Efford 2004; Borchers and Efford, 2008). Sampling units consisting of grids of the square cell (2 km^2) was superimposed on the map of intensive study area of Sariska National Park. We deployed a pair of camera traps in each grid during December 2017 – January 2018. A total of 130 locations were selected for the placement of camera traps covering an area of 414.35 km^2 in the study area. One day was considered as a single occasion, resulting in 32 occasions and effort of 4160 trap nights.

6.2.2 Analysis

We identified all photographs of leopards and striped hyena obtained from camera traps using pelage markings on hind limbs, forelimbs and stripes on flanks (Singh, 2010; Gupta et al., 2010; Harihar, 2010). Following the identification, unique identification numbers were given to individual striped hyenas. We created two matrices that summaries spatio-temporal detection history of individuals and spatio-temporal layout of traps for SECR (Efford, 2015).

6.2.3 Abundance of leopard and striped hyena

Spatially explicit capture-recapture models (Efford, 2004; Borchers and Efford, 2008) estimate density directly from the spatial capture histories thereby avoiding the use of ad hoc estimation of ETA done in traditional capture-recapture studies. SECR uses spatial histories of individual animals to construct centre of activity from where its detection declines as we move away. This process is modelled by two parameters (1) g0, the detection probability at the activity centre and (2) sigma, the spatial movement parameter.

6.3 *Results*

In total, 65 and 309 photographs of 39 and 74 individual leopard and striped hyenas were obtained. The estimated population size of leopard and striped hyena in the study area were 64.55 (50.12 - 97.70, 95% CI) and 213.17 (145.59 - 344.56, 95% CI) respectively. Density estimates of leopard and striped hyena were 13.02±2.74 individuals/ 100 km^2 and 11.67±1.38 individuals/ 100 km^2 in the study area (Table 6.1.).

Table 6.1: Population density (D) estimates of leopard and striped hyena (/ 100 km^2), spatial movement parameter (σ), and detection probability at the activity centre (g0)

Species	g0 (SE)	Sigma (σ) in meters (SE)	Density [striped hyenas / 100 km^2 (95% CI)]
Leopard	0.003 (0.0009)	2219.44 (275.01)	13.02 (8.65 - 19.59)
Striped Hyena	0.013 (0.001)	2812.9 (117.05)	11.67 (9.27 - 14.69)

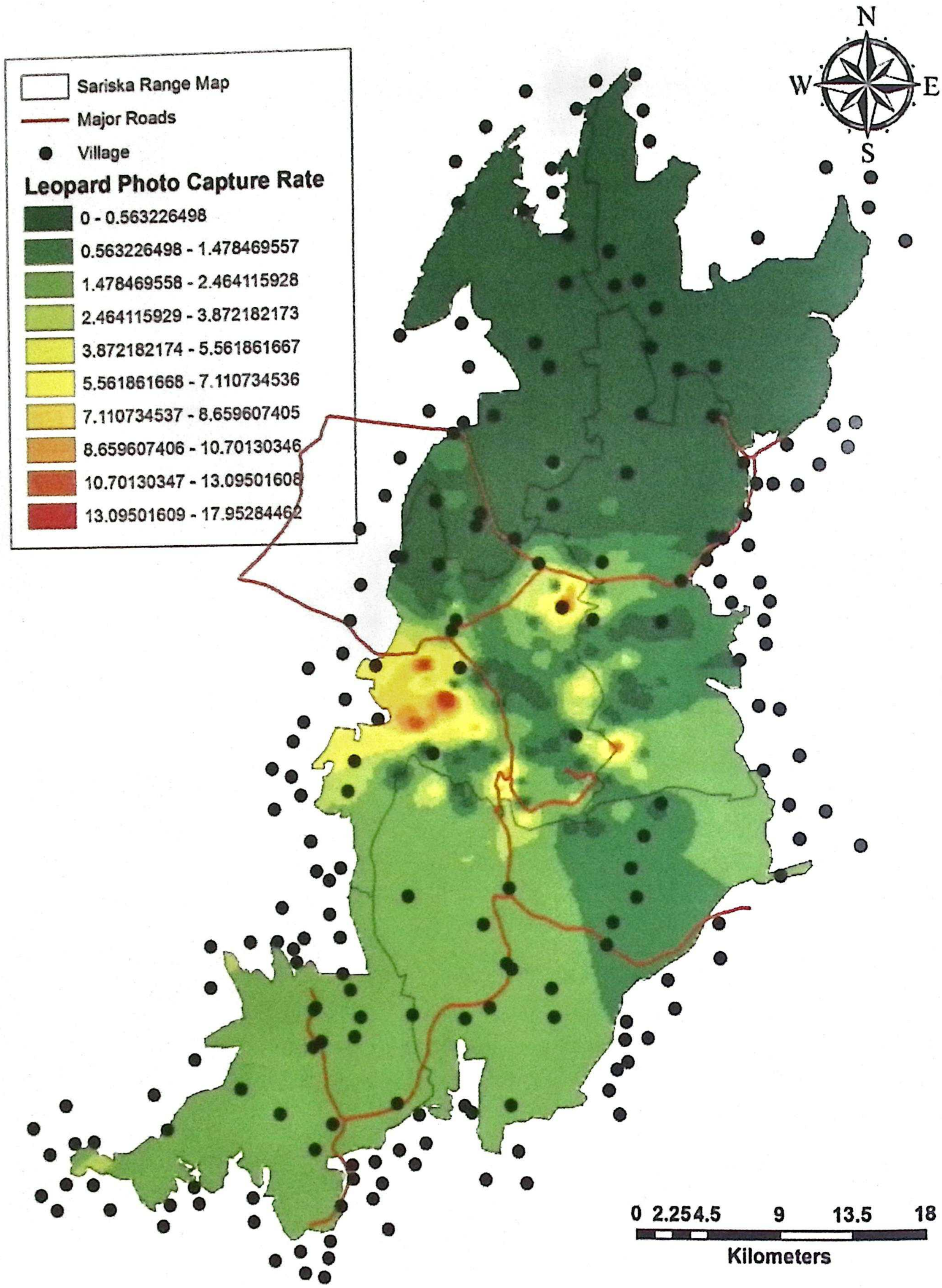


Figure 6.1: Spatial distribution of leopard in Sariska Tiger Reserve

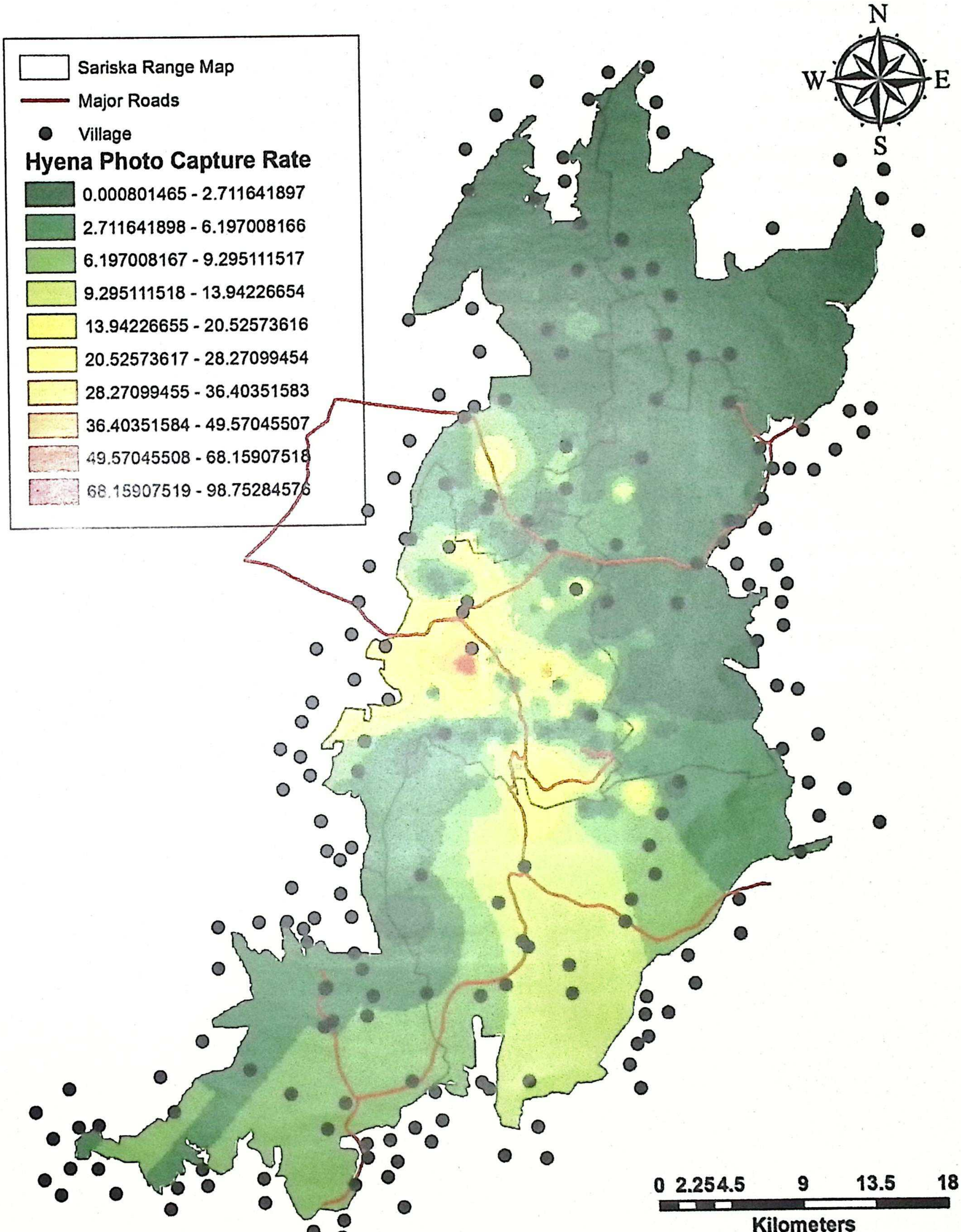


Figure 6.2: Spatial distribution of striped hyena in Sariska Tiger Reserve

6.4 Discussion

Our findings suggest density estimates of leopard and striped hyena were comparatively higher in the study area. Density estimates of both leopard and striped hyena are available only from Rajaji National Park in the Himalayan foothills (Harihar et al., 2009, 2010) and Achanakmar Tiger Reserve (Mandal et al., 2017). Both the above-mentioned areas have low tiger population density (Jhala et al., 2011, 2015). Striped hyena density estimate in the present study is comparatively higher to the estimates obtained from RNP, Kumbhalgrah WLS and Esrana Forest Range. STR probably sustains the reported highest density estimate of striped hyenas in the world (Kruuk, 1976; Wagner, 2006; Singh, 2010).

Table 6.2: Estimated leopard and striped hyena densities in different protected areas of India

Study Site	Leopard Density/ 100 Km^2	Reference	Striped hyena density/ 100 Km^2	Reference
Rajaji National Park	14.9	Harihar et al. 2009	3.91	Harihar 2009
Achanakmar Tiger Reserve	11.34		4.54	Mandal et al. 2017
Satpura National Park	7-10	Edgaonkar 2007	-	-
Mudumalai Tiger Reserve	14.9	Kale et al. 2011	-	-
Kumbhalgarh WLS	-	-	6.5	Singh 2010
Esrana Forest Range	-	-	3.67	Singh 2010
Pench Tiger Reserve	10.6±3.2	Majumder 2011		

Long-term research on leopard demography in Sariska suggests that leopards changed their spatio-temporal behaviour and occupied peripheral habitat to avoid the tigers following the tiger reintroduction in Sariska in 2008 (Mondal et al., 2010). Consequently, leopard density decreased in the best available habitat (Mondal et al., 2012). Although leopard population initially declined, and their diet shifted towards smaller prey, however, the population bounced back during 2012 – 13 probably due to compensatory immigration from peripheral areas (Chatterjee et al., 2016).

Table 6.3: Population density (D) estimates of leopard (/100 km^2) [Source: Leopard Ecology Project final Report]

Year	Density [leopards / 100 km^2 (SE)]
2007	9.3 (2.2)
2008	7.7 (1.9)
2009	5.3 (1.4)
2010	3.3 (1.2)
2011	7.1 (2.0)
2012	16.8 (2.2)
2013	14.16 (2.7)
2014	14.9 (3.6)
2015	16.9 (3.7)

However, the population of striped hyena remained roughly comparable over nine years. Density estimates of striped hyena slightly increased from 12.52±2.17 individuals/ 100 km^2 to 15.44±2.48 individuals/ 100 km^2 over the years (Mandal, 2018).

Table 6.4: Population density (D) estimates of striped hyena (/ 100 km^2) [Source: Mandal, 2018]

Year	Density [striped hyenas / 100 km^2 (SE)]
2007 - 08	12.52 (2.17)
2011 - 12	13.19 (1.67)
2012 - 13	13.90 (1.43)
2013 - 14	14.65 (1.72)
2014 - 15	15.44 (2.48)

SPATIO-TEMPORAL ACTIVITY

7.1 Introduction

Carnivore coexistence is a complex process driven by a plethora of ecological processes such as portioning of diet, space and time (Caro and Stonner, 2003; Chesson and Kuwang, 2008). Carnivore spatio-temporal activity is governed by the activity of their principal/ preferred prey. Species existence is dependent on limiting factors such as food and habitat (Grinnel, 1922). However, niche partitioning such as utilization of food, space and time in a particular however unique and different way than others, other than the limiting resource enables coexistence (MacAurther, 1958). Carnivores with significant diet overlap will try to avoid competition either by partitioning themselves on prey weight class and consequently spatio-temporal activity to exploit those resources in a different manner other than the competitor. Sustenance of specialist carnivores will depend more on the specialized niche. Whereas, subordinate species will broaden their niche to avoid competition with apex predators.

Here, we have used camera trapping to understand the spatio-temporal behavior of the carnivore guild (tiger, leopard and striped hyena), meso-carnivores and their prey with respect to anthropogenic pressure.

7.2 Methods

In total, 130 locations were surveyed using camera traps to understand spatio-temporal activity pattern of large and small carnivores, their prey and human activity. Time evidences obtained from camera traps was then recorded systematically and was analysed using circular statistics (Andersen et al. 2000) in program Oriana and package camtrapR (Niedballa et al., 2016). Peak activity period (95% CI), peak activity time; and overlap among tiger, their prey, other carnivores and human were also analyzed in program ORIANA (Andersen et al., 2000) and package camtrapR (Niedballa et al. 2016). Spatial overlap was calculated using Pianka's Index based on camera trap data.

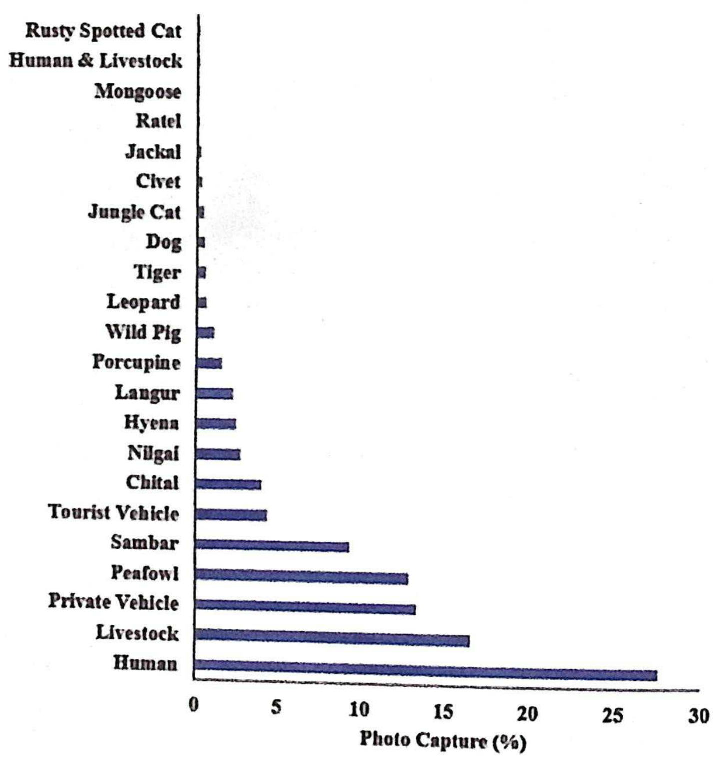


Figure 7.1: Percentage of photographs category wise

7.3 Results

In total, 44,596 photographs were obtained through the camera trapping exercise.

7.3.1 Spatio-temporal activity of carnivores

Tigers exhibited crepuscular activity and were primarily active during twilight hours with a peak at early night (Table 7.1.). Striped hyenas were observed to be completely nocturnal. However, temporal activity of leopard was observed to be bimodal with a peak at early morning [6:18 (03:30 – 09:07)]. Leopard showed a broader span in major activity peak from midnight to early morning.

Table 7.1: Temporal activity of tiger, leopard and striped hyena

Species	Tiger	Leopard	Hyena
Number of Observations	210	254	1058
Activity Peak (95% CI)	23:01 (22:16 - 23:47)	06:18 (03:30 - 09:07)	23:24 (23:07 - 23:41)

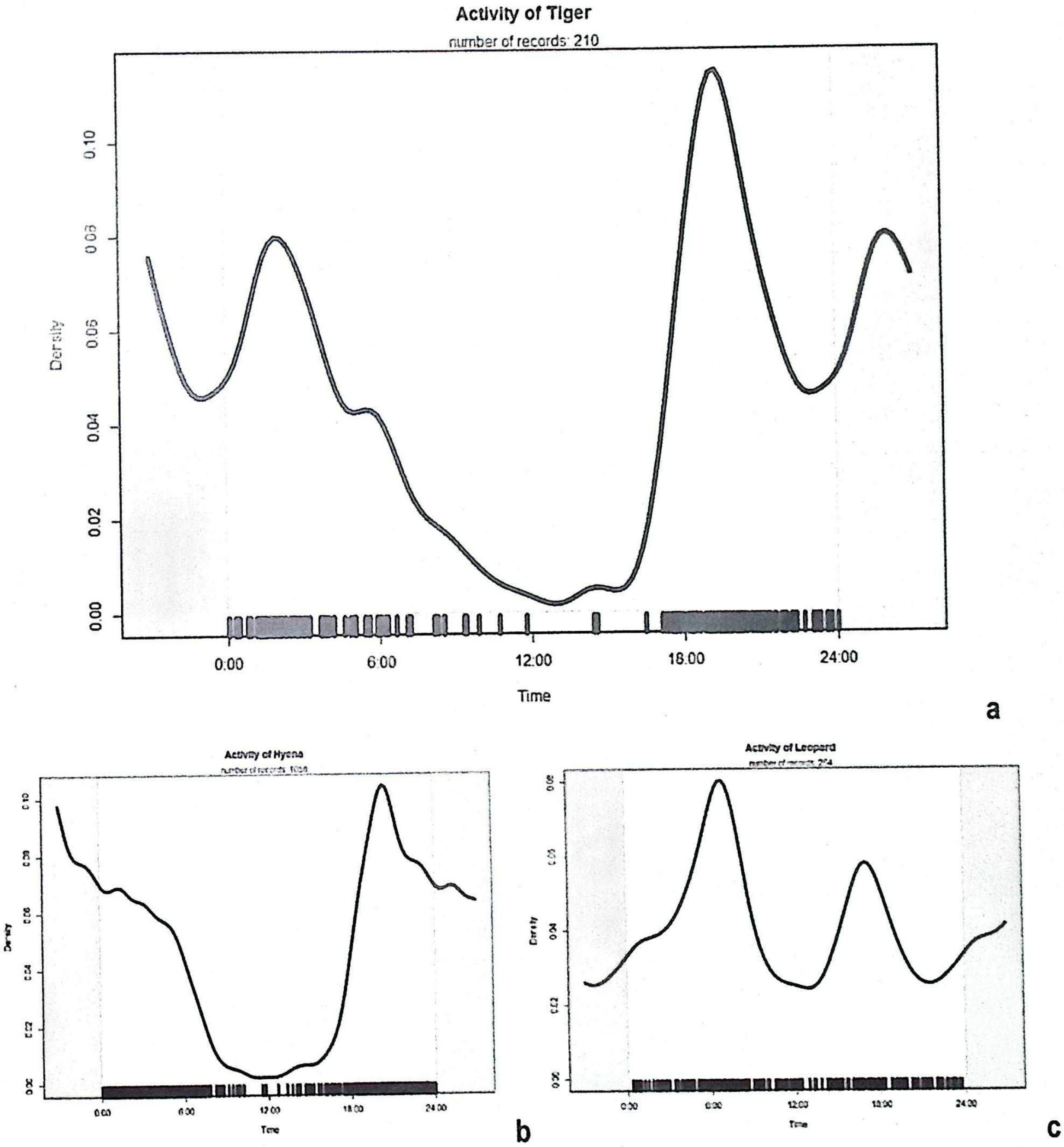


Figure 7.2: Temporal activity pattern of (a) tiger, (b) striped hyena and (c) leopard

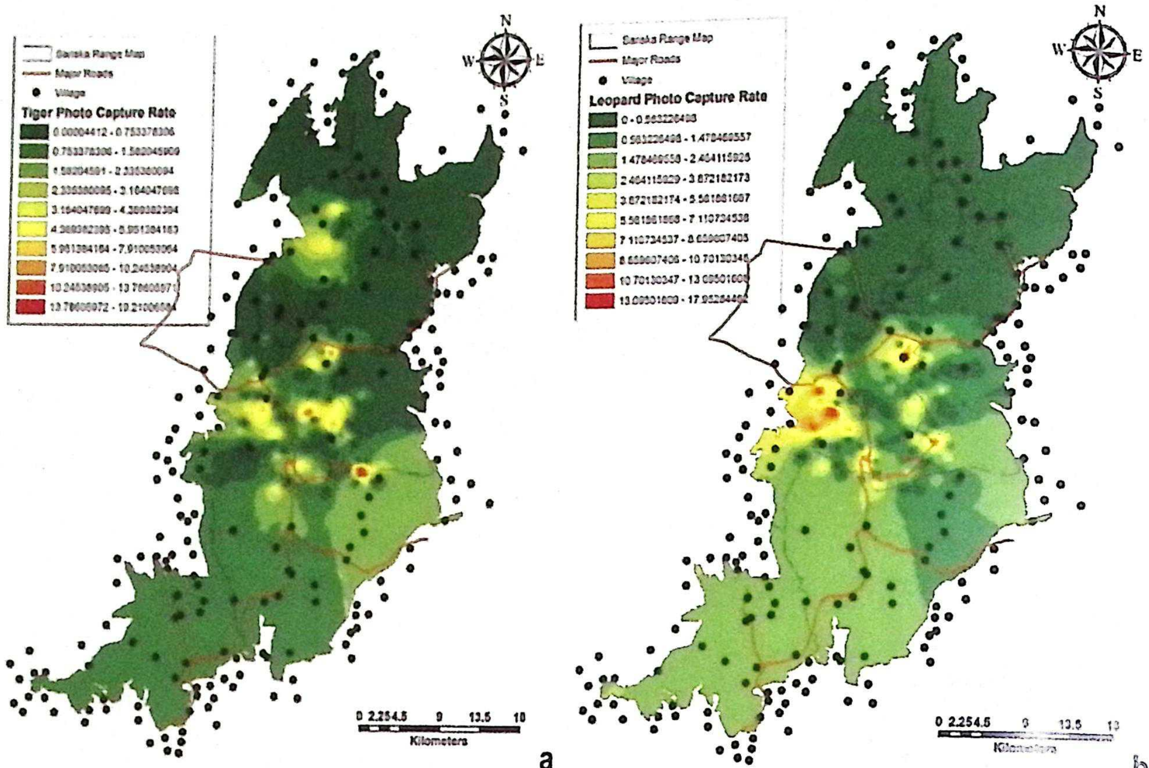


Figure 7.3: Spatial distribution of (a) tiger and (b) leopard in Sariska Tiger Reserve

7.3.2 Spatio-temporal activity of ungulate prey

Chital, nilgai and wild pig's activity were observed to be diurnal and spread out throughout the day, whereas, sambar was overserved to be crepuscular with a peak activity time during 17:58 – 18:32 h (Figure 7.2.).

Table 7.2: Temporal activity of ungulate prey

Species	Number of Observations	Activity Peak (95% CI)
Chital	1754	13:37 (13:24 - 13:50)
Nilgai	1212	12:29 (12:10 - 12:47)
Sambar	4136	18:15 (17:58 - 18:32)
Wild Pig	463	12:18 (11:48 - 12:47)

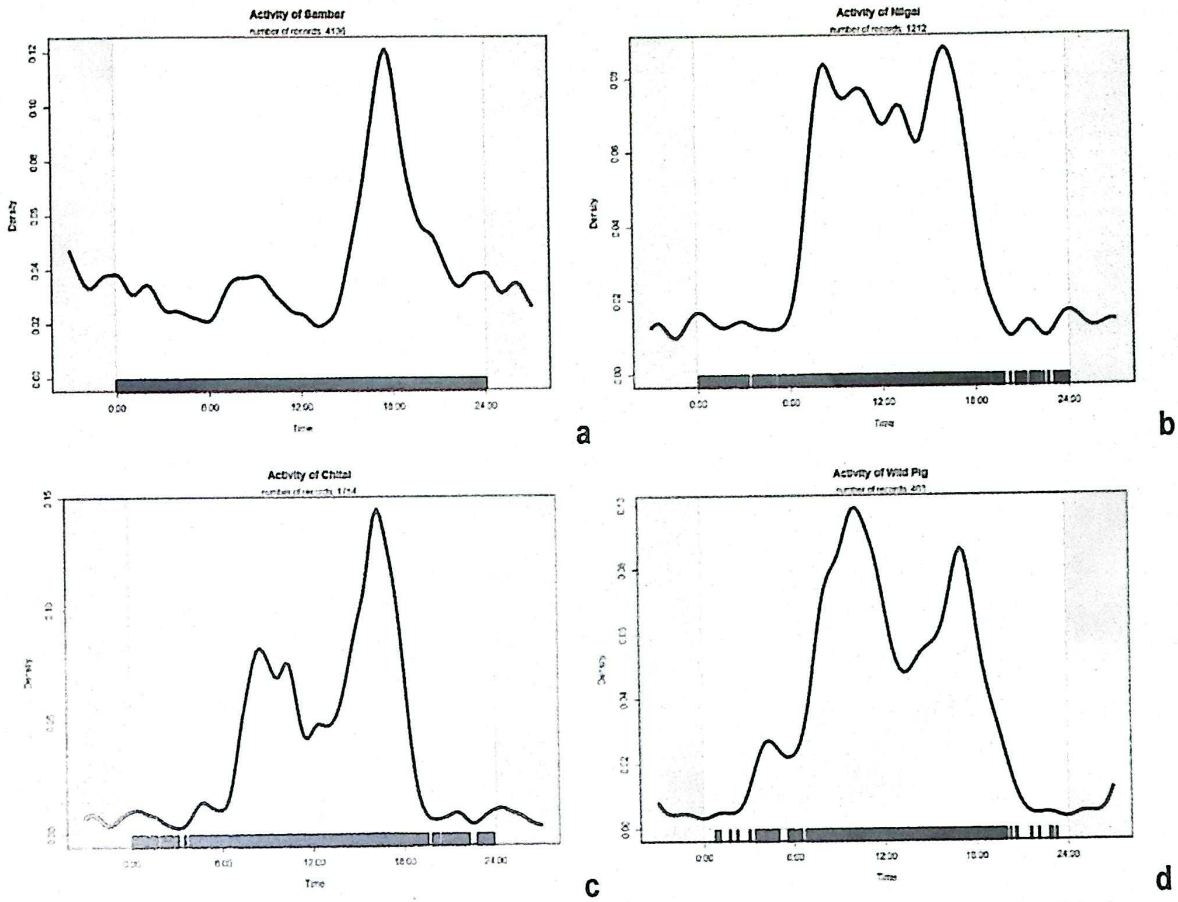
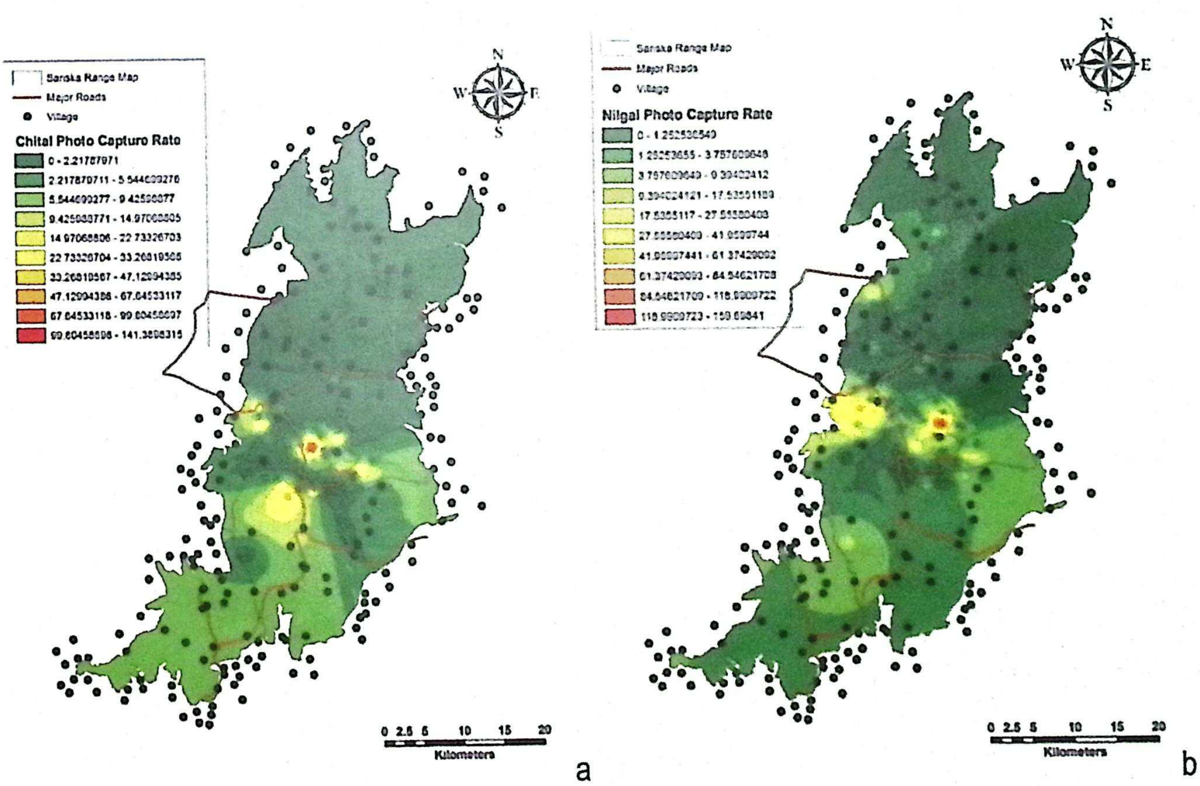
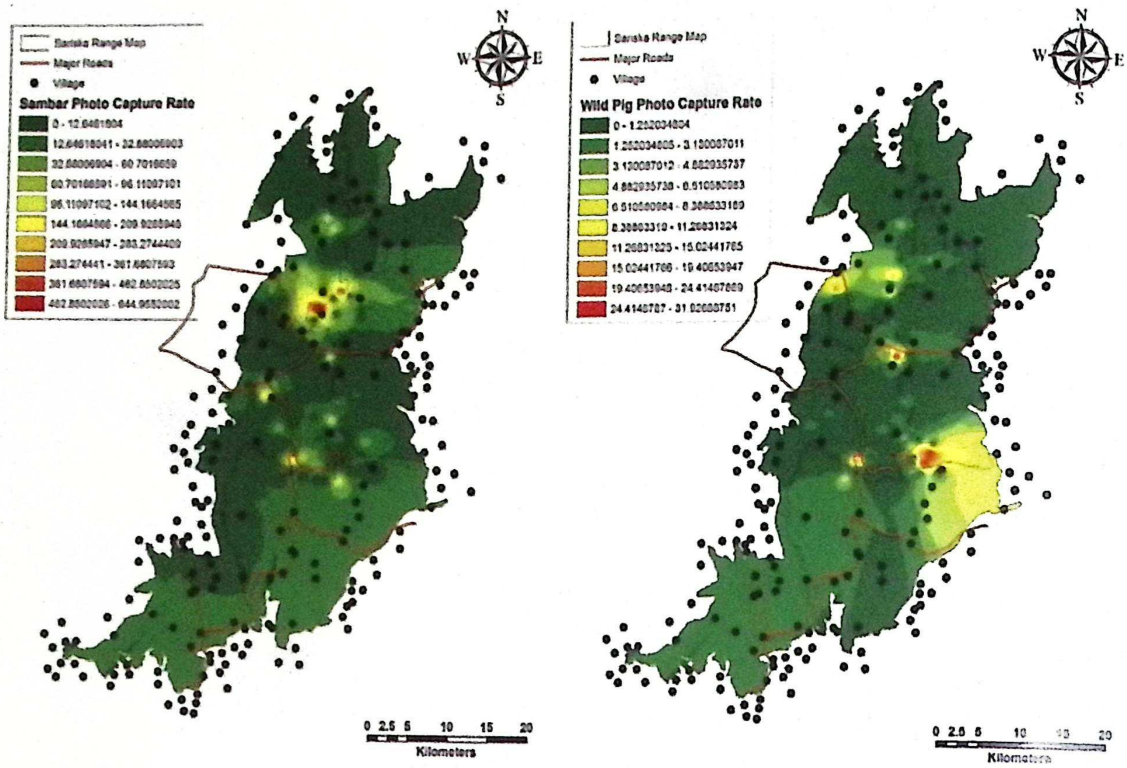


Figure 7.4: Temporal activity pattern of (a) sambar, (b) nilgai, (c) chital and (d) wild pig





c d

Figure 7.5: Spatial distribution of ungulates [(a)Chital, (b)Nilgai, (c)Sambar and (d)Wild Pig] in Sariska Tiger Reserve

7.3.3 Anthropogenic pressure

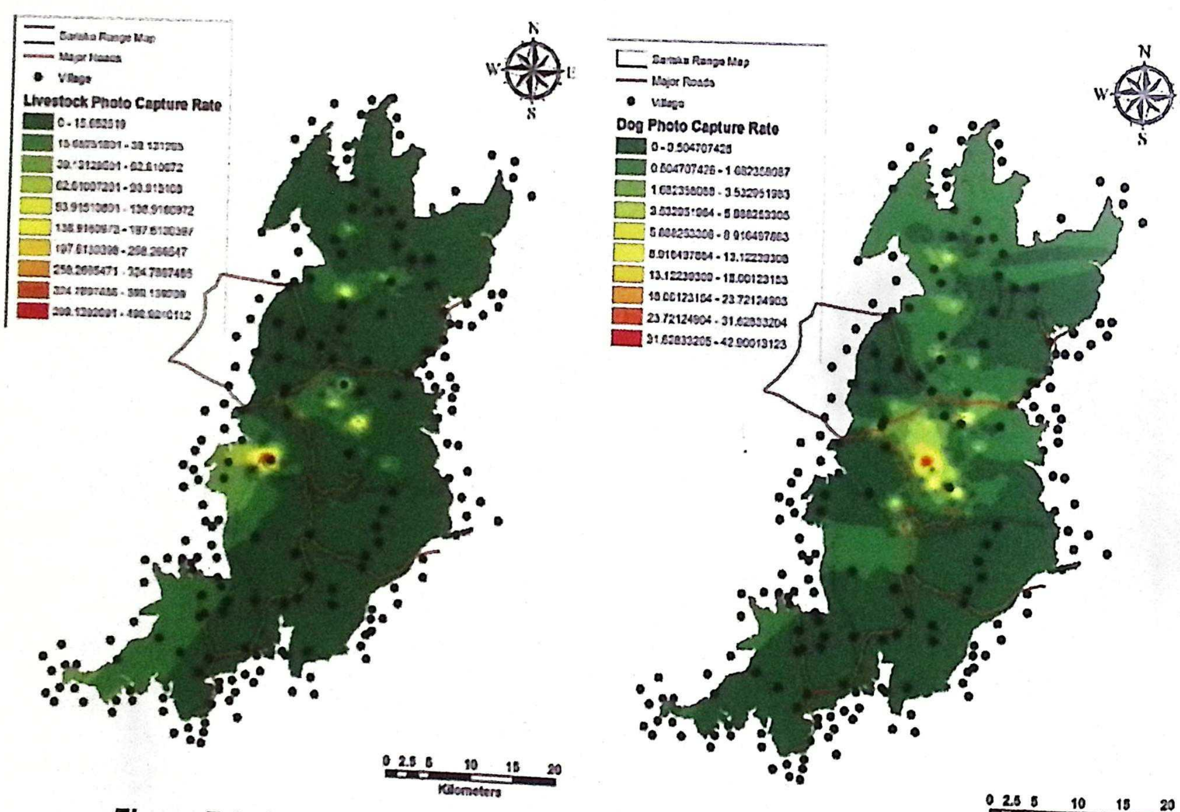


Figure 7.6: Spatial distribution of livestock and dogs in Sariska Tiger Reserve

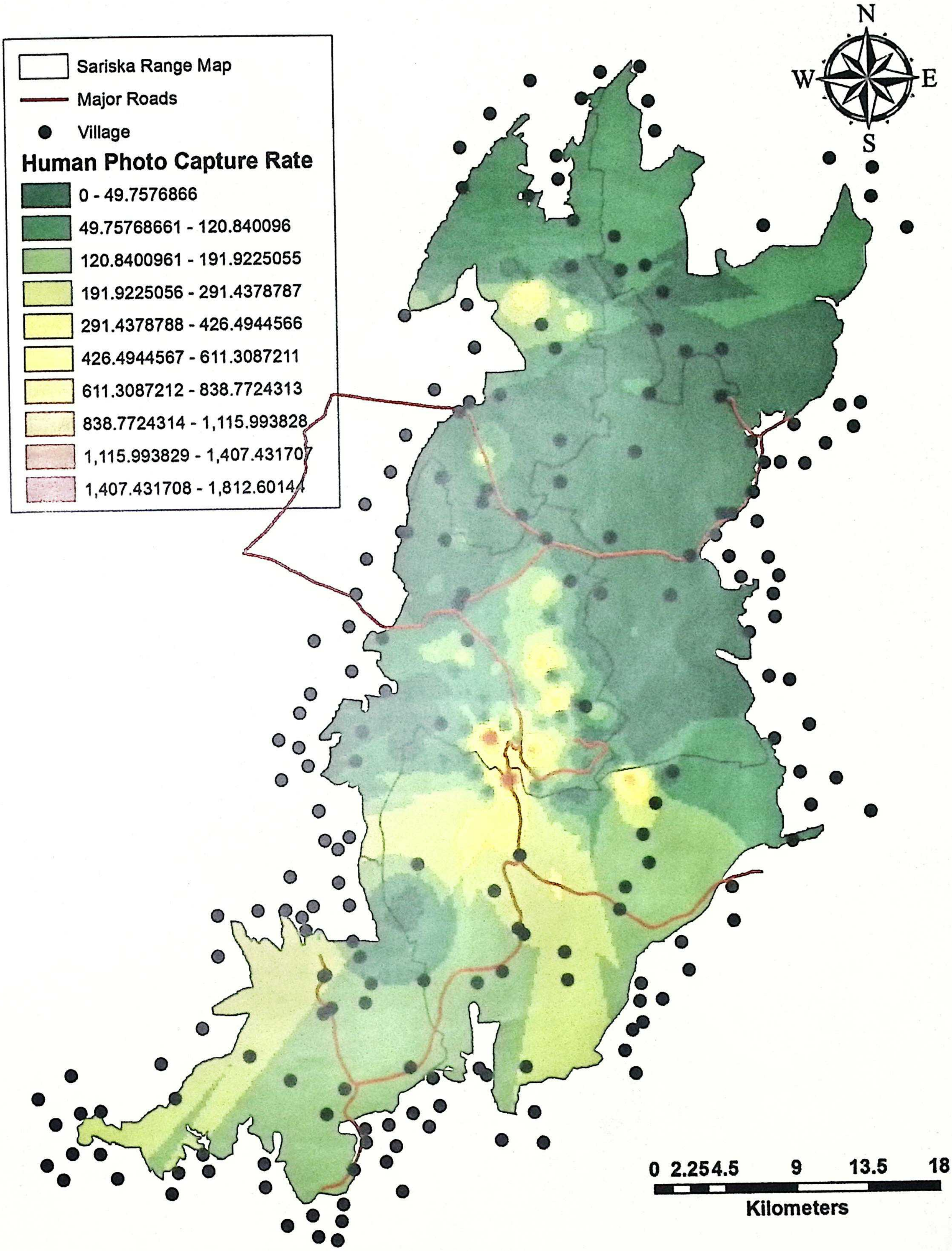


Figure 7.7: Human photo capture rate in Sariska Tiger Reserve

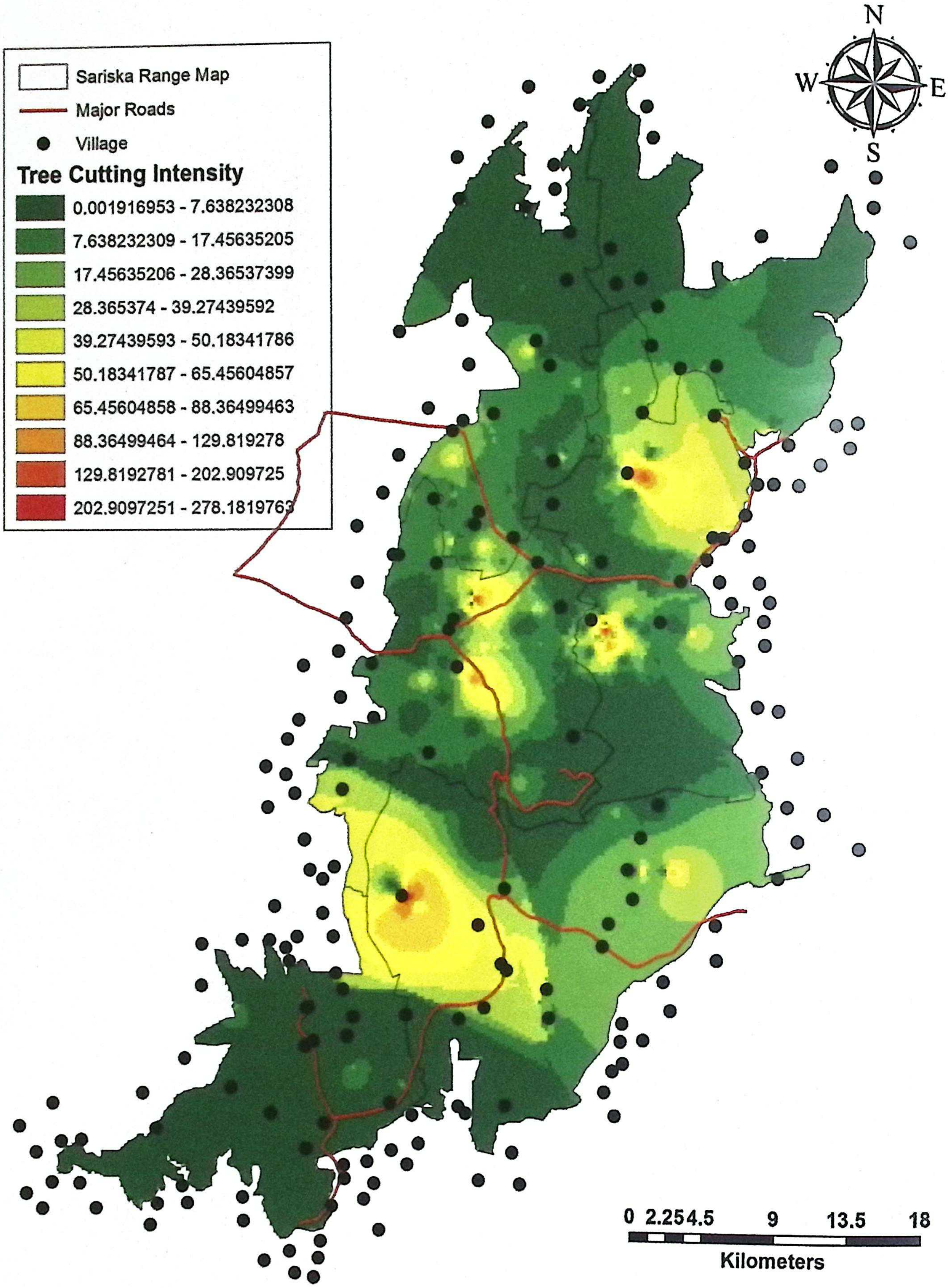


Figure 7.8: Intensity of tree cutting in Sariska Tiger Reserve based on 200 surveyed points

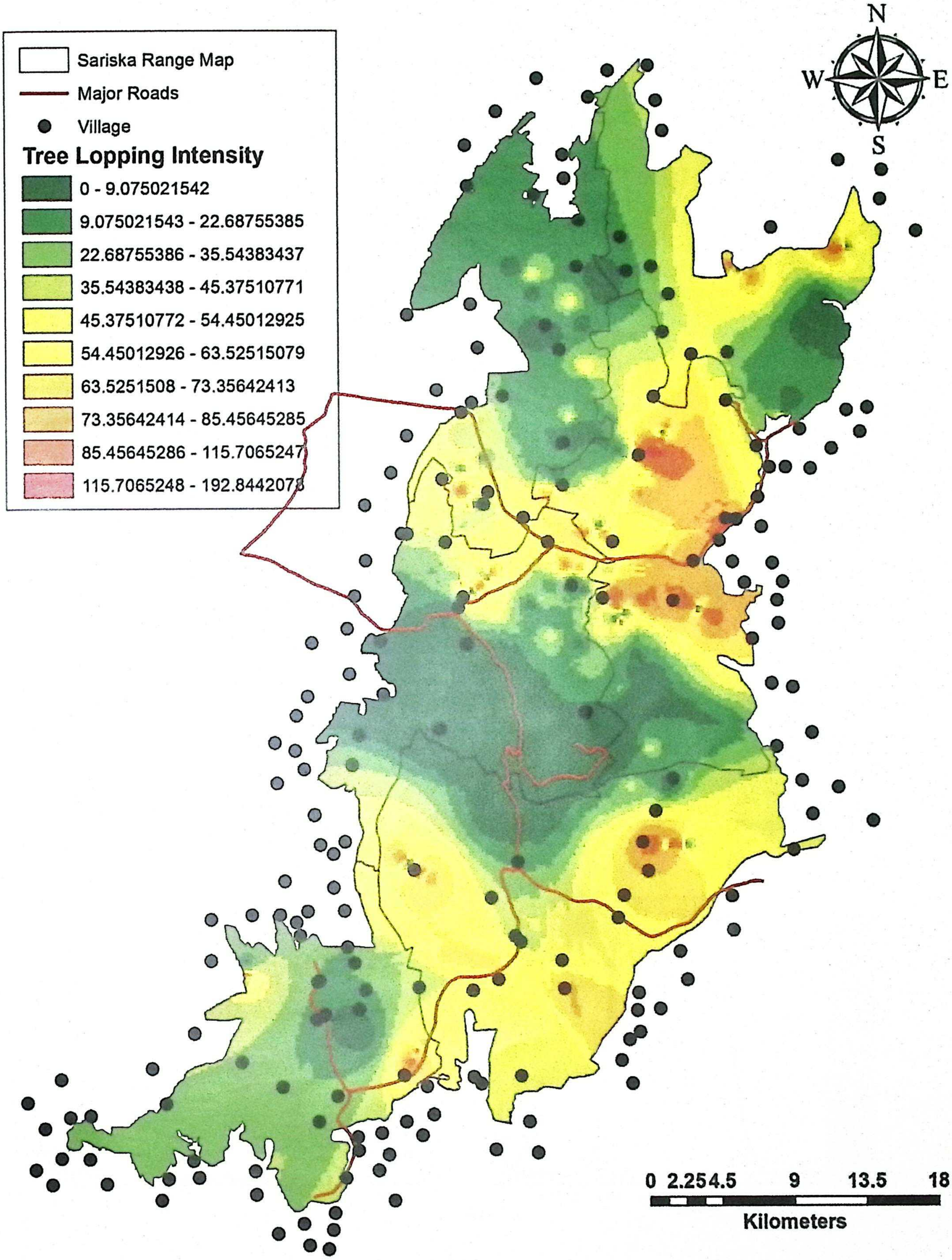


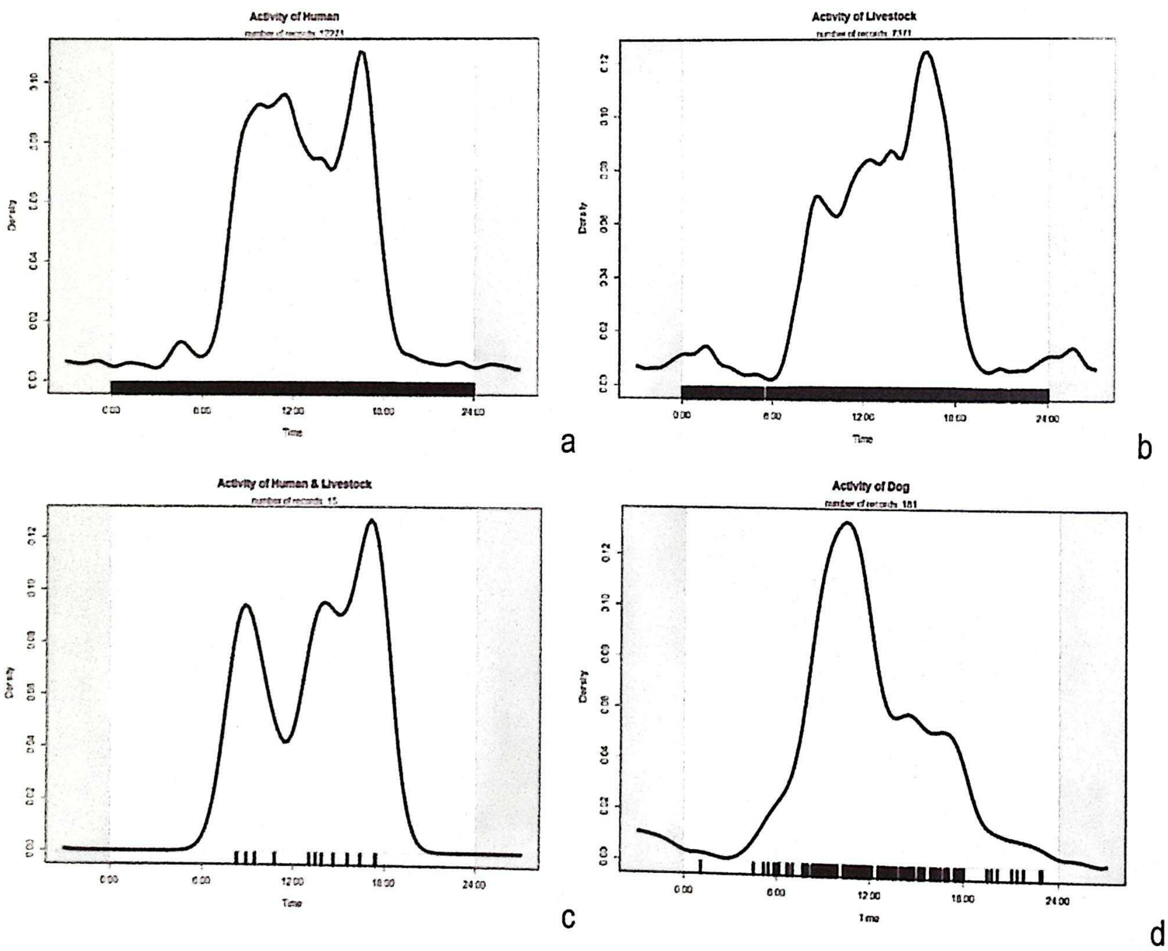
Figure 7.9: Intensity of tree lopping in Sariska Tiger Reserve based on 200 surveyed points

7.3.4 Temporal activity of human, livestock, dog and vehicles

Due to the presence of 29 villages inside the reserve, human activity inside the reserve is high. However, human activity is limited to the day time. Livestock grazing is spread throughout the day with a peak during 13:36 – 13:47 h.

Table 7.3: Temporal Activity of anthropogenic pressure

Species	Number of Observations	Activity Peak (95% CI)
Dog	181	11:41 (11:08 - 12:15)
Human	12271	12:45 (12:41 - 12:49)
Human & Livestock	15	13:42 (11:48 - 15:36)
Livestock	7371	13:41 (13:36 - 13:47)
Tourist Vehicle	1926	13:43 (13:31 - 13:56)
Vehicle	5927	13:38 (13:33 - 13:43)



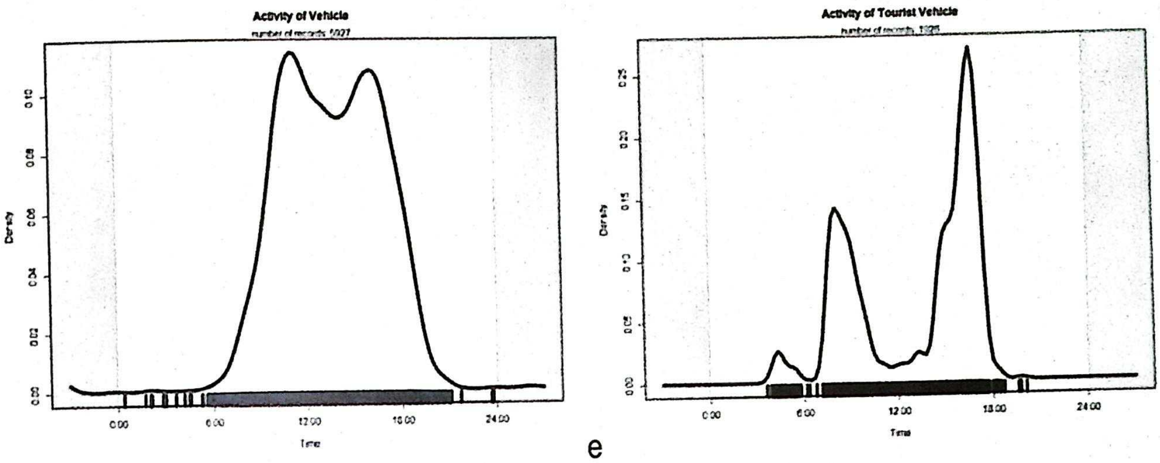


Figure 7.10: Temporal activity of anthropogenic pressure

7.3.5 Spatio-temporal activity of small carnivores

Table 7.4: Temporal Activity of small carnivores

Species	Number of Observations	Activity Peak (95% CI)
Civet	114	23:37 (22:49 - 00:26)
Jackal	75	01:21 (00:10 - 02:33)
Jungle Cat	157	23:35 (22:42 - 00:28)
Mongoose	22	12:33 (11:18 - 13:47)
Ratel	41	00:00 (22:56 - 01:03)
Rusty Spotted Cat	6	23:49 (21:34 - 02:05)

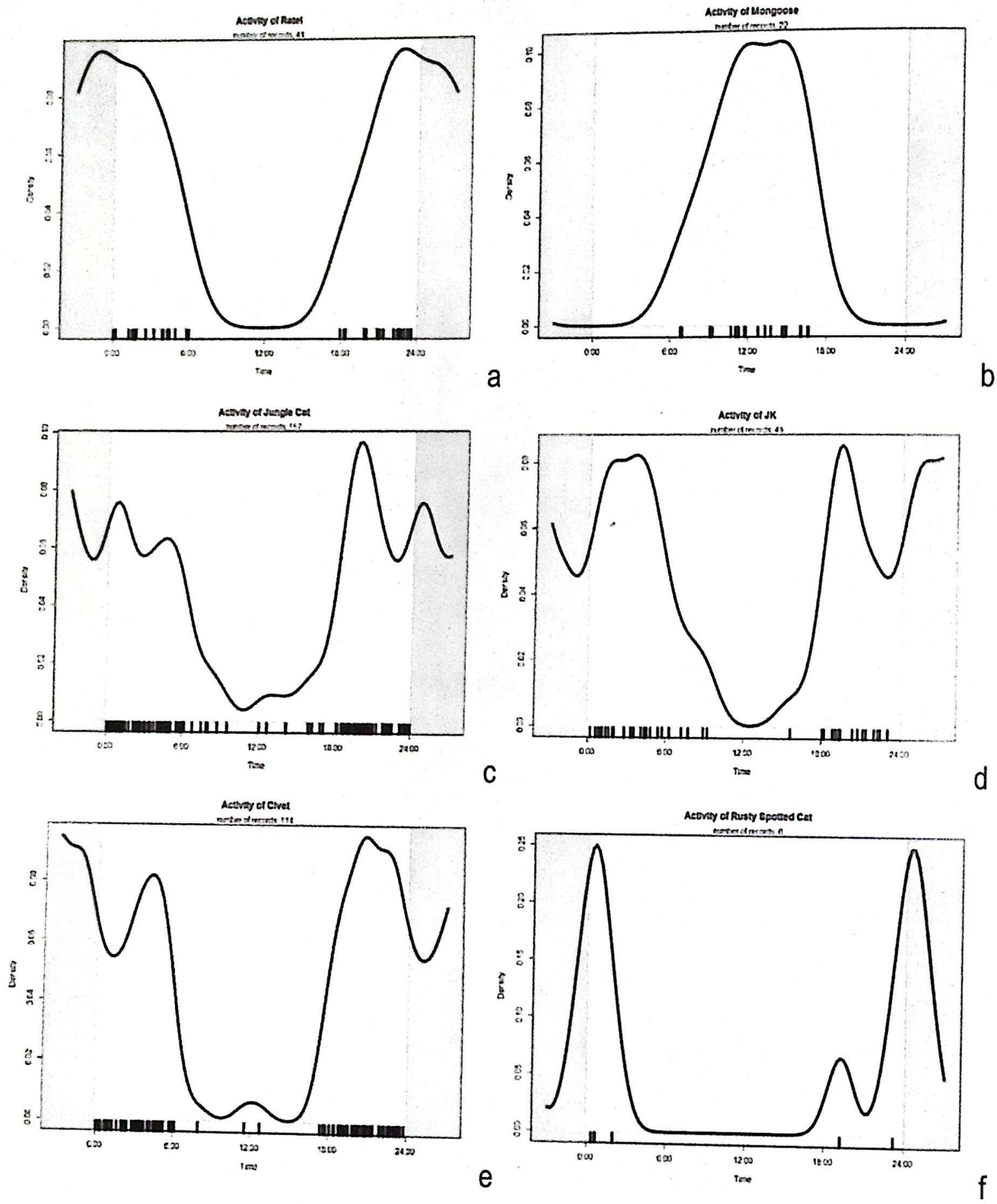
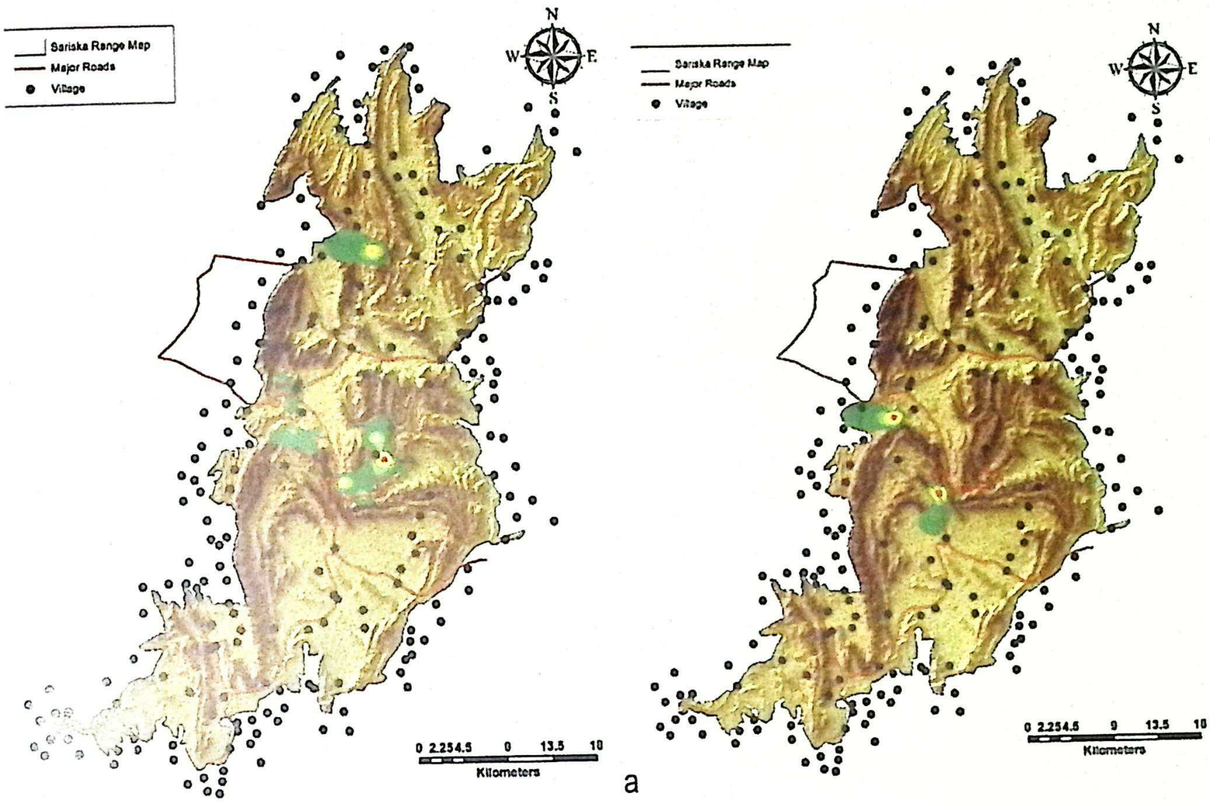


Figure 7.11: Temporal activity of (a) ratel, (b) mongoose, (c) jungle cat, (d) jackal, (e) civet, and (f) rusty spotted cat



a

b

Figure 7.11: Spatial distribution of (a) jungle cat and, (b) rusty spotted cat

7.3.6 Temporal overlap of tiger with prey

Tiger's temporal activity overlapped highest with their principal prey, Sambar followed by chital. Temporal activity overlaps with nilgai and wild pig was minimal.

Table 7.5: Temporal Overlap between tiger and ungulate prey

	Chital	Nilgai	Sambar	Tiger	Wild Pig
Chital	-	< 0.001	< 0.001	< 0.001	< 0.001
Nilgai	1.207	-	< 0.001	< 0.001	< 0.05
Sambar	21.118	15.9	-	< 0.001	< 0.001
Tiger	10.487	8.413	2.776	-	< 0.001
Wild Pig	1.042	0.214	6.483	7.213	-

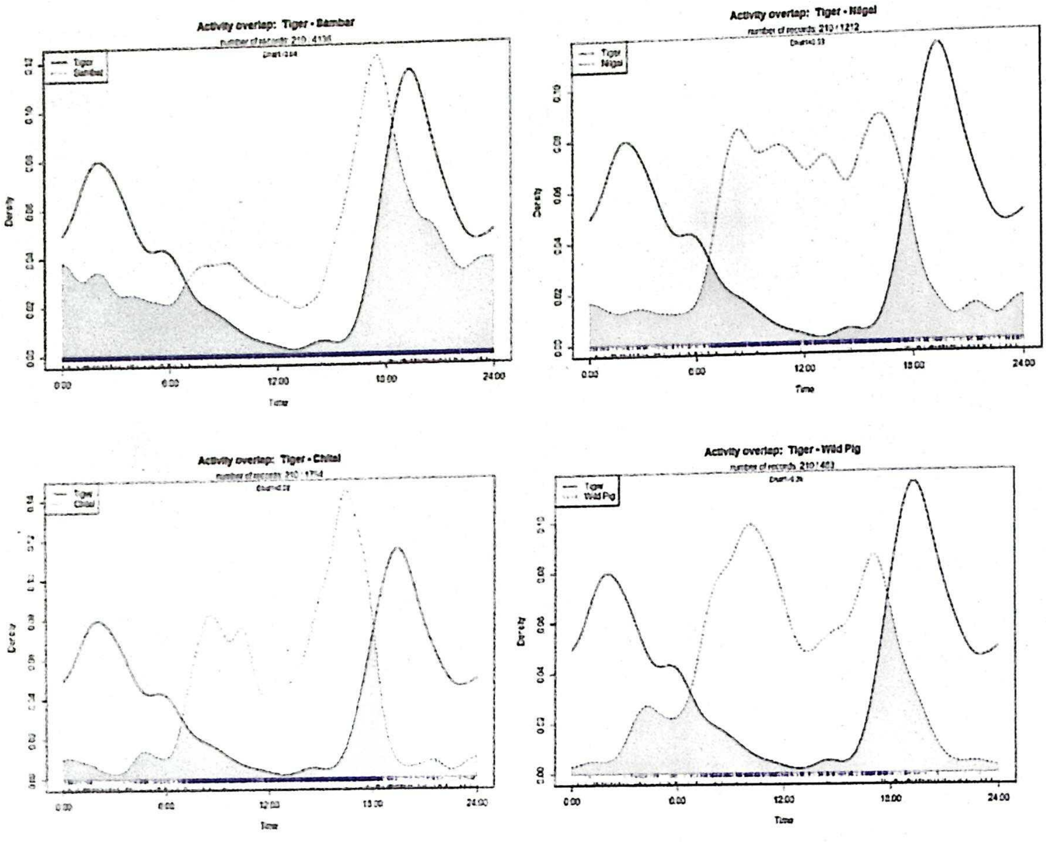


Figure 7.12: Temporal overlap between tiger and its prey

7.3.7 Temporal overlap of tiger with co-predators

Tiger had significant overlap in temporal activity with striped hyena (87%). However, tiger's temporal activity overlap with leopard (61%) was comparatively lower.

Table 7.6: Temporal overlap between tiger, leopard and striped hyena

	Hyena	Leopard	Tiger
Hyena	-	< 0.001	< 0.01
Leopard	4.349	-	< 0.001
Tiger	0.301	2.037	-

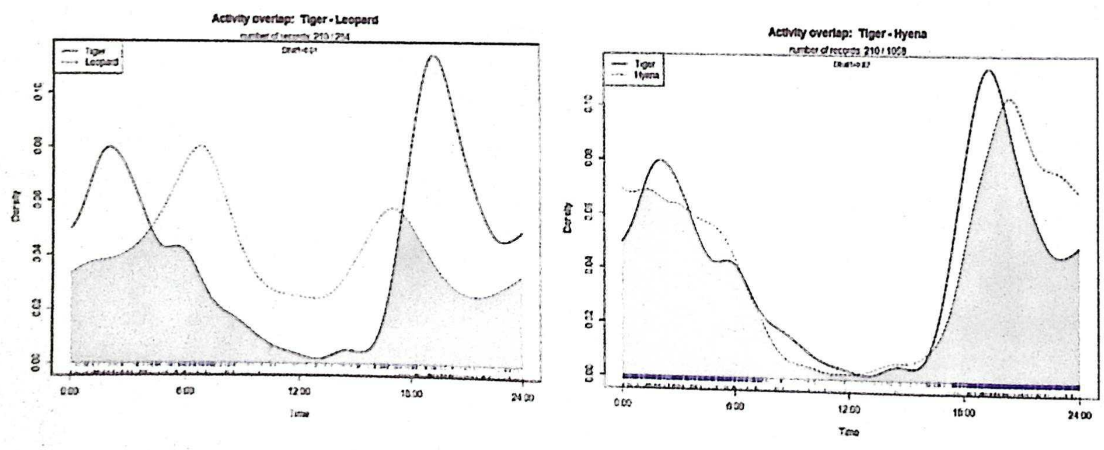


Figure 7.13: Temporal overlap between tiger, leopard and striped hyena

7.3.8 Temporal overlap of tiger with human, livestock and dog

Carnivores, in general were observed to avoid anthropogenic pressure on temporal scale. This has probably permitted them to survive in the human dominated landscape in high density by segregating themselves on temporal scale.

Table 7.7: Temporal overlap between tiger and anthropogenic pressure

	Dog	Human	Human & Livestock	Livestock	Tiger	Tourist Vehicle	Vehicle
Dog	-	< 0.001	0.2 > p > 0.1	< 0.001	< 0.001	< 0.001	< 0.001
Human	0.509	-	> 0.5	< 0.001	< 0.001	< 0.001	< 0.001
Human & Livestock	0.148	0.063	-	> 0.5	< 0.001	0.2 > p > 0.1	0.5 > p > 0.2
Livestock	1.312	5.105	0.047	-	< 0.001	< 0.001	< 0.001
Tiger	5.688	12.27	1.01	11.602		< 0.001	< 0.001
Tourist Vehicle	2.802	15.468	0.119	10.706	12.763	-	< 0.001
Vehicle	1.279	7.641	0.097	4.135	13.729	19.914	-

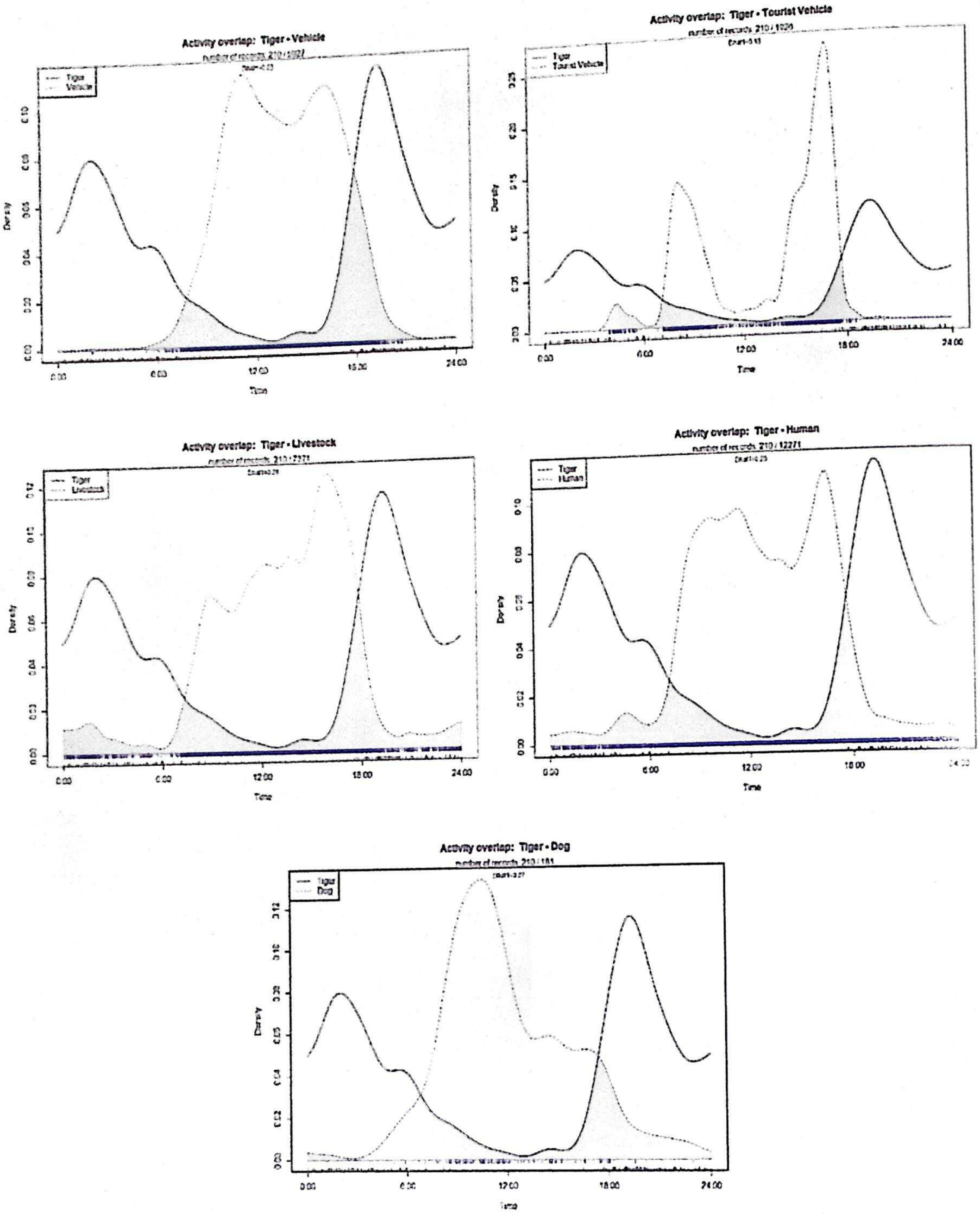


Figure 7.14: Temporal overlap between tiger and anthropogenic activity

7.3.9 Temporal overlap of livestock with herbivores

Livestock had a considerable temporal overlap with ungulate prey of tigers indicating huge grazing pressure and competition for ungulates in Sariska.

Table 7.8: Temporal overlap between livestock and ungulate prey

	Chital	Livestock	Nilgai	Sambar	Wild Pig
Chital	-	< 0.001	< 0.001	< 0.001	< 0.001
Livestock	2.38	-	< 0.001	< 0.001	< 0.001
Nilgai	1.207	2.64	-	< 0.001	< 0.05
Sambar	21.118	57.614	15.9	-	< 0.001
Wild Pig	1.042	2.189	0.214	6.483	-

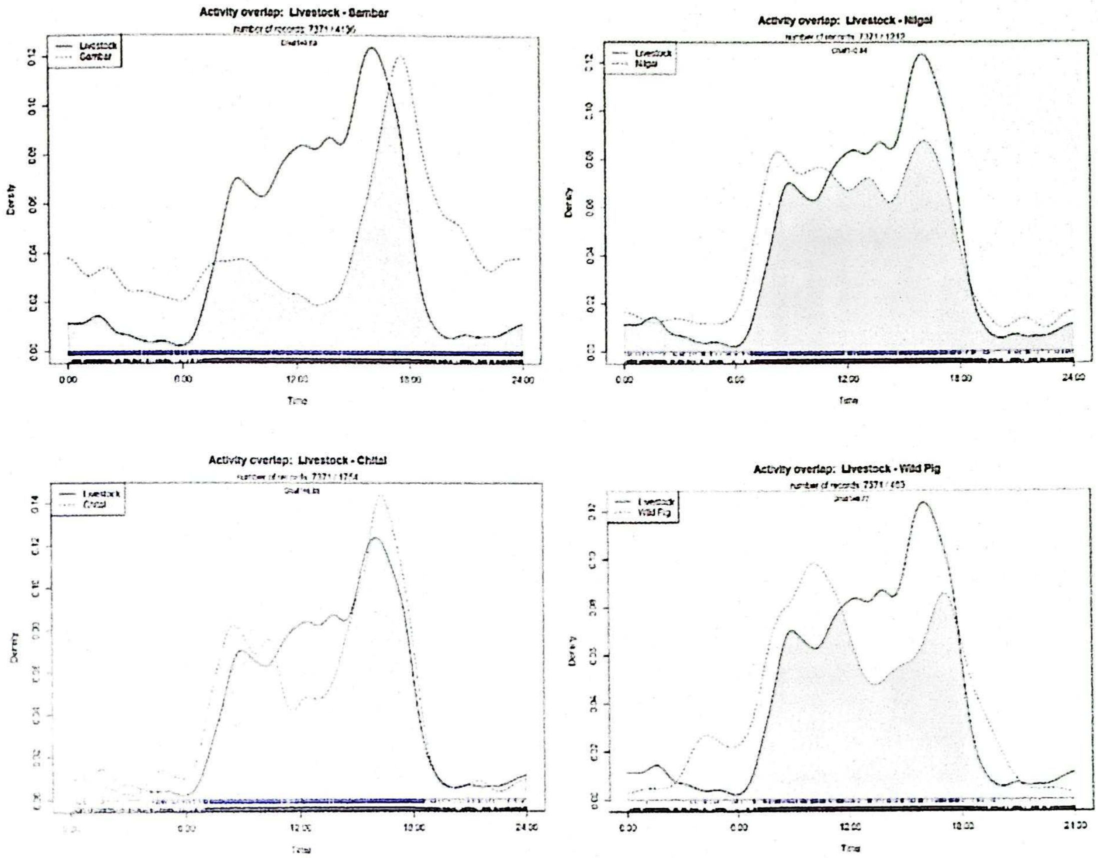


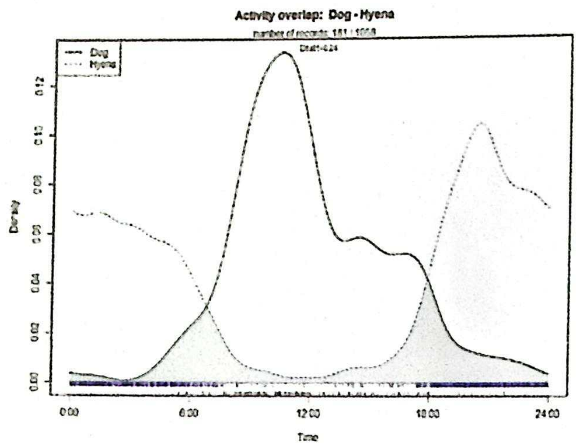
Figure 7.15: Temporal overlap between livestock and wild ungulates

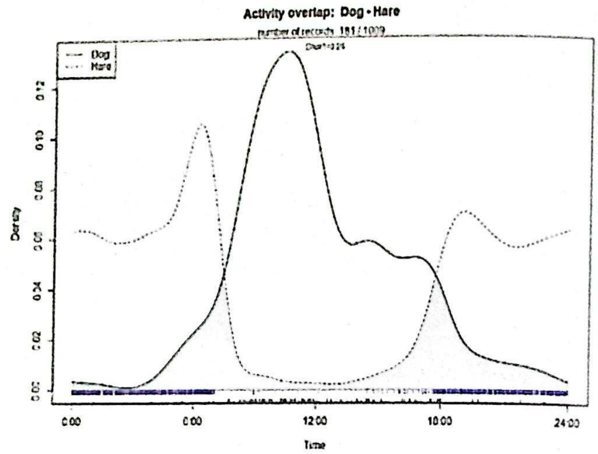
7.3.10 Temporal overlap between dog and wild animals

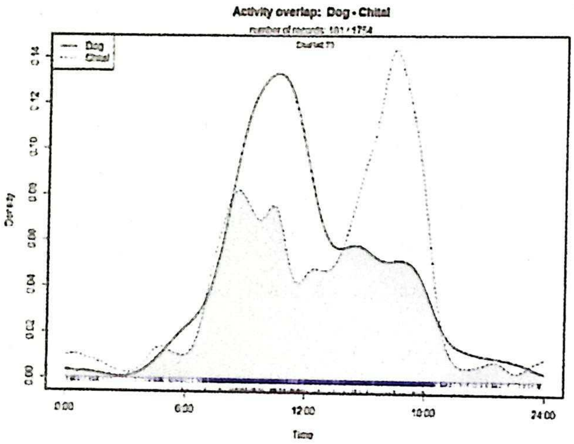
Recent studies are showing dogs have huge effect on wildlife. Dogs had significant temporal overlap with wild animals. Management should focus on eradication of dogs following relocation efforts from the tiger reserve.

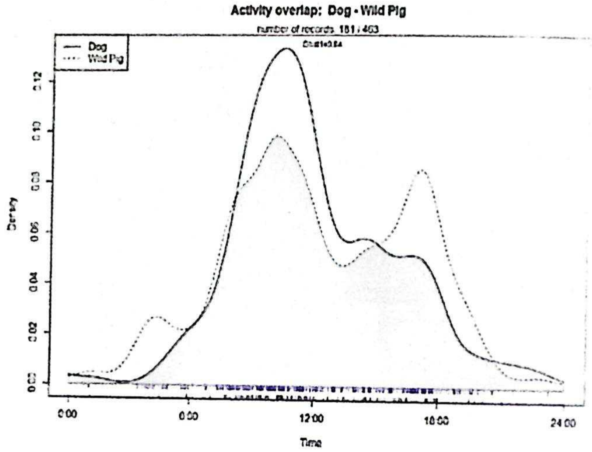
Table 7.9: Temporal overlap between dog and wild animals

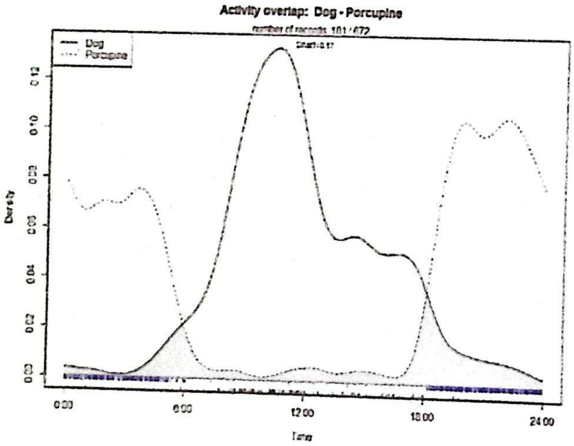
	Chital	Dog	Hyena	Jungle Cat	Nilgai	Peafowl	Porcupine	Sambar	Wild Pig	Hare
Chital	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Dog	1.374	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Hyena	38.98	9.69	-	0.2 > p > 0.1	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Jungle Cat	7.572	4.806	0.121	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.02
Nilgai	1.207	0.67	28.483	6.15	-	< 0.001	< 0.001	< 0.001	< 0.05	< 0.001
Peafowl	2.944	0.559	60.923	9.238	0.978	-	< 0.001	< 0.001	< 0.001	< 0.001
Porcupine	31.246	9.535	0.487	0.469	23.841	43.213	-	< 0.001	< 0.001	< 0.001
Sambar	21.118	4.79	15.757	2.315	15.9	62.424	14.396	-	< 0.001	< 0.001
Wild Pig	1.042	0.42	17.583	5.612	0.214	0.701	16.852	6.483	-	< 0.001
Hare	37.197	9.297	1.701	0.25	26.862	59.654	3.017	14.148	15.845	-

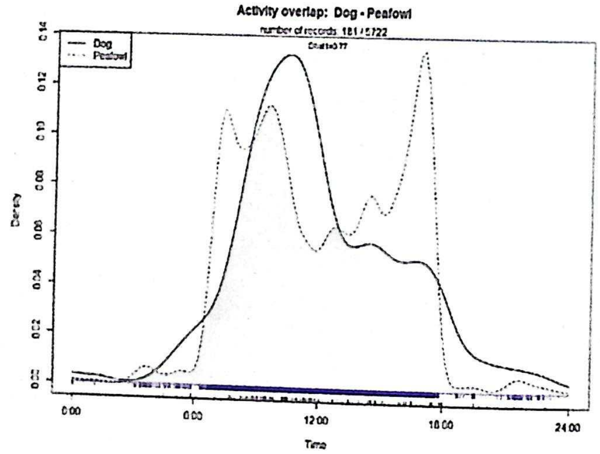

Activity overlap: Dog - Hyena
Dog
Hyena
Density
Time


Activity overlap: Dog - Hare
Dog
Hare
Density
Time


Activity overlap: Dog - Chital
Dog
Chital
Density
Time


Activity overlap: Dog - Wild Pig
Dog
Wild Pig
Density
Time


Activity overlap: Dog - Porcupine
Dog
Porcupine
Density
Time


Activity overlap: Dog - Peafowl
Dog
Peafowl
Density
Time

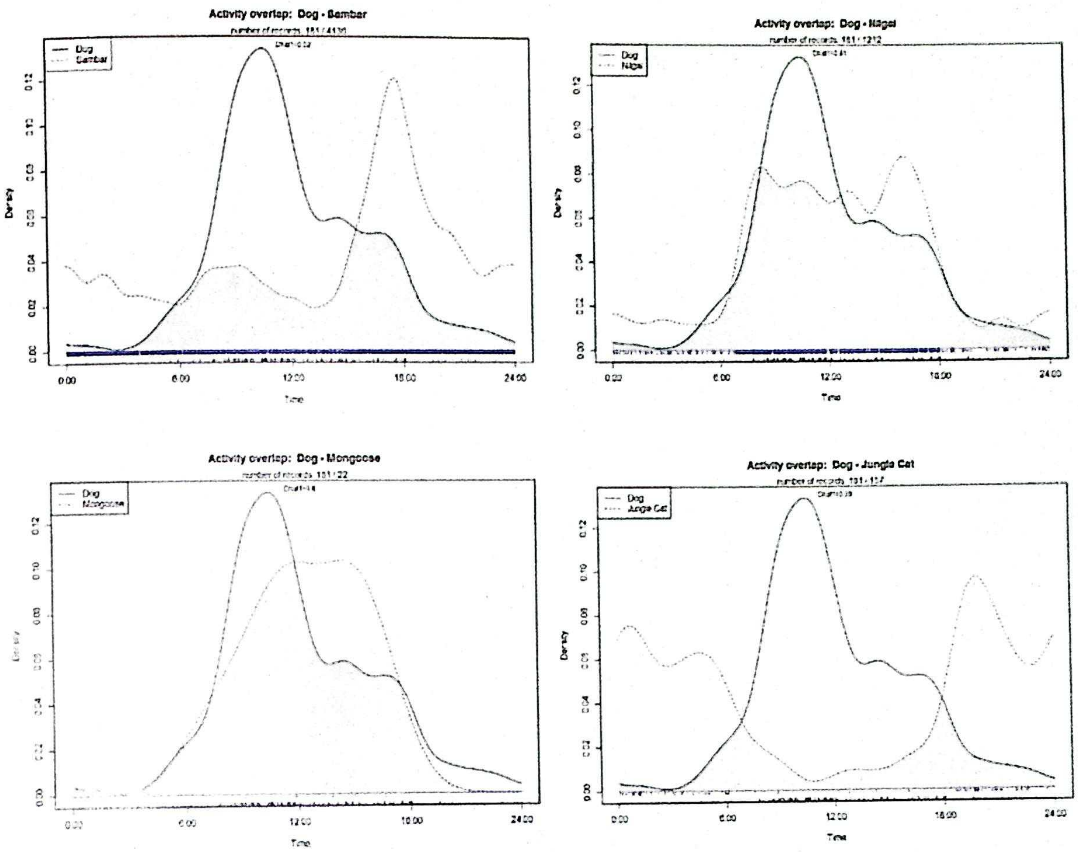


Figure 7.16: Temporal overlap between dogs and wild animals

7.4 Discussion

Tigers had high spatial overlap with co-predators, their prey (sambar and chital) and also with human and livestock. However, tigers temporally segregated themselves from anthropogenic activity (human and livestock) which probably enabled them to persist in this landscape without major human-tiger conflict. Although, leopards had higher spatial overlap with tigers, they avoided tigers on a temporal scale. Tigers had highest spatio-temporal overlap with their principal prey sambar. Sambar approximately contributes to 40-50% in tiger diet (Sankar et al., 2013). Thus, sambar population management will be crucial for tiger population in future.

Table 7.10: Spatial overlap between tiger, co-predators, their prey and anthropogenic pressure

Category	Variables	Pianka Index
Tiger & Co-predators	Tiger & Leopard	3.25
	Tiger & Hyena	2.86
Tiger & Prey	Tiger & Sambar	4.53
	Tiger & Chital	0.11
	Tiger & Wild Pig	0.17
	Tiger & Nilgai	2.60
Tiger, Human & Livestock	Tiger & Livestock	3.63
	Tiger & Human	2.57

Figure 7.17: Spatio-temporal overlap between tigers, co-predators, prey, livetsock and human

	SPACE	TIME	SPACE-TIME OVERLAP
CHITAL			LOW SO & LOW TO
WILD PIG			LOW SO & MEDIUM TO
HUMAN			MEDIUM SO & LOW TO
NILGAI			MEDIUM SO & HIGH TO
HYENA			MEDIUM SO & HIGH TO
LEOPARD			HIGH SO & LOW TO
LIVESTOCK			HIGH SO & LOW TO
SAMBAR			HIGH SO & HIGH TO

CHAPTER 8
FIRST PARTURITION OF REINTRODUCED TIGERS

8.1 *Introduction*

Management of wildlife, especially carnivores with low reproductive rates requires knowledge of reproductive parameters such as the age at first reproduction, reproductive rate, litter size, and inter-birth interval (Carter et al., 1999). Reproductive parameters are important indicators also to detect the lineage persistence in a population (i.e., lineage loss, individual fitness, population viability; Kelly, 2001). Gompper et al., (1997) suggested that lineage persistence is inversely related to age at first reproduction of a species and can be used to calculate rate of lineage loss per generation and generation timings (i.e., the average span between the birth of individuals and the birth of their offspring) which is crucial for conservation when considering risks. Small and isolated populations (<50 individuals) are vulnerable to such losses (i.e., genetic viability) if matriline losses are excessive; genetic diversity may be lost at a much more rapid rate in small and isolated populations than expected (Berger and Cunningham, 1995). Here, we study the first parturition of tigers in Sariska Tiger Reserve which is an isolated reserve with small tiger population.

8.2 *Methods*

Each individual reintroduced females were monitored since their reintroduction (Table: 8.1) by a team of two trained persons from 2008 onwards. All the reintroduced tigers were collared and monitored through ground tracking. In case, collars stopped working, tigers were tracked based on direct sighting, camera trapping and pugmark tracking every day.

8.3 *Results*

All the reintroduced females were monitored since their reintroduction (Table: 8.1). No female littered before reintroduction. The mean age of all females at first parturition was 59.8±08.16 months. The maximum age at which a female tiger starts breeding in semi-arid habitat of STR was 93 months. Approximate mean age of first reproduction of reintroduced tigers (ST2, ST09 & ST10) in Sariska was 68.33±11.11 months. Mean time of first reproduction of females since they were reintroduced was 31.33± 6.87 months. Two females (ST3 and ST5) did not reproduce till date. ST2 had littered two cubs [ST13 (M), ST14 (F)] again after a gap of 24 months in April 2014 at the age of 116 months.

In total, 12 cubs (four females, three males and three unknown) were born to three females. Mean litter size of reintroduced tigers in Sariska TR was 2±0.23 cubs.

Table 8.1: Age of first reproduction of reintroduced tigers in Sariska Tiger Reserve

Individual Id.	Approximate date of birth	Date of Reintroduction/ photographed	Age at the time of reintroduction/ photographed	Approximate age at first breeding	First time photographed with cubs	Id. Of Cubs
ST2	Oct-04	8/7/2008	48	May-12 (93 months)	8/7/2012	ST7 (F), ST8 (F)
ST3	Oct-06	27/02/2009	30	-	-	-
ST5	Oct-07	1/8/2010	36	-	-	-
ST9	Dec-11	22/01/2013	30	Dec-15 (66 months)	29/08/2014	ST15 (M)
ST10	Dec-11	22/01/2013	30	Jun-14 (46 months)	7/2/2016	ST11 (M), ST12 (F)
ST14	Mar-14	12/7/2014	04 months	Jan-18 (45 months)	6/4/2018	ST16 ST17
ST12	Jun-14	29/08/2014	03 months	18-Jun (49 months)	31/08/2018	ST18, ST19, ST20

Mean age of female cubs at which they separated from their mother was 22.5±0.95 months and males were 22±1.24 months. There was no significant difference in age of separation between sexes. However, all the four females established their territory adjacent to their natal area, while all the males have dispersed from the natal area.

Individual Id.	First time photographed (age at that time)	Established own home range
ST7 (F)	08/07/2012 (4 months)	Feb 2014 (21 months)
ST8 (F)	08/07/2012 (4 months)	Feb 2014 (21 months)
ST12 (F)	29/08/2014 (3 months)	April 2016 (21 months)
ST14 (F)	12/07/2014 (4 months)	May 2016 (25 months)
Mean age of separation: 22.5 ± 0.95 (SE) months		
ST11 (M)	29/08/2014 (3 months)	May 2016 (24 months)
ST13 (M)	12/07/2014 (4 months)	Feb 2016 (19 months)
ST15 (M)	07/02/2016 (3 months)	Oct 2017 (23 months)
Mean age of separation: 22 ± 1.24 (SE) months		

8.4 Discussion

Mean age of first reproduction in Central Indian landscape was reported be **31 – 39.8 months** [Chundawat et al., 2002 (n=5), Majumder et al., 2012 (n=1)]. Smith and MacDougal (1991) reported mean age of first reproduction in Nepal to be **40.8 months** (n=5). However, mean age of first reproduction in Ranthambore TR, the founder population was reported to be comparatively higher [**51.3±4.5 months** (Singh et al., 2013)].

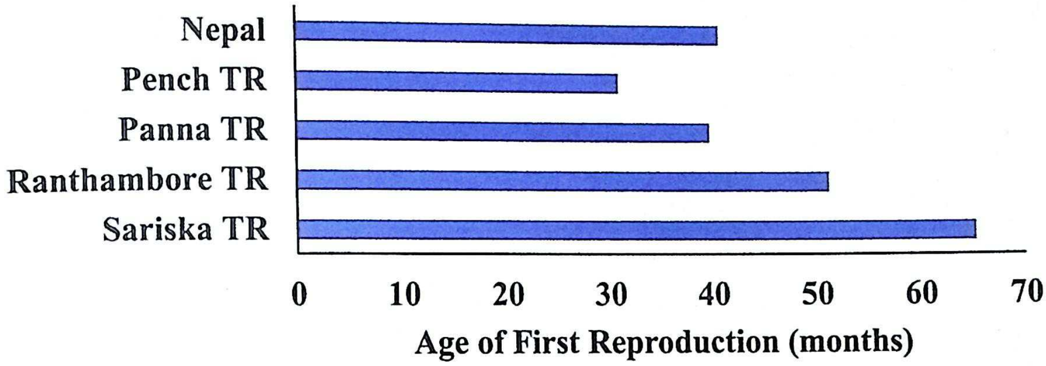
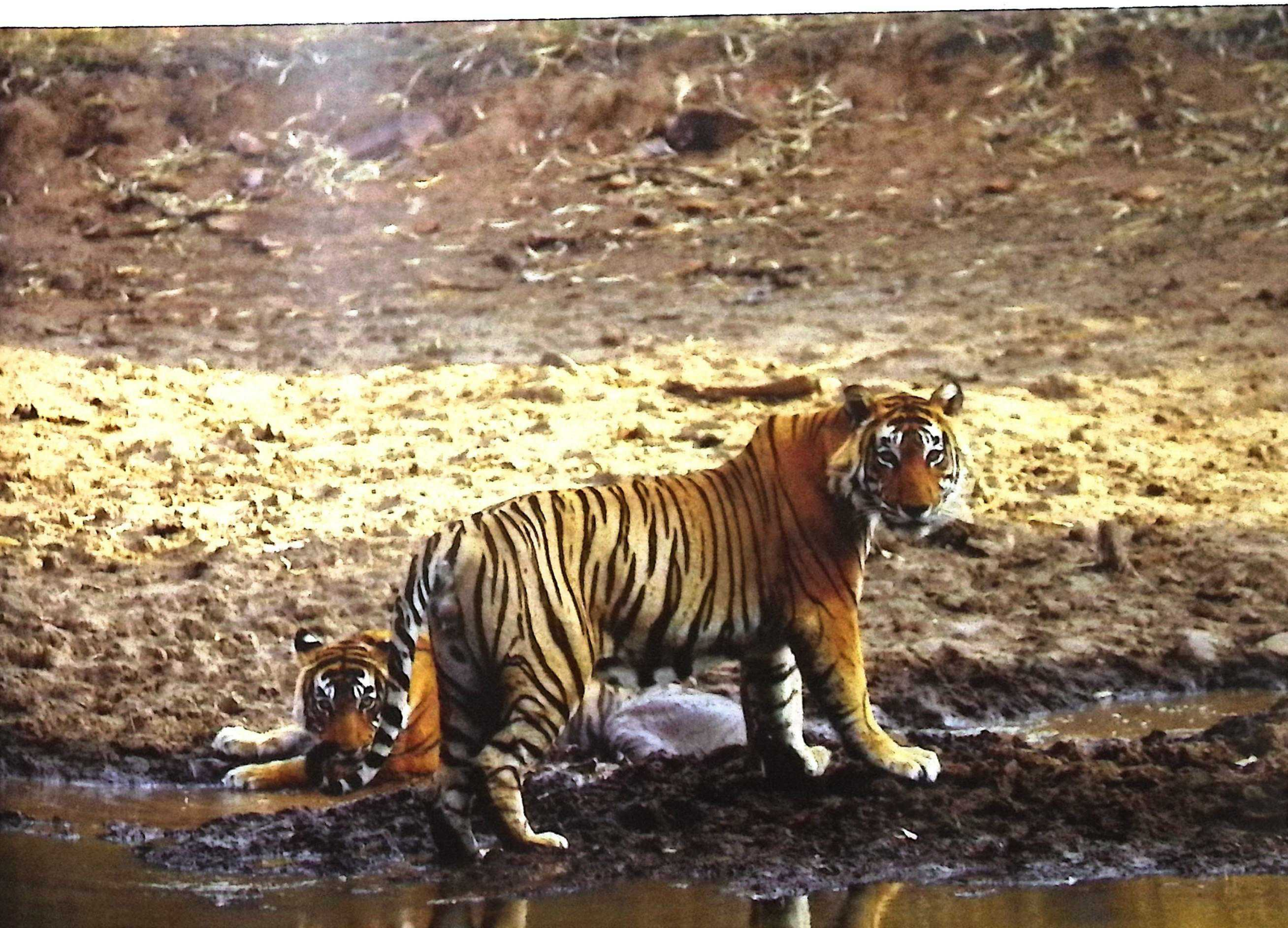


Figure 8.1: Age of first reproduction of tigers in Indian sub-continent

Mean time of littering after reintroduction in Panna TR was comparatively lower [**16.20±9.07 months** (Sarkar pers. comm)] than Sariska TR.

This is probably due to scarce availability of suitable breeding patches in Sariska TR. Our findings suggest reintroduced tigers may have been exploring the area to identify suitable breeding patches for comparatively higher time.



CHAPTER 9
FACTORS GOVERNING BREEDING OF TIGERS

9.1 Introduction

Tiger population decline is driven by large-scale habitat and prey loss caused by complex socio-cultural, political and economic reasons. The smaller, porous, and isolated areas together with linear development and human habitations across landscape further pose a challenge to conservation. The present study aims to understand the factors influencing the spatial dynamics and breeding ecology of reintroduced tigers of Sariska Tiger Reserve, Rajasthan and explore future conservation implications.

Sariska Tiger Reserve (1200 km^2) is an isolated reserve that shares sharp boundary with human habitation with 29 villages within the reserve. The reserve situated in the semi-arid landscape of western India represents the westernmost distribution limit of the tiger.

9.2 Methods

Radio-telemetry (n=04), direct sighting, camera trapping and pugmark tracking were used to monitor individual tigers during the study period (2013 – 16). Seven annual home range polygons of seven adult females were considered to study the factors governing breeding and spatial dynamics of tigers. The polygons were further classified as breeding/ non-breeding. Home range polygon was classified as 'breeding,' if the female was accompanied by cub(s). Rate of photo capture of human and livestock, distance to village, road and waterholes, prey availability and ruggedness were used as variables to understand the influence of different variables on breeding of tigers using multiple linear regression. Multiple linear regression was used to predict suitable areas using ArcGIS for tiger breeding in Sariska. We used Jenks natural breaks to categories suitable areas for breeding (i.e. High, medium and low) to prioritise villages for relocation at the site level.

9.3 Results

The present study showed that ruggedness and human disturbance significantly influenced breeding and spatial dynamics of tigers in Sariska (Adjusted R^2: 0.9953, P Value: 0.047). While ruggedness positively, human disturbance negatively influenced tiger breeding. Terrain complexity appeared to have masked human disturbance at some breeding sites. For example, tigresses have littered and used areas despite being very close (>1 km) to the highway and surrounded by villages owing to terrain complexity.

Table 9.1: Result of Multiple Linear Regression to explain factors influencing breeding of tigers in Sariska Tiger Reserve

	β Estimate	Standard Error	t value	P Value	
(Intercept)	-1.1434	0.2473	-4.623	0.1356	
age	0.3064	0.1027	2.982	0.206	
hum	-1.0787	0.1096	-9.839	0.0645	.
road	-0.8454	0.1628	-5.192	0.1211	
vill	-1.4123	0.2107	-6.704	0.0943	.
rugg	4.1764	0.231	18.081	0.0352	*

Dependant Variable: Breeding or Non-breeding [(0/1), bred]
Model: Intercept, age, hum (Human Disturbance), road_dist (Distance to Road), vill_dist (Distance to Village), rugg (Ruggedness)
Residual standard error: 0.0368 on 1 degrees of freedom
Multiple R-squared: 0.9992, **Adjusted R-squared:** 0.9953
F-statistic: 253 on 5 and 1 DF, **P-value:** 0.04769

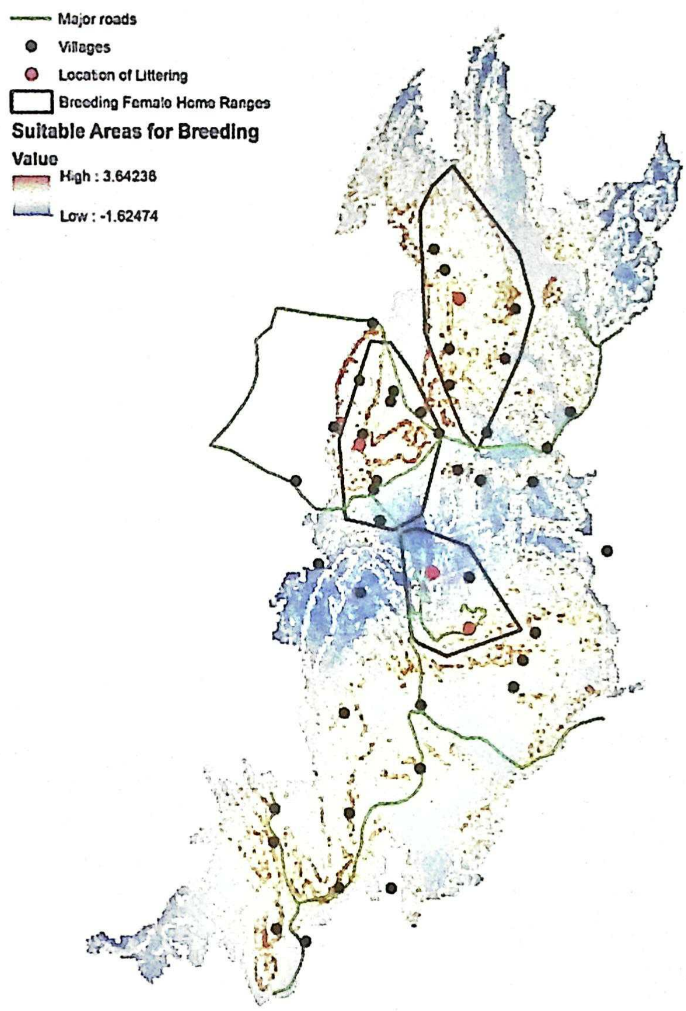


Figure 9.1: Map showing suitable patches for tiger breeding in Sariska with home ranges of breeding tiger overlaid on the map

9.4 Discussion and Management Implications

Based on the suitable areas for breeding, we prioritize two separate blocks consisting of 6 villages for relocation to achieve optimum conservation success in creating inviolate space for tiger breeding and population recovery.
Block I: Sukola, Dabli, Kiraska and Lilunda;
Block II: Haripura and Kankwadi

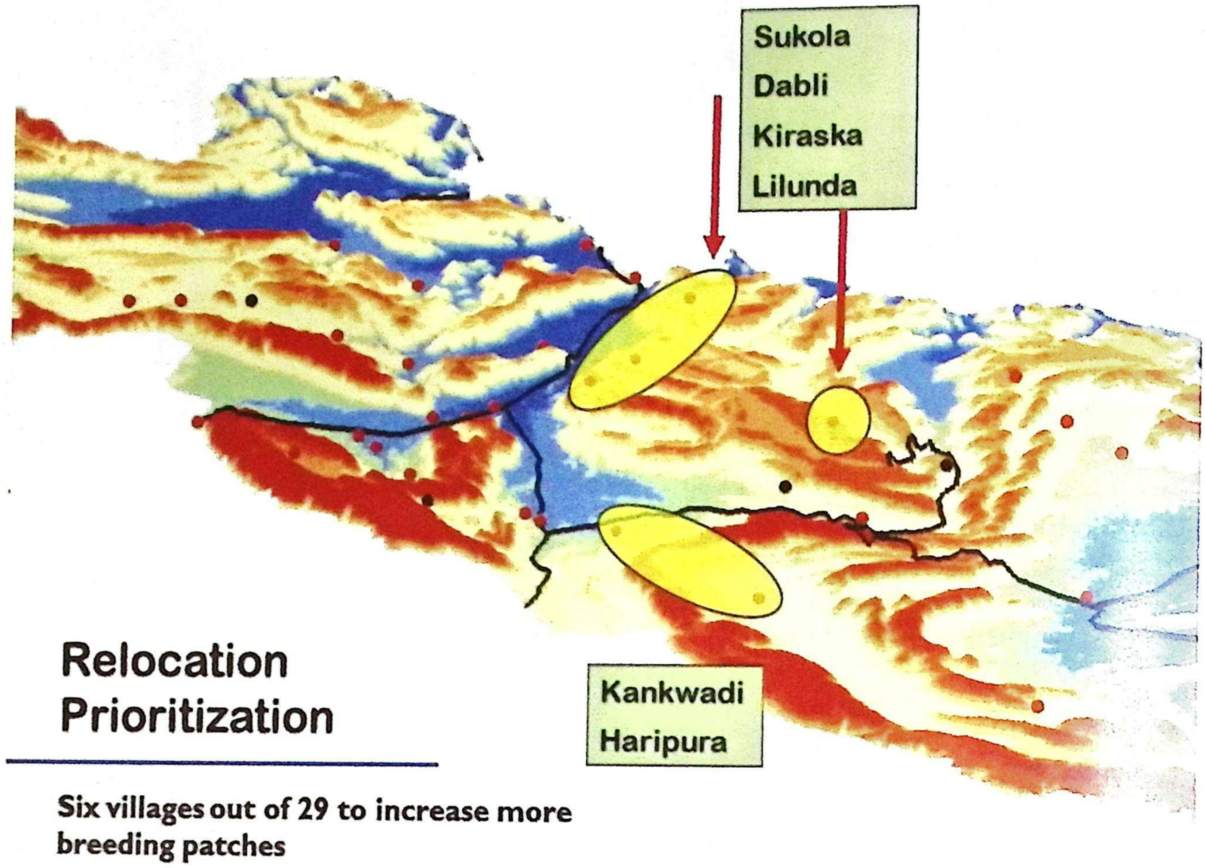


Figure 9.2. Prioritized villages for relocation

Our site level analysis showed that optimum conservation success can be achieved by relocating 6 villages out of a total of 29 villages using 26% of the required budget. Relocation of these villages are crucial to create more inviolate space for tiger breeding in Sariska. Although, potential tiger carrying capacity of Sariska based on prey availability is 44 tigers, our findings suggest it is gross over estimate as suitable breeding area are less to accommodate these many tigers in Sariska. The study also highlighted the importance of terrain complexity in concealment and producing apparent inviolate areas, crucial for tiger breeding. Our results also indicate the importance of site prioritization for village relocation, imperative in determining reintroduction success.

9.5 Future population Management Scope

Population Viability Analysis (PVA) was used to predict viability of the tiger population (100 years) under different management scenarios for active management of reintroduced tiger population in Sariska. In total, we have created five scenarios using Vortex v10 program.
These five scenarios were modelled to create realistic scenarios with the population exhibiting demographic parameters reported from Sariska, demographic parameters reported from wild tiger population with or without supplementation in a highly managed scenario (no prey base depletion and village relocation).

Simulations show that without supplementation and village relocation working in tandem to create more inviolate space to accelerate recruitment rate in Sariska, the population is vulnerable to extinction in approximately 50 years.

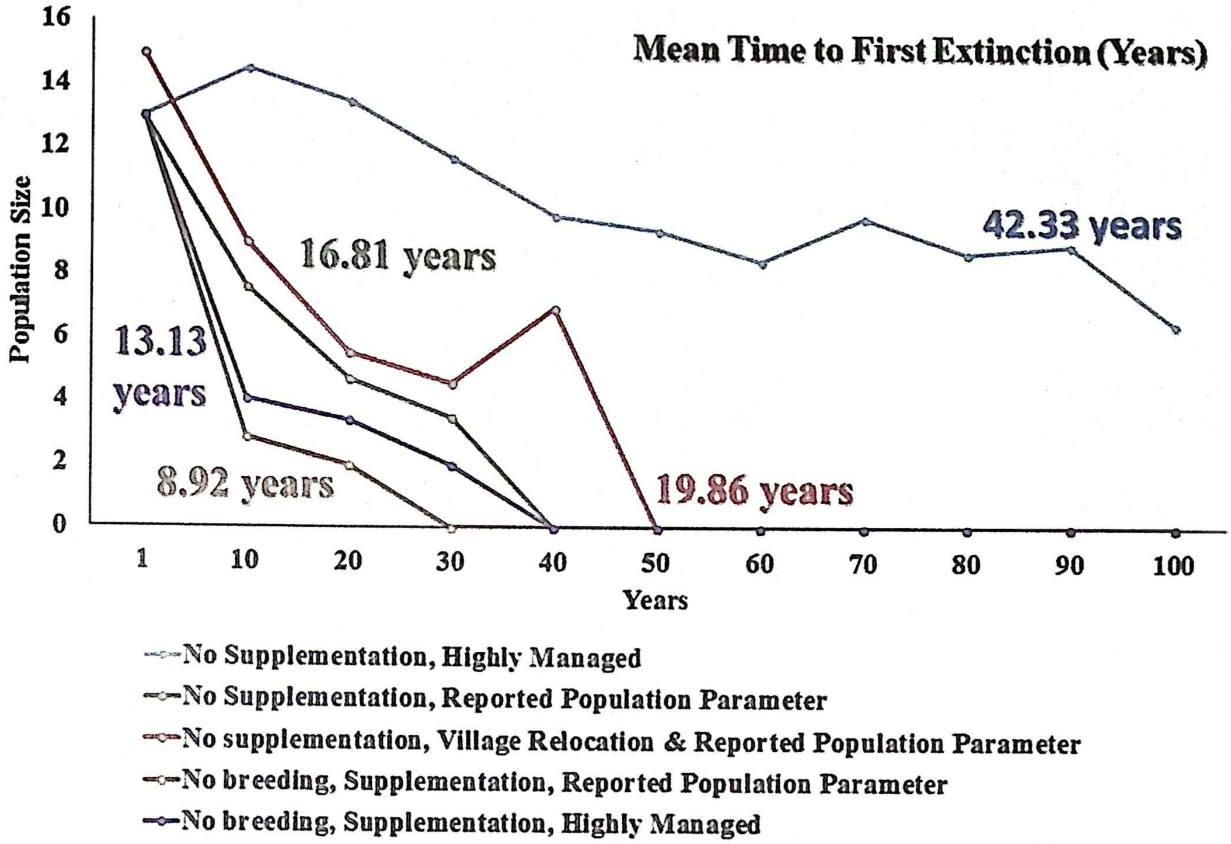


Figure 9.3: Various scenarios for tiger population management in Sariska

It is highly recommended that the population should be supplemented in a regular interval following the recommendation proposed in Annual Report of 2015 – 16. However, age-sex dynamics of Sariska's tiger population should be considered with great importance in consultation with experts before any further supplementation to the population and identification of potential individual tigers.

Recommended Scenario during Annual Report 2015 - 16
Natural Mortality with supplementation
Population Viability Analysis revealed further supplementation of at least two individuals (one male and one female) every 3-5 years for next 15-20 years to rule out extinction.

9.6 Sariska, A Reintroduction Success?

Reintroduction success for a small population of large carnivores is defined by a 3-year breeding population with natural recruitment exceeding mortality (> 10 years) or breeding by wild born generations (10 years post-reintroduction) (Hayward et al., 2007). Although, population proliferation in Sariska was not like that of the reintroduced population of Panna Tiger Reserve, the tiger reintroduction in Sariska has been a successful effort by both the definitions.

Initial stocking and supplementation of the population has been undertaken during 2008 – 13. During the last 10 years, recruitment rate (five litters resulting in birth of nine cubs in Sariska) was higher than the mortality.

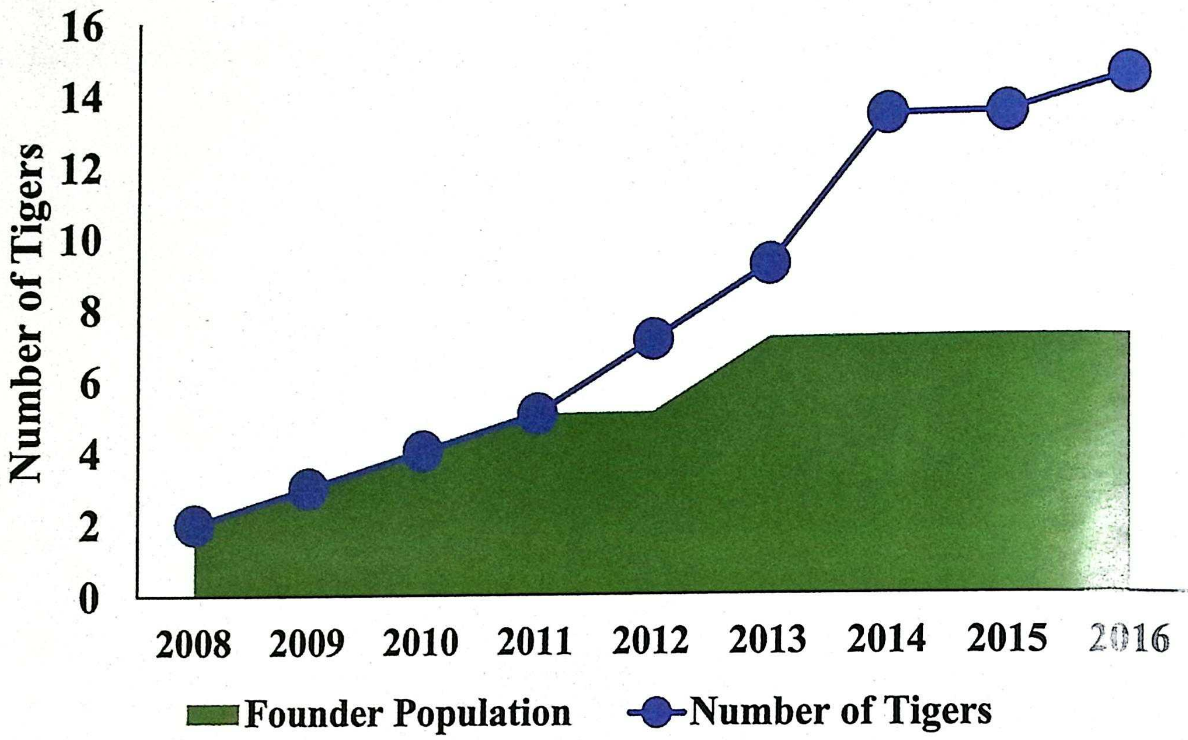


Figure 9.4: Population growth of tigers in Sariska

ST14 (F2 Generation), wild born litter of ST2 has given birth at an approximate age of 45 months. She along with her cub was photographed during April 2018.

Thus, tiger reintroduction in Sariska is a success [a 3-year breeding population with natural recruitment exceeding mortality (> 10 years) or breeding by wild born generations (10 years post-reintroduction) (Hayward et al. 2007)] by both the definitions.

CHAPTER 10
EFFECT OF VILLAGE RELOCATION ON GROUND BIRDS AND SMALL MAMMALS

10.1 Introduction

Human conversion of natural habitat is the largest primary cause of loss of biological diversity. Studies have reported that the protected areas that are interspersed with human settlement result in variable negative effects due to anthropogenic dependency and pressures. Due the rise of the unsustainable demand of natural resources by the local communities as well as the stress due to various developmental activities, the natural system are subjected to great strain. The balance between natural habitat and human-dominated landscapes will determine the future of biological diversity conservation over large areas of the planet. The expansion of the land use that accompanies human population growth also results in the fragmentation of natural habitat. Fragmentation causes the reduction, isolation, and removal of native vegetation from the natural landscape which is detrimental for the biodiversity (Fahrig, 1997).

Long-term studies are needed to understand biotic sustainability in regenerating and degraded forests. These studies should include habitat use, dispersal, and population viability. The amount of forests (i.e. thresholds) required to retain forest species richness in human-dominated areas is needed to for better knowledge. Information is required for understanding the mechanisms of species losses in isolated forests. Specifically, the evidence is necessitated on the synergistic or additive effects of biodiversity loss drivers such as forest degradation, invasive species, drought, wildfires and climate change on forest biodiversity in human-dominated landscapes (Brook et al., 2008; Cleary, 2003; Silk et al., 2002)

In India voluntary relocation of villages has been one of the principles in the management of protected areas. The aim of voluntary relocation from wildlife sanctuaries and national parks is to create inviolate space for biodiversity conservation where minimal human use is allowed (Shahabuddin 2005). Such inviolate spaces are essential for sustaining natural biodiversity in large continuous forest habitats. However, most village relocations in the country have historically taken place in the absence of information related socio-economic status or forest dependency or identification of key needs that are required in new sites. For example, Bhadra tiger reserve, relocation programmes have been ineffective in successfully rehabilitating people, leading to severe impoverishment and social dislocation of marginalised groups (Karanth 2007). For those reasons village relocation has always been a controversial issue in conservation circles. Yet little is known about the socio-economic impacts of such displacements or their effectiveness in restoring biodiversity.

Sariska Tiger Reserve is one such Indian protected area where village relocation has been prioritised as one of the key programmes to be undertaken for saving biodiversity. Sariska was one of the important conservation areas for the Tiger (*Panthera tigris*) in its north-western limit in India until it got locally extinctions in 2004-2005. It represents the last few remnants of native tropical dry forest and scrub still to be found in the Aravalli Range.

Sariska already has a long history of village relocations. Relocation of villages located within the Sanctuary area was undertaken in1960's. One village, Karnakawas was moved from the Core area between 1975-77, and unsuccessful attempts have been made to move two other villages, Kirska and Kanakwari. Since then 7 villages have successfully been relocated from the reserve till date. Some villages are still remaining inside the park and need to be relocated. The relocation of villages was successfully carried out in the year 1966-67, 1976-77, 2008-09 and 2011-12. Some of the villages were partially relocated and still the relocation programme is ongoing. These different phases of relocation produced heterogeneous mosaic of different successional stages of secondary forest, interspersed with cleared areas dominated by shrubs and bushes, and pockets of primary forest.

Table 10.1: Name of villages with their status of relocation

Name of Villages	Year of Relocation
Kalighati, Slopka	1966-67
Kanyawas	1976-77
Deori, Rotkyla	2008-09
Bhagini, Umri	2007-10
Kankawadi-Karat-	2011 (Partially relocated)
Pilapani	
Haripura, Dabli &	2013 (relocation ongoing)
Kiraska, Sukola	
Lilunda, Kundalka &	Not relocated
Rekamala	

10.2 Methods

10.2.1 Population estimation of ground birds

For most species, estimation of abundance is a fundamental too for conservation. Line transect method was used to estimate the population of target species of galliformes in the study area. For estimating biological population line transect sampling is practical, efficient and relatively inexpensive (Anderson et. al., 1979). Few researches suggest that line transects method found to be more accurate than point counts for estimating birds (Raman, 2003).

From the centre of each village a 1.5 km radius circular area was chosen for intensive sampling. The size of the area was 7.07 sq. km. The area was divided into 500x500 m grid and 15 transect was laid in chequerboard design to cover all types of habitat in the study area. Length of the transects varied from 500 m to 680 m. Total 60 transect were laid in all four village sites and total effort was 36.17 Km. All the transects were walked once in the morning between 07:00 AM to 09:30 AM from the month of December to April. In total 60 transect in all four village sites (study site), five species of ground birds were detected on line transect. These were peafowl (*Pavo cristatus*), jungle bush quail (*Perdicula asiatica*), grey francolin (*Francolinus pondicerianus*), painted spur fowl (*Galloperdix lunulata*) and red spur fowl (*Galloperdix spadicea*).

Data was analysed using the program DISTANCE 6.2 (Thomas et. al., 2009). Four key functions (uniform, half-normal hazard rate and negative exponential all with cosine series adjustment) were considered for analysis. Minimum Akaike Information Criterion (AIC) and Chi-square was used for the selection of the best fit models. The encounter rates were obtained using the formula by Rodgers (1991). Encounter rate (ER) = n / l (Whereas 'n' is the number of individual and '1' is the total length of the transect). The value derived from the above calculation was used for obtaining the index of abundance.

10.2.2. Population estimation of rodents

Rodent density was estimated using trapping web design at four different village sites of the intensive study area. Two trap points were selected for rodent trapping from the 500x500 m grid of each village site. One trap point was selected within 200 m from the centre of the village site and other one is far from 1 km. The standard Sherman live traps (5 x 6.5 x 16.5 cm) were used for rodent trapping at eight different sites in all four study area (village site). Each trap was run for 15 consecutive trap nights with total sampling period amounted to 120 trap nights in all four study area. The traps were operated in 0.28 hector area (60 m x 60 m) concentric rings of 30 m radius. The traps were kept near bushes, trees, rocks, fallen logs or any other possible run way of rodents in sampling area. All the traps were baited with peanut butter between evening 05:30 PM to morning 07:00 AM and checked for animals between 07:00 AM to 08:30 AM in the morning. Trapped rodents were identified, weighed and measured for the tail length and body to head length (HBL). Rodents were identified up to species level using field guides (Prater, 1980; Menon, 2014). Animal sex was identified based on their genitalia. Each of the rodents were marked by paint colour at the base of the tail or either on the hind limb. Four colours were used for marking rodent viz red, blue, green and pink. The capture animal was marked and released at the spot where they were trapped. Program Mark was used for data analysis. Huggins **p** and **c** models were selected for closed capture data type. Minimum Akaike Information Criterion (AIC) was used to select the best fitted models.

10.2.3. Quantification of Vegetation

Most of the study shows that changes in bird community happen because of habitat alteration by changes in forest vegetation structure such as in the density of trees, density of bamboo understory, tree size class variation, densities of old trees and snags, amount of woody litter and tree species composition (Raman et al., 1998; Lohr et al., 2002). Vegetation structure (e.g. – Canopy cover, shrub cover, ground layer cover and invasive species) were recorded in each transects at an interval of 200 m. Three plots were selected in each transect. The first plot was laid at the beginning of the transect and rest of the two plot laid at 200 m and 400 m. Three types of circular area were laid for sampling vegetation in each plot. For trees, a 15m radius circular plot, 5m radius plot for shrub and two 0.5m radius plot for ground layer cover were laid for sampling vegetation. Total 180 plots were laid for vegetation sampling in all four village sites. Percentage of canopy cover, shrub cover and abundance of invasive species was calculated and compare between four village sites. The lopping score for each tree was additionally measured on a scale of 0–4 as follows: 0, no lopping; 1, rudimentary signs of lopping; 2, up to half of the main branches lopped; 3, more than half of the main branches lopped; 4, the tree reduced to a stump. The scale of lopping was calculated as the total lopping score divided by the total number of trees present. To obtain the Human disturbance factors such as wood cutting, lopping, grazing, human trails, and livestock dung was quantified in each plot. These were quantified at each plot in a scale of 0 to 4 (0–none, 1–low, 2–medium, 3–high and 4–very high). 1 = Low (Less than 25%) 2, = Medium (25%–50%) 3, = High (50%–75%) 4 = Very high (Above 75%).

10.2.4. Camera trapping for Small carnivores

A reconnaissance survey was carried out in each village sites before placing camera traps. Indirect signs such as spoor, scats and track signs of carnivores were identified and marked using a hand held Global Positioning System (Garmin etrex vista). The camera trapping was carried out within 1.5 Km radius circular area. A single camera was deployed in a 500x500 m grid on the basis of any evidence (spoor, scats and track sign). A total of 24 to 30 locations were selected for deploying cuddeback (Model-Attack, Ambush and C1) camera traps in each 7.07 sq. Km. intensive study area. Each camera traps ran for a minimum of 7 days to maximum of 25 days. CamtrapR software was used for analysing the data.

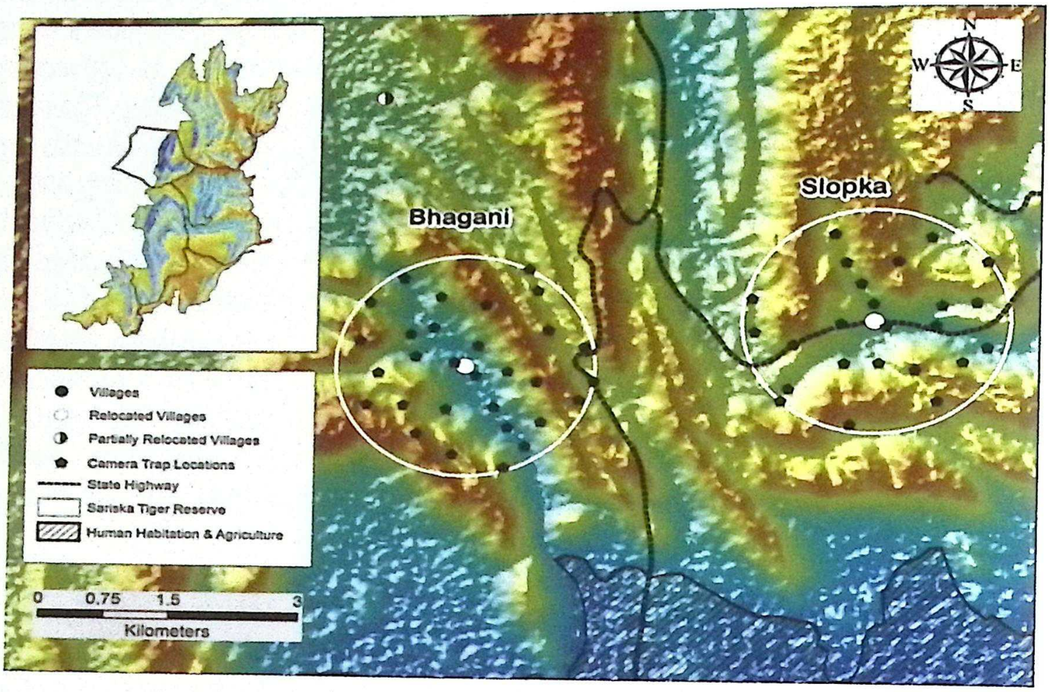


Figure 10.1: Camera trap locations of the village Slopka and Bhagani.

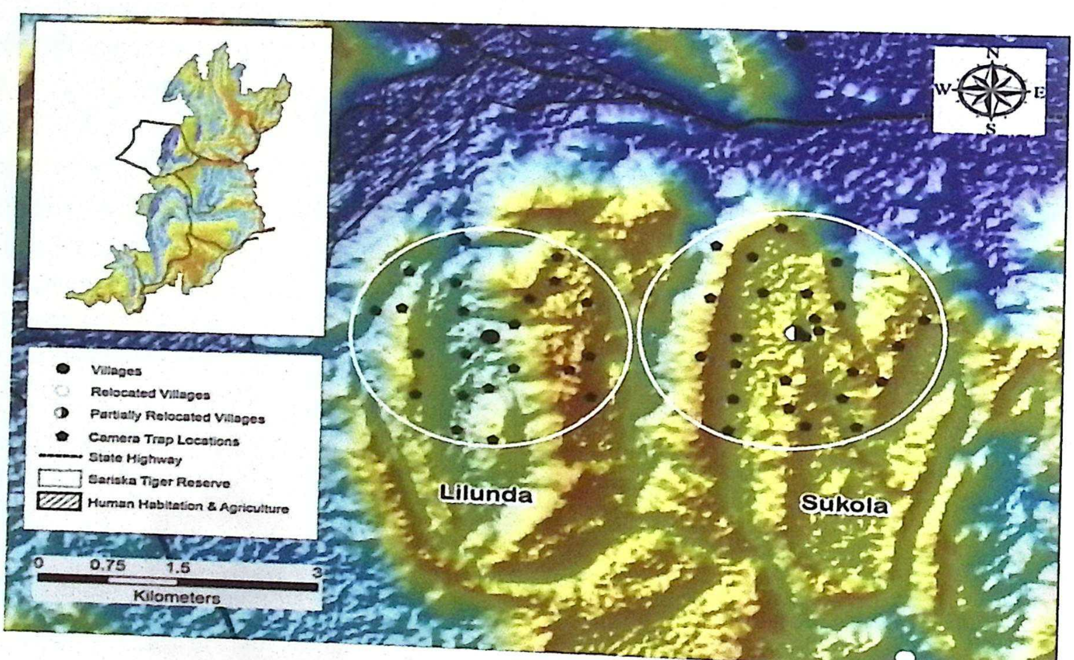


Figure 10.2: Camera trap locations of the village Sukola and Lilunda

10.3. Results

10.3.1. Density estimates of ground birds

In total 5 species of galliformes (ground birds) were detected on line transect. These involve peafowl (*Pavo cristatus*), jungle bush quail (*Perdicula asiatica*), grey francolin (*Francolinus pondicerianus*), painted spur fowl (*Galloperdix lunulata*) and red spur fowl (*Galloperdix spadicea).* Density estimates of galliformes was estimated for each village sites of Sariska. There were only few sightings of grey francolin (n=23, 20, 12 & 6), painted Spurfowl (n=6,4, &2), Red Spurfowl (n=3,1) and jungle bush quail (n=3,1) so we could not estimate their density separately. Estimated density of galliformes was highest for Bhagani (331/Km²) followed by Slopka (240/Km²), Lilunda (181/Km²) and Sukola (180/Km²) respectively. (Table 10.2 & Figure 10.2)

Table 10.2: List of tables with ground bird density in four different villages of Sariska Tiger reserve.

Name of villages	Species	Model	AIC	Chi square P value	Effective strip width (SE)	Mean Group size	Detection probability	Encounter rate (SE) per km	Group density (SE) per sq.km.	Individual density (SE) per sq.km.
Slopka	Galliformes	Half-normal-cosine	119.17	0.90	38.08 (±6.77)	2.75 (±0.26)	0.82	0.006 (±0.0009)	87.13 (±18.7)	240.42 (±56.5)
Bhagani	Galliformes	Half-normal-cosine	102.08	0.87	24.66 (±3.30)	3.07 (±0.32)	0.58	0.005 (±0.0007)	107.87 (±21.7)	331.40 (±75.53)
Sukola	Galliformes	Half-normal-cosine	71.20	0.96	27.46 (±4.41)	2.91 (±0.35)	0.54	0.003 (±0.0005)	61.97 (±14.8)	180.79 (±48.79)
Lilunda	Galliformes	Half-normal-cosine	67.78	0.99	21.78 (±3.46)	2.09 (±0.21)	0.64	0.003 (±0.0004)	86.43 (±18.9)	181.32 (±43.9)

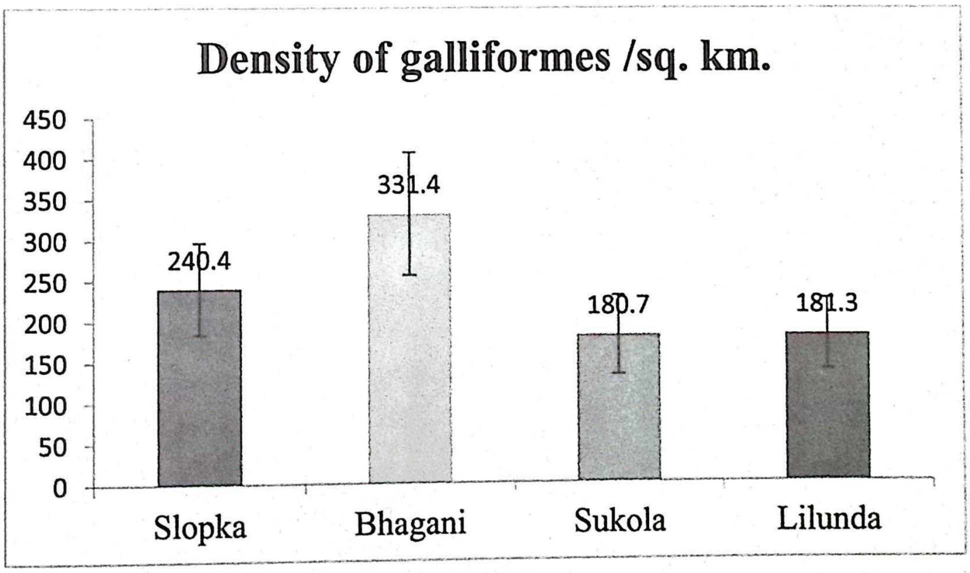


Figure 10.2: Density of galliformes in the all four villages of Sariska Tiger reserve.

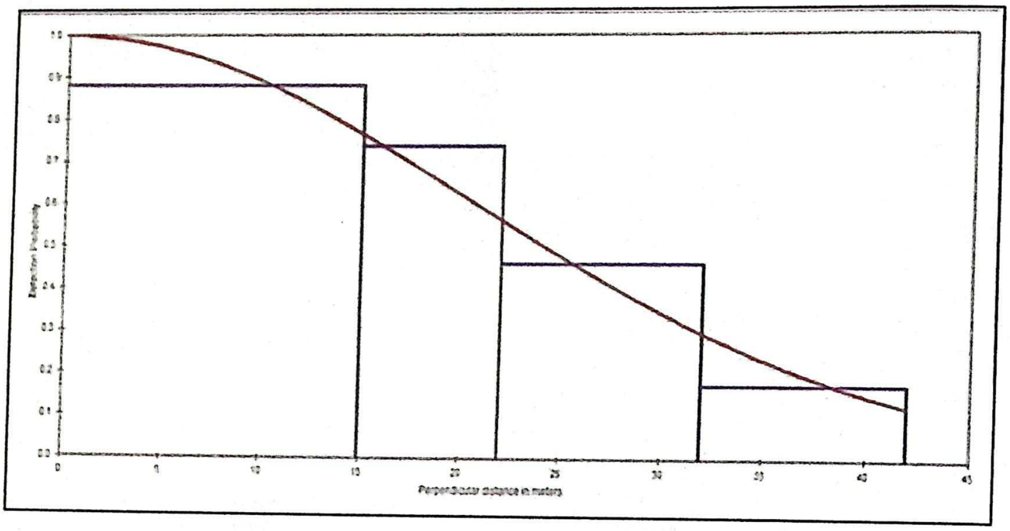


Figure 10.3: Detection function of best selected model for galliformes in Bhagani, Sariska.

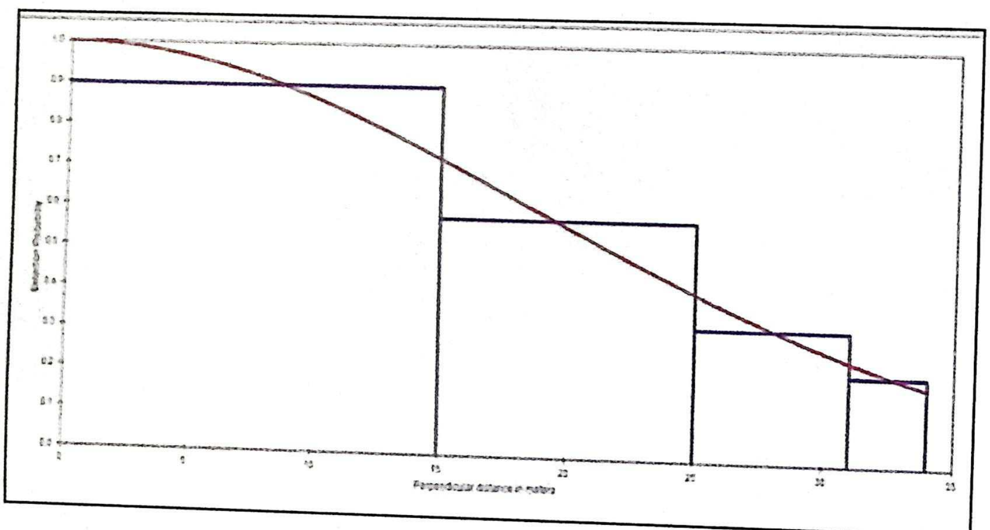


Figure 10.4: Detection function of best selected model for galliformes in Lilunda, Sariska

10.3.2. Density of Peafowl

Among all galliformes species peafowl was found most abundant in all study sites. Detection of peafowl was best explained by half normal detection function with cosine adjustment. Estimated density of peafowl was highest in Bhagani (158/ Km²) followed by Lilunda (124/Km²), Sukola (115/Km²) and Slopka (108/Km²) respectively. (Table 10.3 & Figure 10.5)

Table 10.3: List of tables with Peafowl density in four different villages of Sariska Tiger Reserve.

Name of village	Species	Model	AIC	Chi square P value	Effective strip width (SE)	Mean Group size	Detection probability	Encounter rate (SE) per km	Group density (SE) per sq.km.	Individual density (SE) per sq.km.
Slopka	Peafowl	Half-normal-cosine	56.65	0.99	33.08 (±6.77)	2.24 (±0.34)	0.73	0.003 (±0.0004)	48.61 (±12.2)	108.89 (±32.17)
Bhagani	Peafowl	Half-normal-cosine	42.30	0.98	18.49 (±3.59)	2.16 (±0.36)	0.54	0.002 (±0.0002)	73.16 (±17)	158.72 (±45.69)
Sukola	Peafowl	Half-normal-cosine	32.31	0.91	17.19 (±2.60)	1.70 (±0.2)	0.66	0.0023 (±	67.4(±13.8)	115.05 (±27.4)
Lilunda	Peafowl	Half-normal-cosine	36.09	0.97	17.69c (±4.10)	1.79 (±0.21)	0.65	0.002 (±0.0003)	69.63 (±19.7)	124.7 (±38.28)

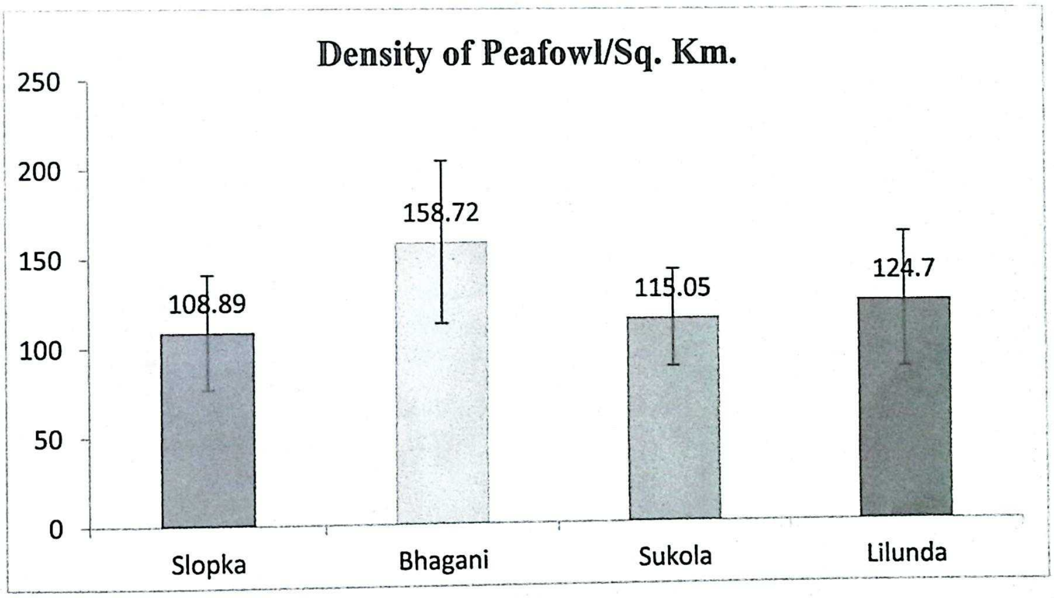


Figure 10.5: Peafowl density in four different villages of Sariska Tiger Reserve.

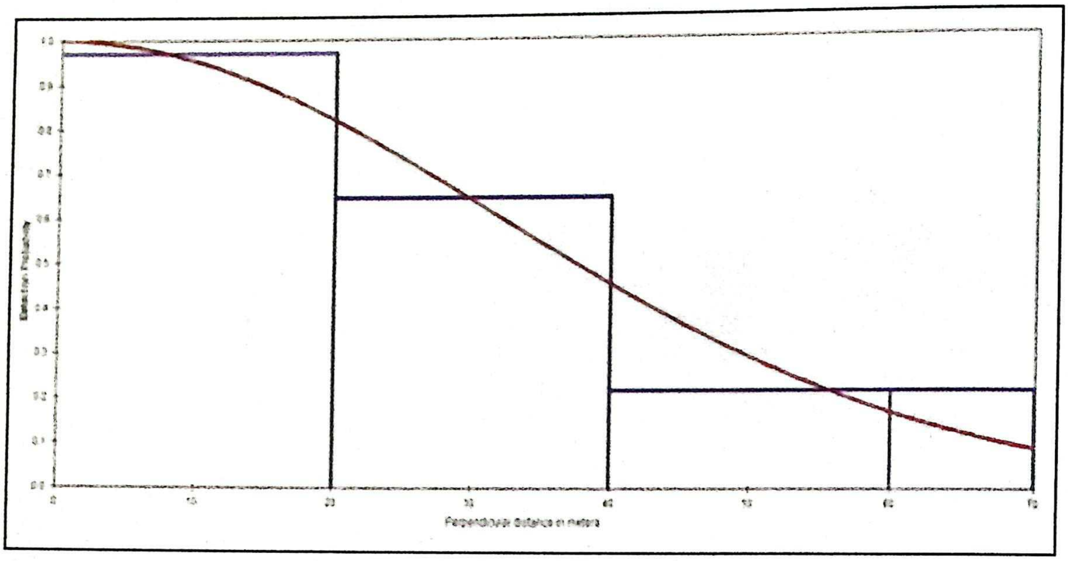


Figure 10.6: Detection function of best selected model for peafowl in Sukola

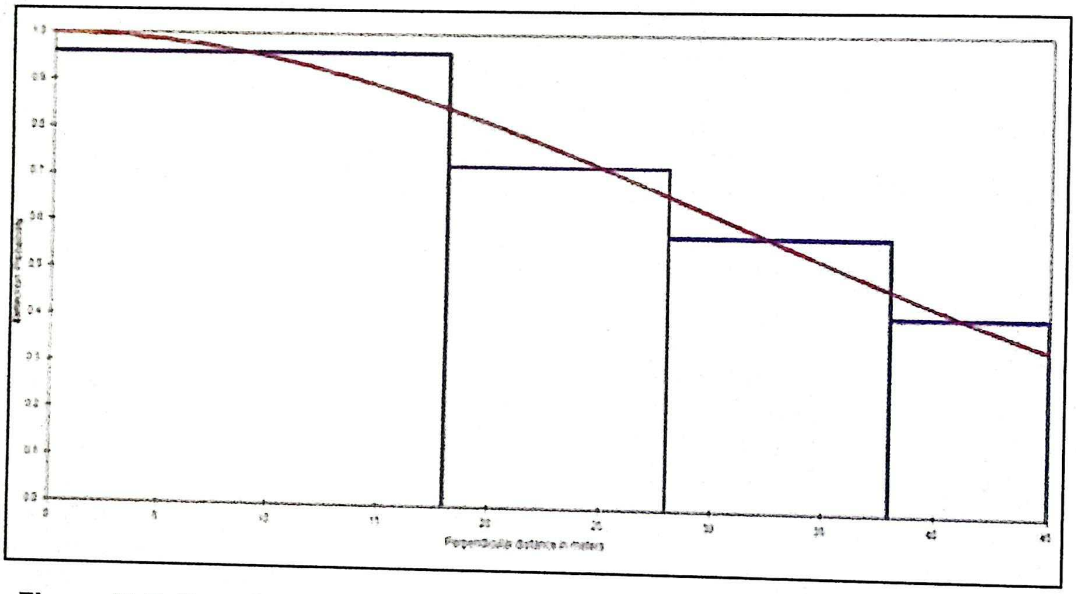


Figure 10.7: Detection function of best selected model for peafowl in Slopka, Sariska

10.3.3. Encounter rate of Galliformes

In total, 117 individuals of five species were detected on the line transect during the study period. The encounter rate was recorded highest for peafowl (2.13±0.11 per Km.) followed by grey francolin (1.26 ±0.11 per km), painted Spurfowl (0.33 ±0.112 per km), red Spurfowl (0.03 ±0.11 per km) and jungle bush quail (0.11 ±0.11)(Figure 10.8). We also calculate the encounter rate of all galliformes species in different habitat types as most of the galliformes species are very specific in terms habitat use.

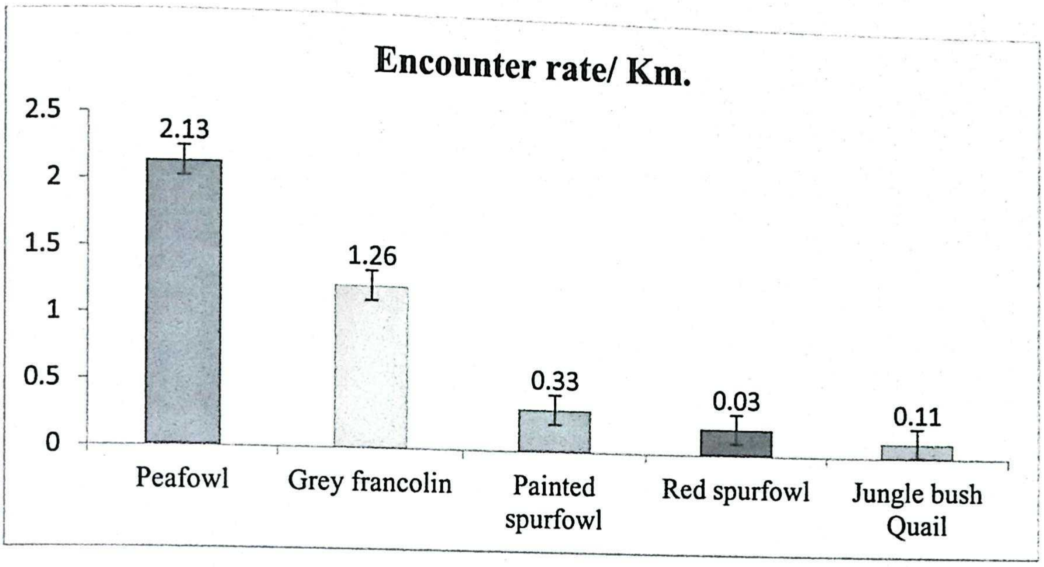


Figure 10.8: Encounter rate of all galliformes species in Sariska Tiger Reserve.

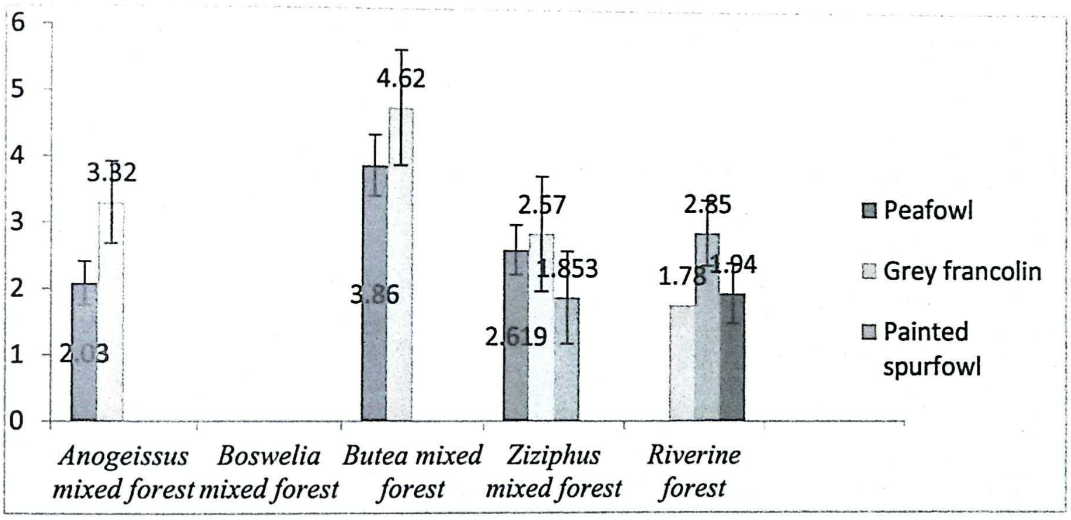


Figure10.9: Encounter rate of galliformes/ km in different habitat types of village Slopka.

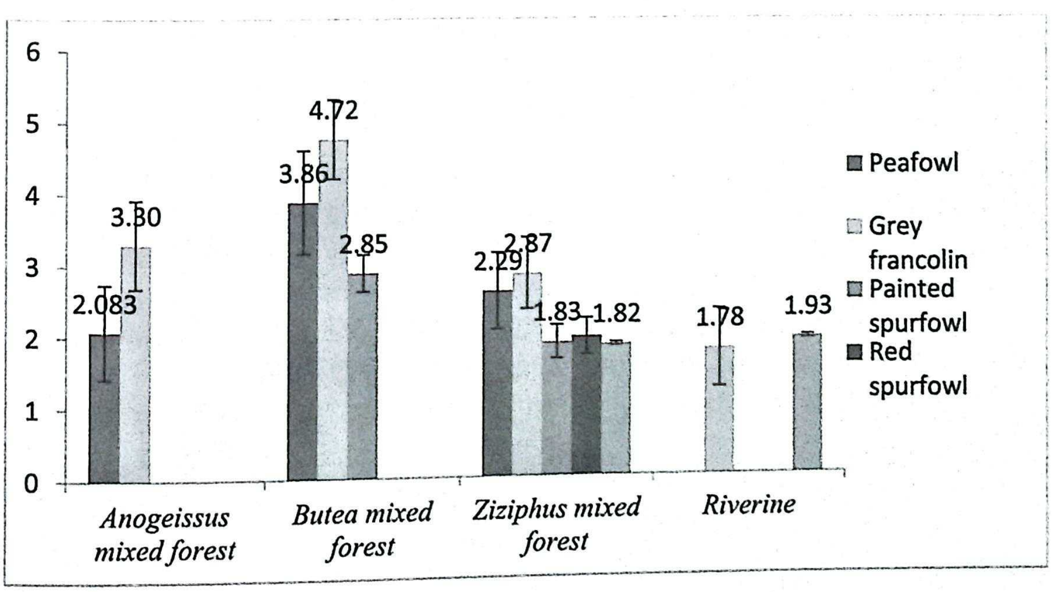


Figure 10.10: Encounter rate of galliformes / km in different habitat types of village Bhagani.

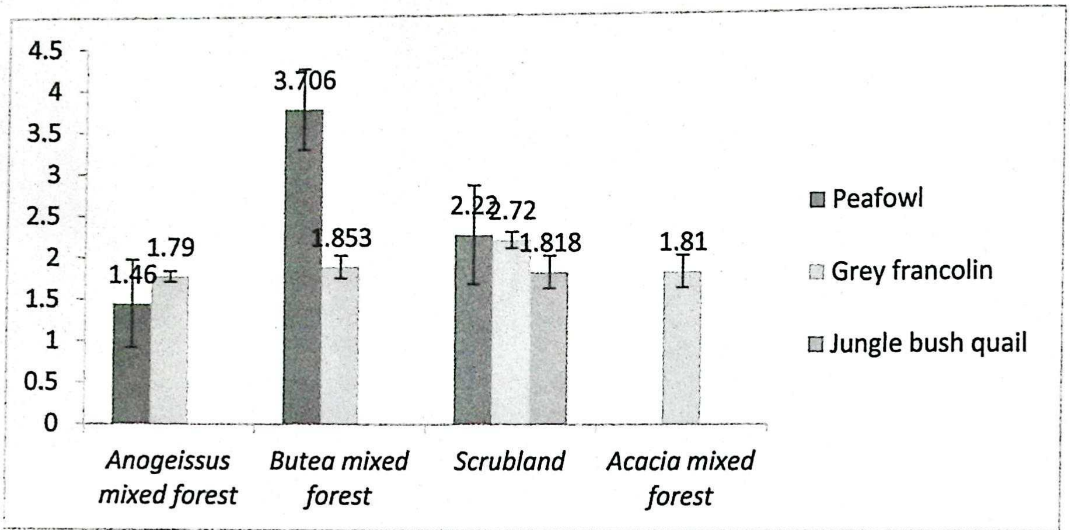


Figure10.11: Encounter rate of galliformes/ km in different habitat types of village Sukola

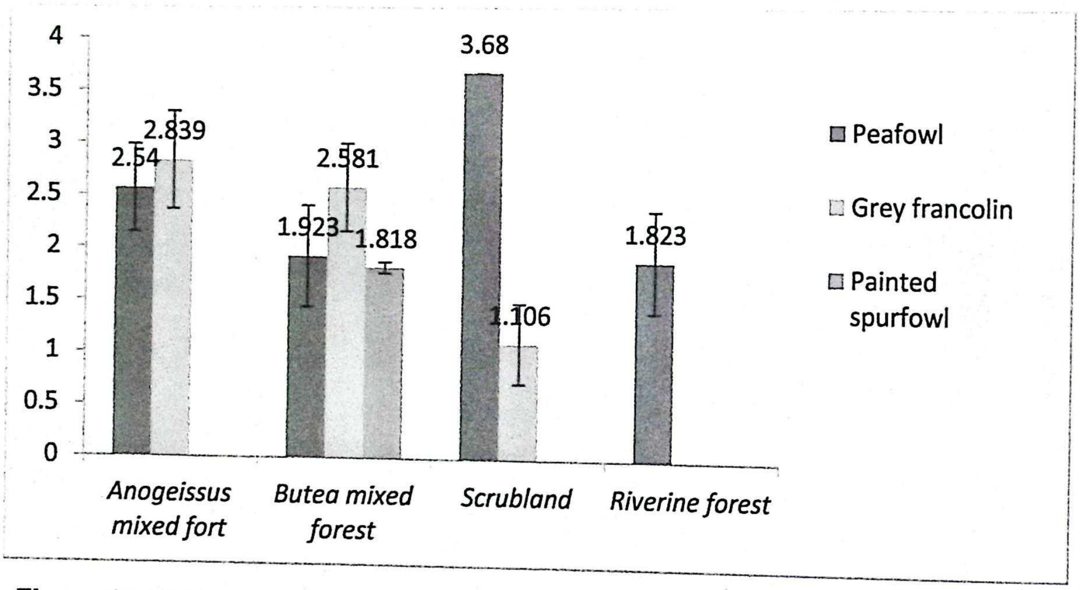


Figure 10.12: Encounter rate of galliformes in different habitat types of village Lilunda.

Encounter rates of galliformes species show marked difference in the different habitat types of different village sites of Sariska tiger reserve. The encounter rate of peafowl was highest in Butea mixed forest ((3.86/km, 3.86/km,3.70/km & 1.92/km) followed by Ziziphus mixed forest (2.61/km, 2.29/km) and Scrubland (2.22/km,3.68/km). Grey francolin was also observed in Butea mixed forest (4.62/Km, 4.72/Km) as well as Ziziphus mixed forest (2.57/Km, 2.87/Km). Encounter rate of Painted Spurfowl and red Spurfowl shows mark preference in riverine (1.78 & 1.82/Km) areas as well as Ziziphus mixed forest (2.57/km,1.83/km & 1.82/km)

10.3.4. Density estimates of Rodents

In total 34 individuals of six species were captured in four study sites of Sariska. Among all species Indian bush rat (*Gollunda ellioti*) was abundant (n=14) across all study sites followed by Little Indian field mouse *(Mus boduga*) (n=10) and Indian gerbil (*Tatera indica*) (n=3). The other species were Soft furred rat (*Millardia meltada*) (n=1), House mouse (*Mus musculus*)(n=3), and Brown rat (*Rattus norvegicus*) (n=3). Sampling of rodent was carried out in all four village sites. Program Mark was used to estimate rodent density for each site. Huggins' p and c model was selected in program Mark for density estimation and minimum AIC value was taken for model selection (Table 10.4). Highest density of rodents was estimated from Slopka (13.08 ± 0.31/ha) followed by Bhagani (9.72 ±1.38/ha), Sukola (9.12 ± 0.42/ha) and Lilunda (3.21± 0.71/ha) (Table 10.4).

Table 10.4. Density of rodents at four different villge of Sariska.

	Model selection	AIC	Density /ha	Standard error
Slopka	Huggins' p and c	226.09	13.08	0.31
Bhagani	Huggins' p and c	130.92	9.72	1.38
Sukola	Huggins' p and c	155.38	9.12	0.42
Lilunda	Huggins' p and c	71.23	3.21	0.71

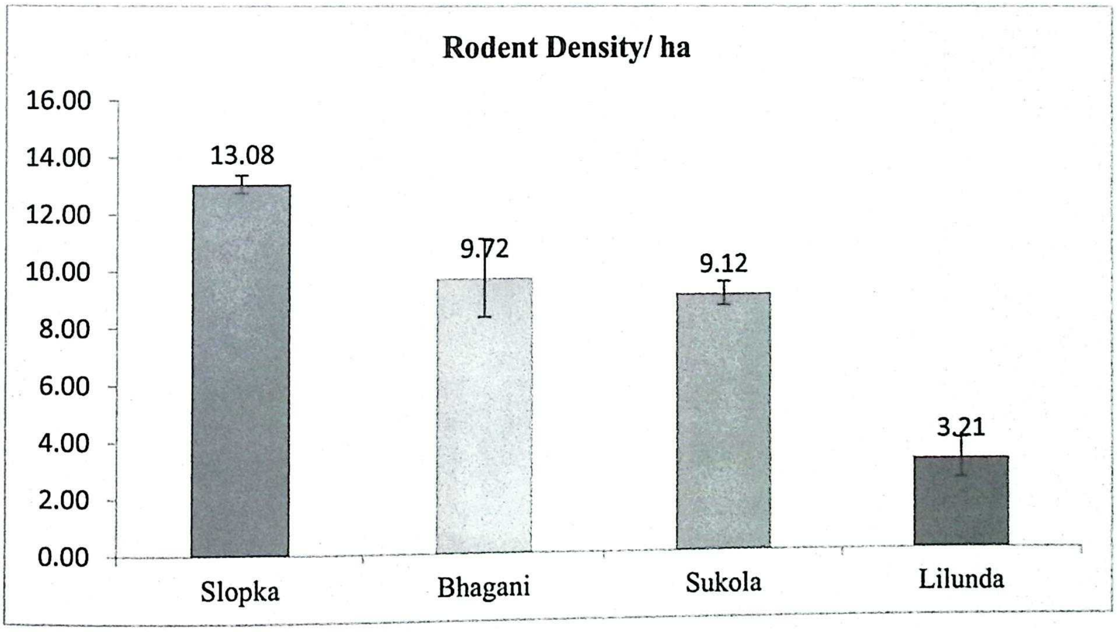


Figure 10.13 Density of rodents at four different villages of Sariska.

Table 10.5: Average body length ,tail length and weight of all rodent species captured during the study period

S. No.	Species	*HBL (mm)	Tail length	Weight (gm)
1	Indian Bush Rat	73.06	78.12	63.15
2	Little Indian Field Mouse	76.83	79.72	65.28
3	Indian Gerbil	77.83	113.00	54.67
4	House Mouse	51.25	60.00	49.38
5	Soft Furred Fat	42.00	50.00	46.00
6	House Mouse	150.00	135.33	164.33

*HBL= Head body length

10.3.5. Vegetation quantification

A total of 45 circular plots of 15m radius circular area were laid in each village. Different Parameters of human disturbance were recorded in each plot. Sign of cutting, lopping and grazing was recorded from each plot. Densities of trees along with canopy cover, shrub cover and presence of invasive species were compared with disturbed and undisturbed site. Abundance of different tree species was computed for all study sites. *Anogeissus pendula* was found to be most abundant tree species (1266 ± 1.43) followed by *Ziziphus mauritiana* (495 ± 0.94), *Butea monosperma* (408 ± 0.73), Boswelia *serrata* (452 ± 0.55) and Acacia catechu (369 ±0.59) (Figure 10.14).

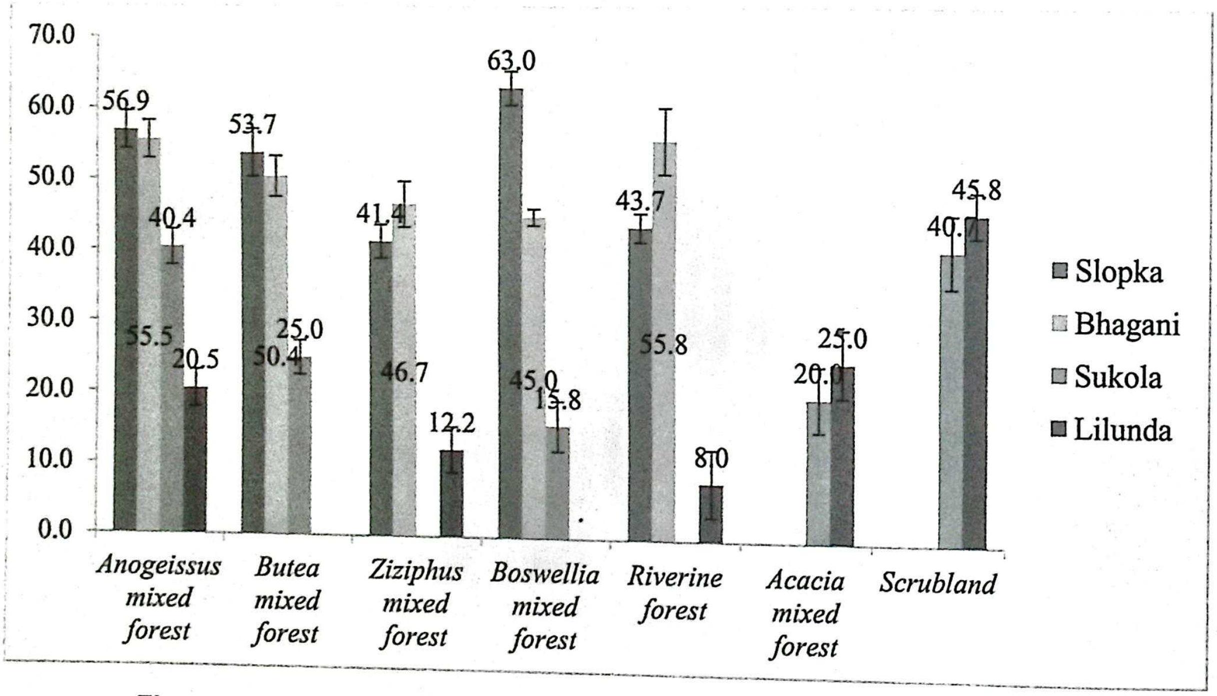


Figure 10.14: Different types of habitat at four village sites in Sariska tiger Reserve.

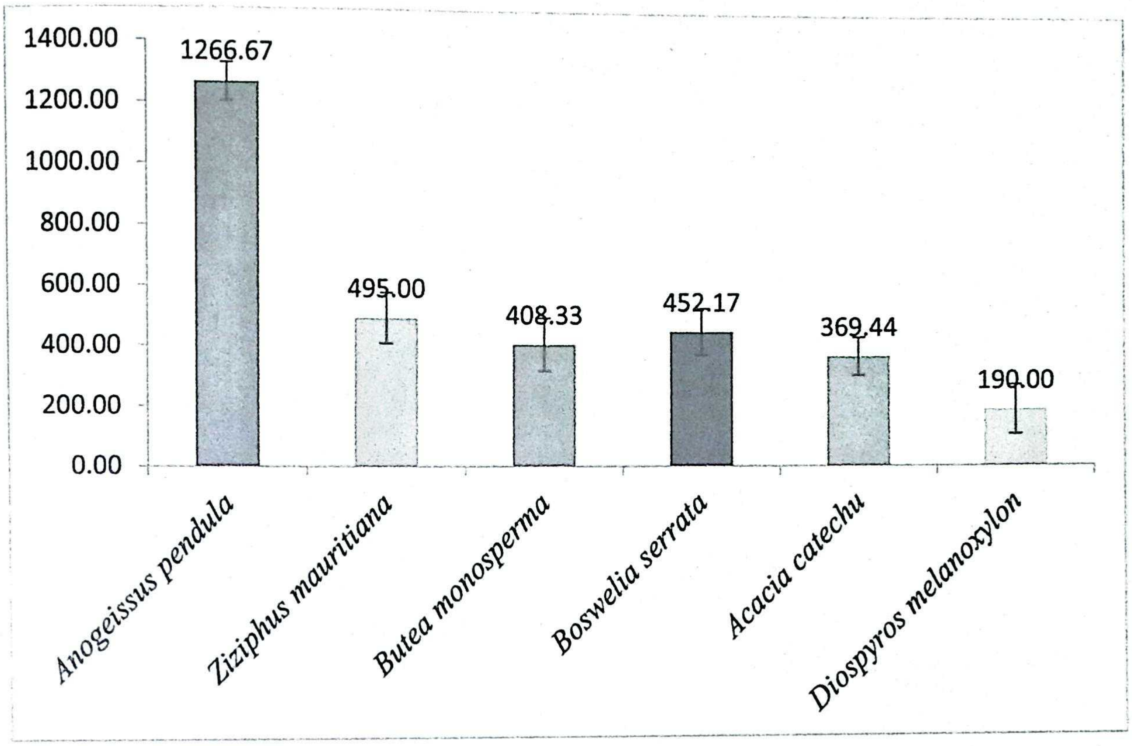


Figure 10.15: Abundance of different tree species in all four village sites of Sariska Tiger reserve.

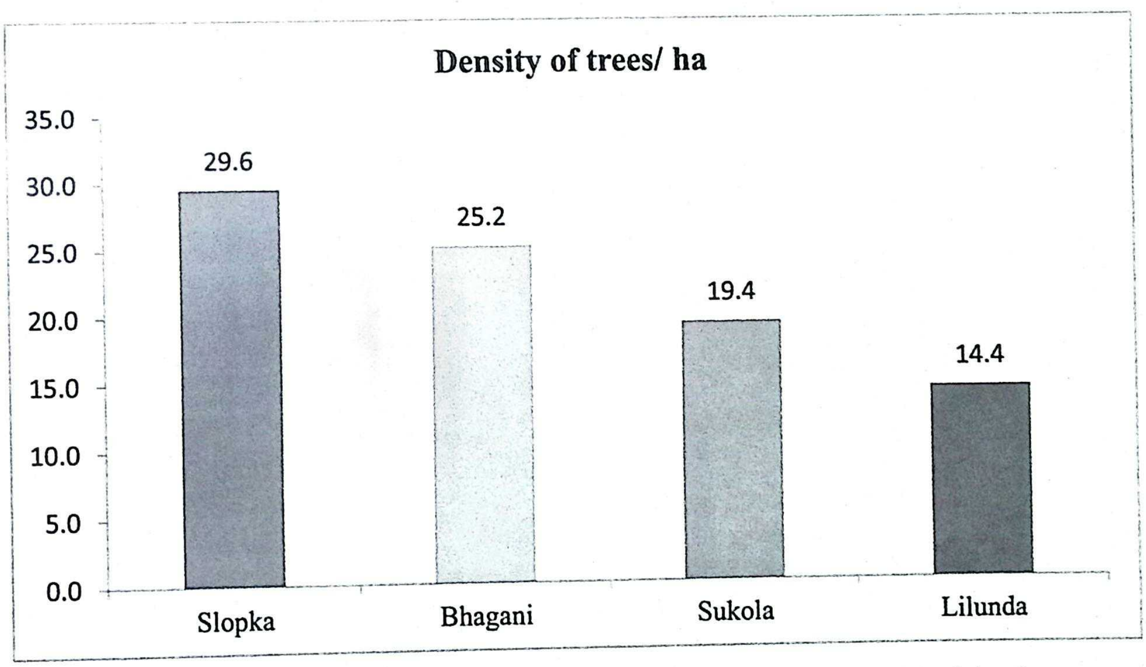


Figure 10.16: Density of tree was computed in different village sites of Sariska tiger reserve.

Densities of trees were assessed for each village site. Estimated density of tree was highest in Slopka (29.6/ha), followed by Bhagani (25.2/ha), Sukola (19.4/ha) and Lilunda (14.4/ha) (Figure 10.16).

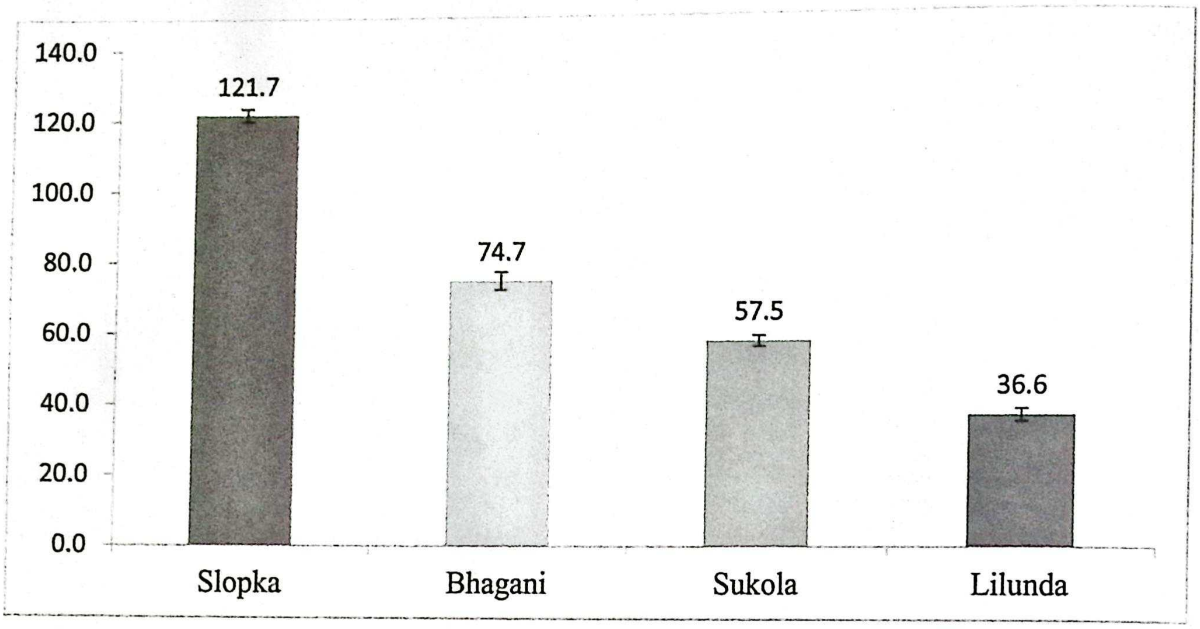


Figure 10.17: Percentages of shrub cover at different village sites of Sariska.

Shrub cover for each was assessed for each village site. Highest shrub cover was recorded from village Slopka (121.7±1.77/ha), followed by Bhagani (74.7±2.50/ha), Sukola (57.5±1.52/ha) and Lilunda (36.6±1.80/ha). (Figure 10.17)

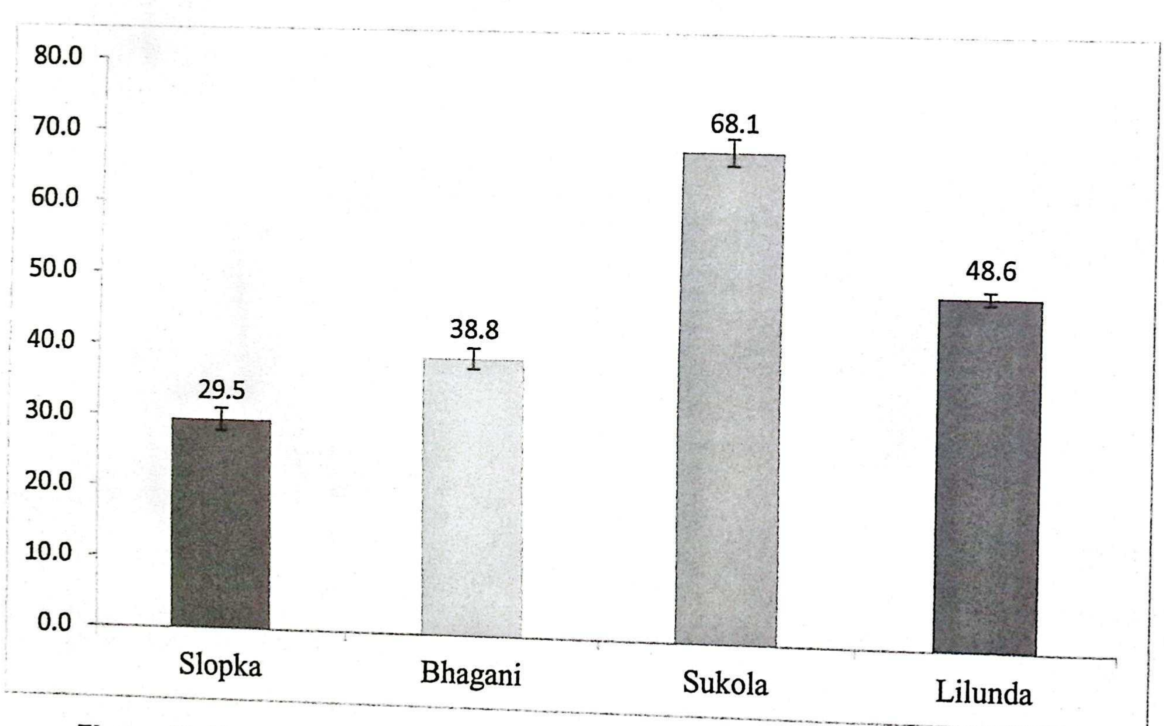


Figure 10.18: Abundance of invasive species at four different sites of Sariska tiger reserve.

Abundance of invasive species was quantified for each village site. Highest abundance of invasive species was found in Sukola (68.1±1.58/ha), followed by Lilunda (48.6±1.44/ha) and Bhagani (38.8±1.87/ha). Among all villages Slopka has the low abundance of invasive species (29.5±0.85/ha). (Figure 10.18)

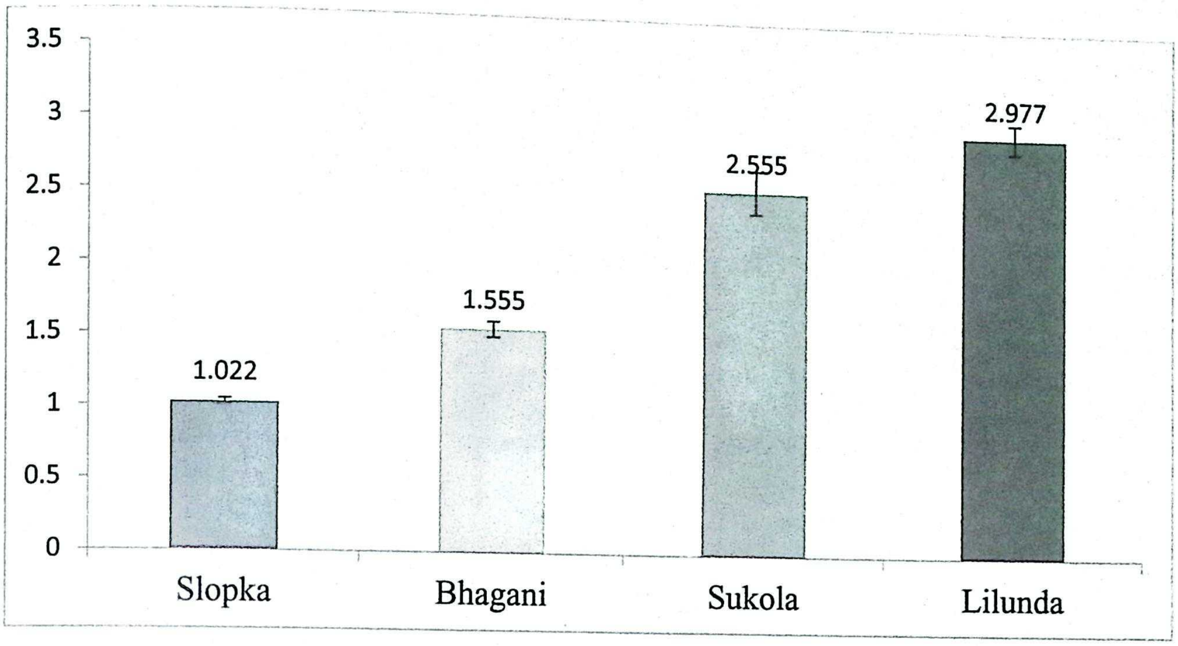


Figure 10.19: Human disturbance in four different sites of Sariska tiger reserve.

Human disturbance for each village site was quantified by scaling 0 to 4 in each plot. Average value was calculated for each village site. Lilunda had the highest score (2.977±0.2/ha), followed by Sukola (2.555±0.05/ha), Bhagani (1.55±0.14/ha) and Slopka (1.022±0.10/ha) (Figure 10.19)

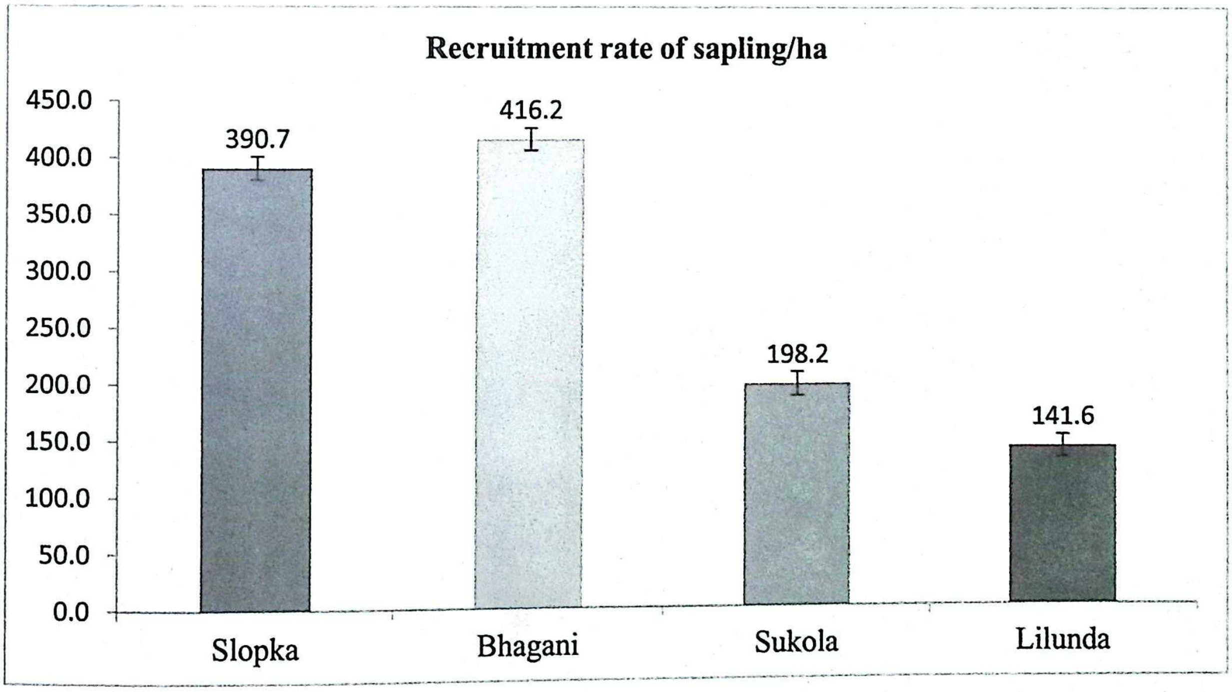


Figure 10.20: Recruitment rate of sapling in four different sites of Sariska tiger reserve.

Number of saplings was counted in each plot for all village sites. Highest recruitment rate was estimated in Bhagani (416.2±10.2/ha), followed by Slopka (390.7±9.83/ha), Sukola (198.2±10.5/ha) and Lilunda (141.6±9.95/ha). (Figure 10.20)

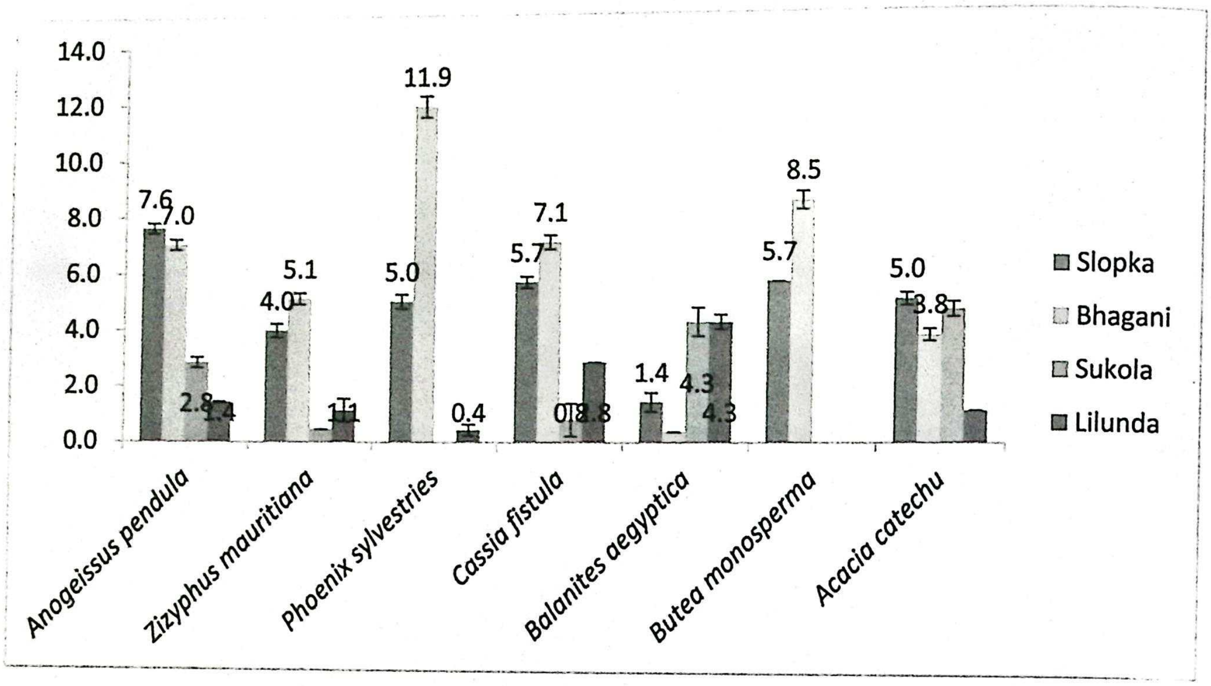


Figure 10.21: Recruitment rate of different tree species in all the four villages.

Recruitment rate of each tree species was observed in each plot. Highest recruitment rate was observed in Anogeissus pendula tree in village Slopka (7.6/ ha) followed by Cassia fistula (5.7/ha), Phoenix sylvestries (5.0/ha) and Butea monosperma (5.7/ha). Bhagani has highest recruitment rate for phoenix tree (11.9/ha), followed by Anogeissus (7.0/ha), Butea (8.5/ha) and Ziziphus (5.1/ha). Village Sukola has highest recruitment rate of Balanites tree (4.3/ha), followed by Acacia (3.8/ha), Anogeissus (2.8/ha). Balanites (4.3/ha) has the highest recruitment rate followed by cassia (2.8/ha) and Anogeissus (1.4/ha). (Figure 10.21)

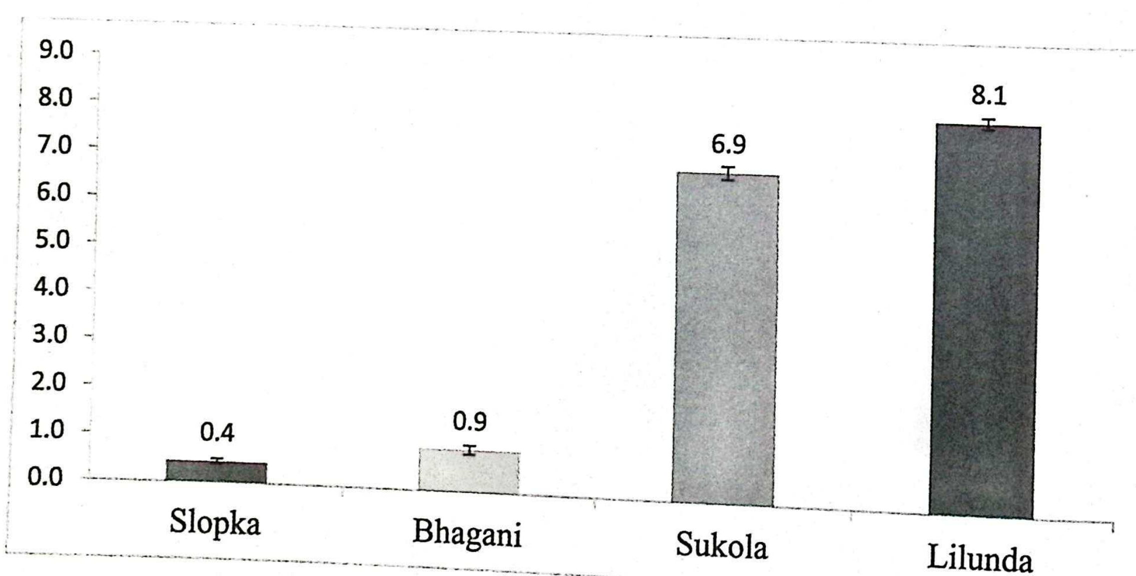


Figure 10.22: Amount of lopping pressure at four different sites of Sariska Tiger Reserve

Highest signs of lopping was found in the village Lilunda (8.1/ ha), followed by Sukola (6.9/ha) and Bhagani (0.9/ha). Slopka has the lowest signs of lopping (0.4/ha). (Figure 10.22)

10.3.6. Results of Camera trapping

In total, 102 camera traps were deployed in all four sites for 1530 camera trap nights during the whole study period. In each village site, approximately 25 camera trap locations were selected for deploying the camera trap. Photographic capture rate of each species was calculated and used for the evaluation of habitat use by wild animals. Activity pattern of wild animals and their overlap with human activity, show marked difference in each village sites respective to the amount of disturbance. A total nineteen species and human were photographed during the entire study period. (Figure 27) Highest capture rate was found for livestock (294.5/100 trap nights), followed by human (252.4/100 trap nights), chital (157.6/100 trap nights) Peafowl (144.9/ 100 trap nights) and Sambar (107.05/trap nights). (Figure 10.23)

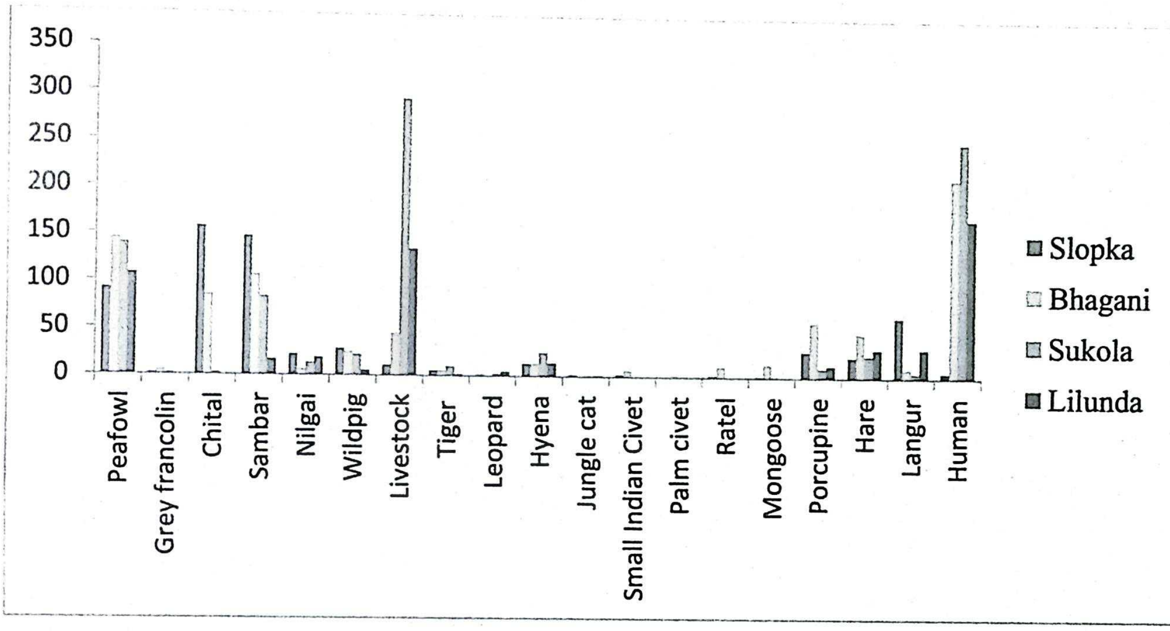


Figure 10.23: Photographic capture rate of all species in the four village sites of Sariska.

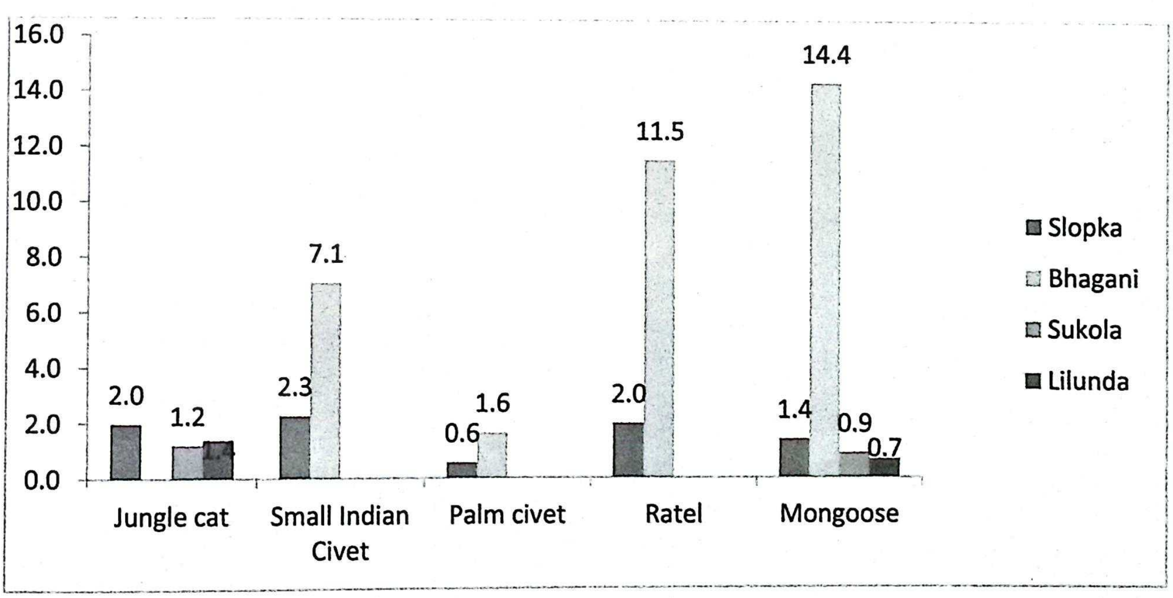


Figure 10.24: Photographic capture rate of Small carnivores in Sariska.

Highest capture rate for small carnivore was recorded from Bhagani followed by Slopka, Sukola and Lilunda. Slopka has the highest capture rate of Small Indian civet (2.3/100 trap nights) followed by

Ratel (2.0/100 trap nights), Jungle cat (2.0/100 trap nights), Mongoose (1.4/100 trap nights) and Palm civet (0.6/100 trap nights). In Bhagani highest capture rate was recorded for Mongoose (14.4/100 trap nights), followed by Ratel (11.5/100 trap nights), Small Indian civet (7.1/100 trap nights) and Palm civet (1.6/ 100 trap nights). Sukola has the capture rate of jungle cat (1.2/100 trap nights) and Mongoose (0.9/100 trap nights). Highest capture rate was found for Jungle cat (1.4/100 trap nights) followed by Mongoose (0.7/100 trap nights) (Figure 10.24).

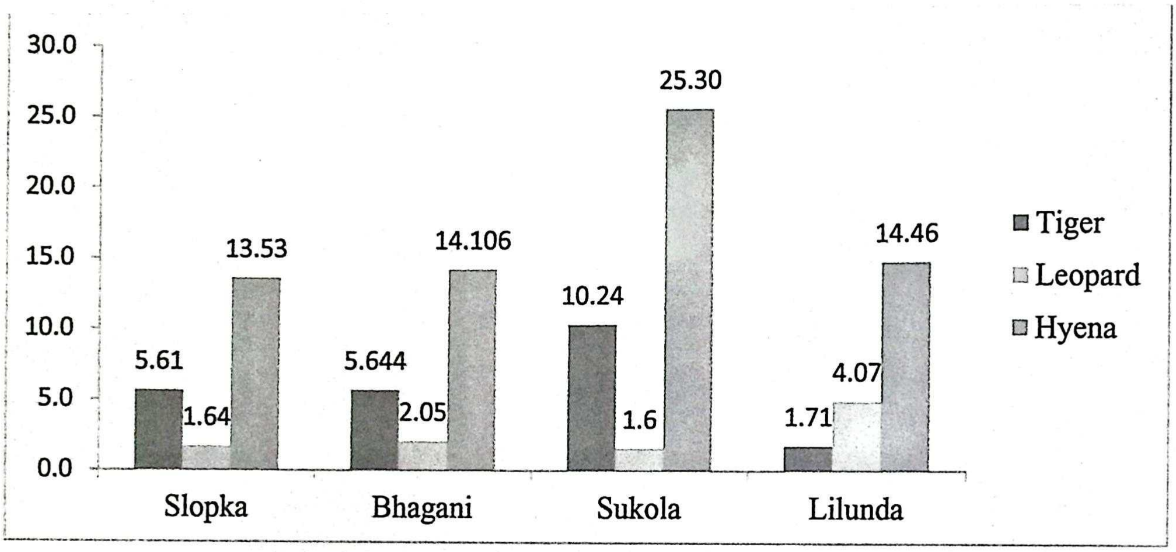


Figure 10.25: Photographic capture rate of large carnivore in all four village sites of Sariska.

Highest capture rate of Tiger (25.30/100 trap nights) was recorded from the Sukola followed by Lilunda (14.46/100 trap nights), Bhagani (14.10/100 trap nights) and lilunda (13.53/100 trap nights). Lilunda has the highest capture rate of leopard (4.07/100 trap nights), followed by the Bhagani (2.05/100 trap nights), Slopka (1.64/ 100 trap nights) and Sukola (1.55/100 trap nights). Highest capture rate of Hyena was found in the village Sukola (10.24/100 trap nights), followed by Bhagani (5.64/100 trap nights), Slopka (5.61/100 trap nights) and Lilunda (1.71/100 trap nights).(Figure 10.25)

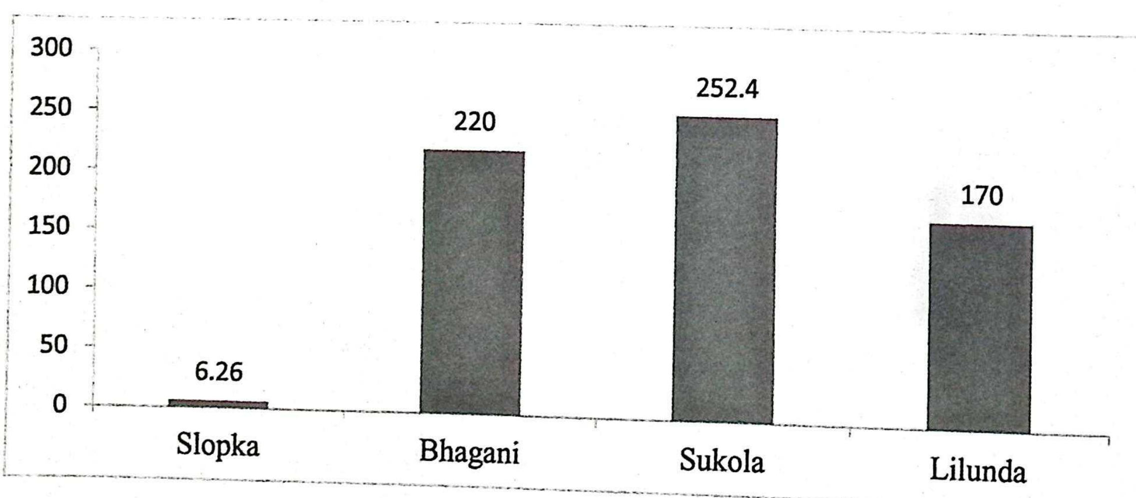


Figure 10.26: Photographic capture rate of Human in all four villages of Sariska.

Highest capture rate was found in the village Sukola (252.4/100 trap nights), Bhagani (220/100 trap nights), Lilunda (170/100 trap nights) and Slopka (6.26/100 trap nights) (Figure 30). Human capture rate was higher in Bhagani because it has a road at the periphery of its boundary. (Figure 10.26 & 10.27)

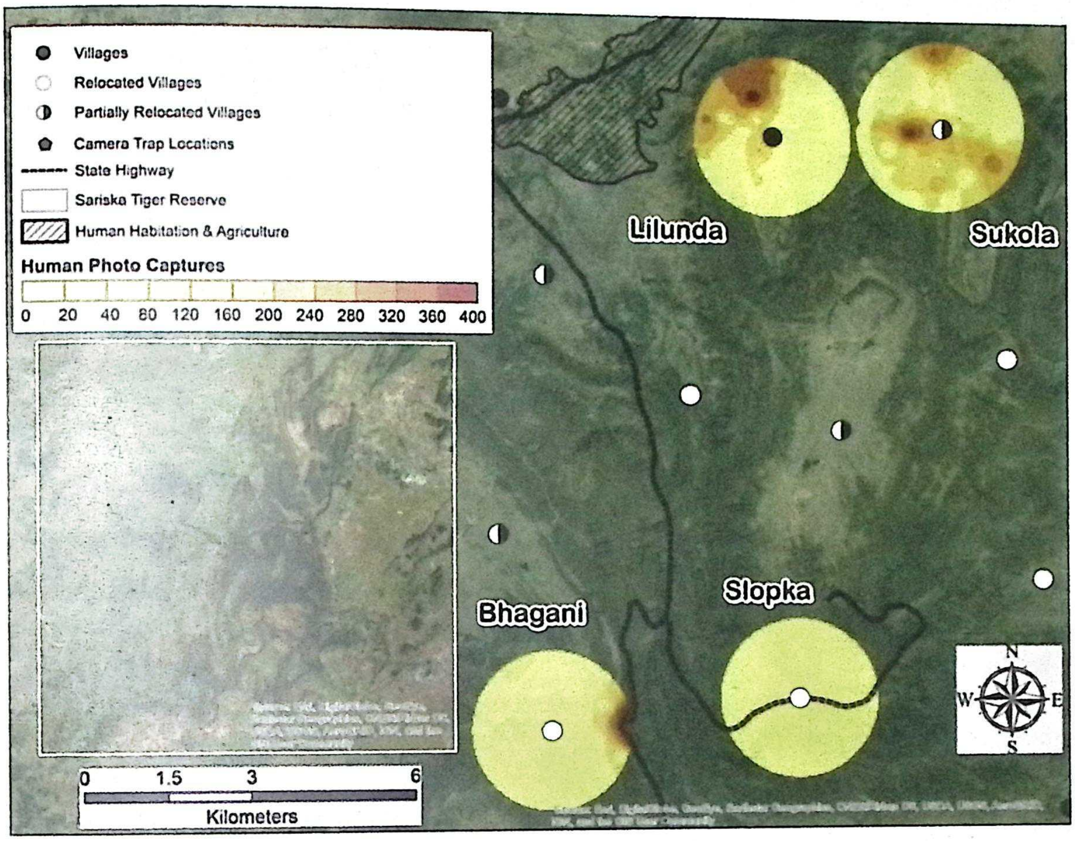


Figure 10.27: Map showing photographic capture rate of Human in four different village sites of Sariska.

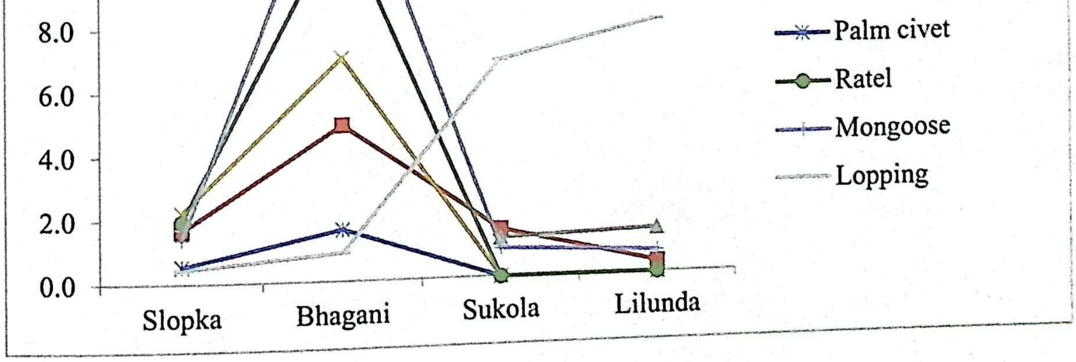


Figure 10.28: Capture rate of Small carnivores along with lopping pressure

Activity pattern of galliformes with humans in relocated village of Slopka

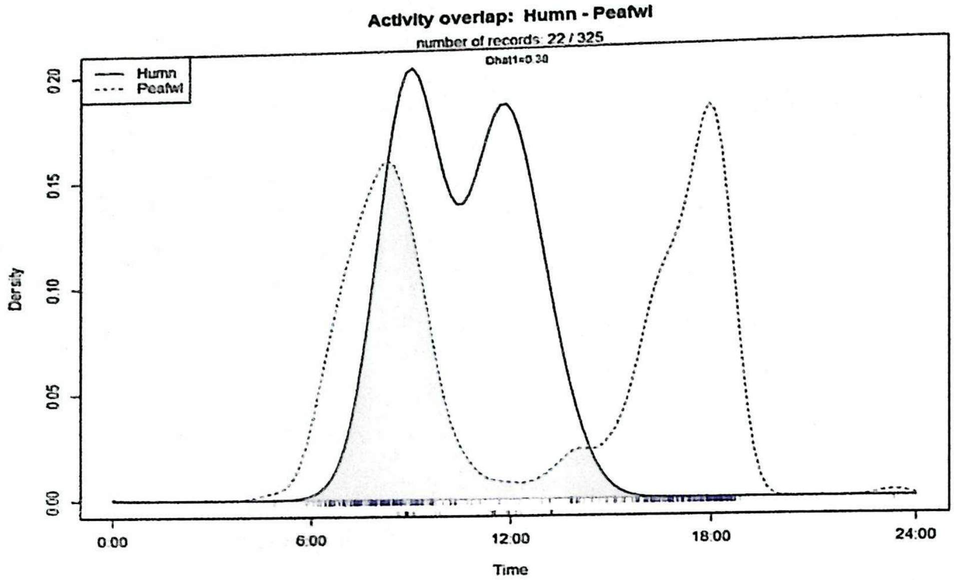


Figure 10.29: Activity overlaps of Peafowl with Human

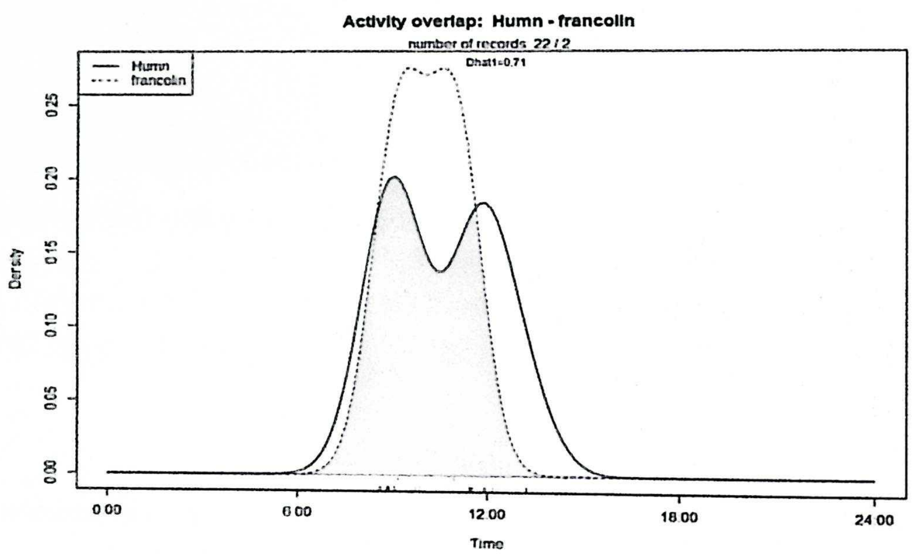


Figure 10.30: Activity overlaps of Grey francolin with human

Activity overlaps of Small carnivores with Human at relocated village Slokpa

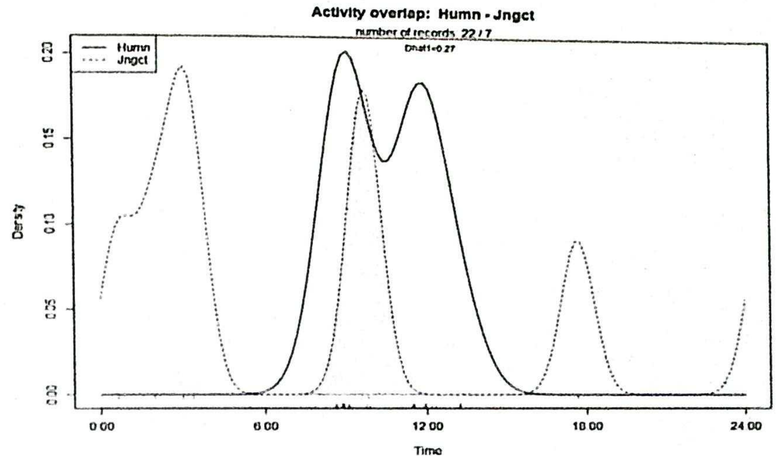


Figure 10.31: Activity overlaps of Jungle cat with Human

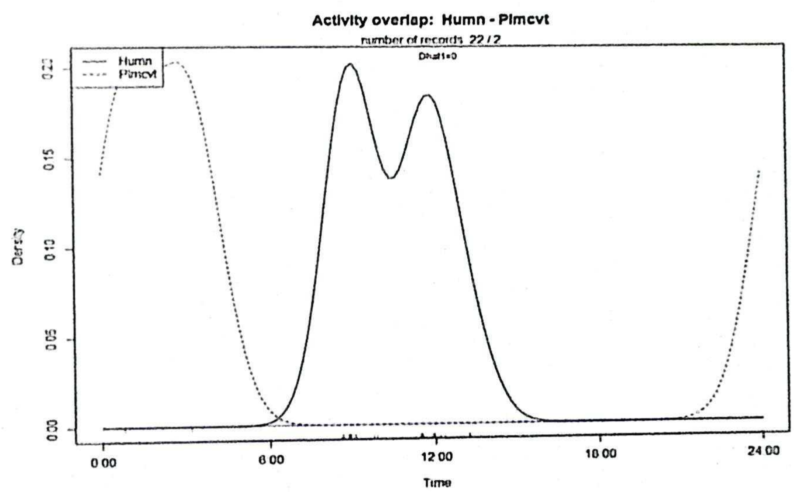


Figure 10.32.- Activity overlaps of Palm civet with Human

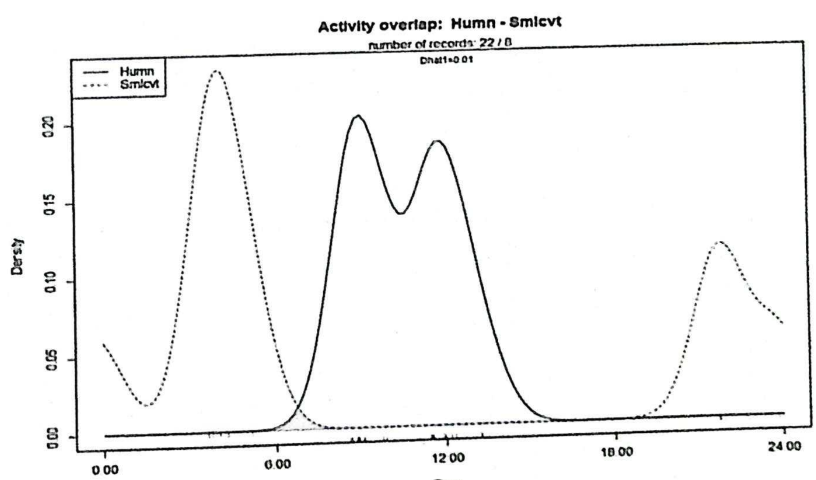


Figure 10.33: Activity overlap of Small Indian civet with Human

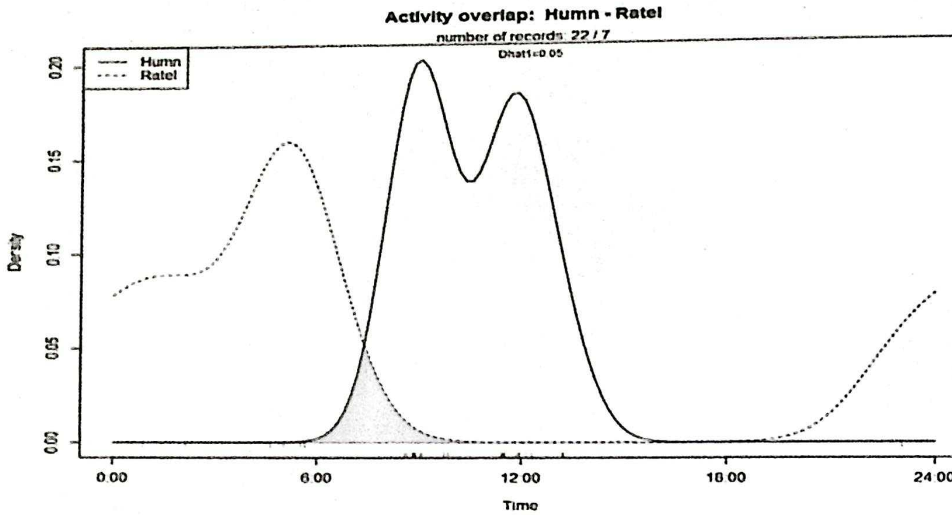


Figure 10.34 –Activity overlaps of Ratel with Human

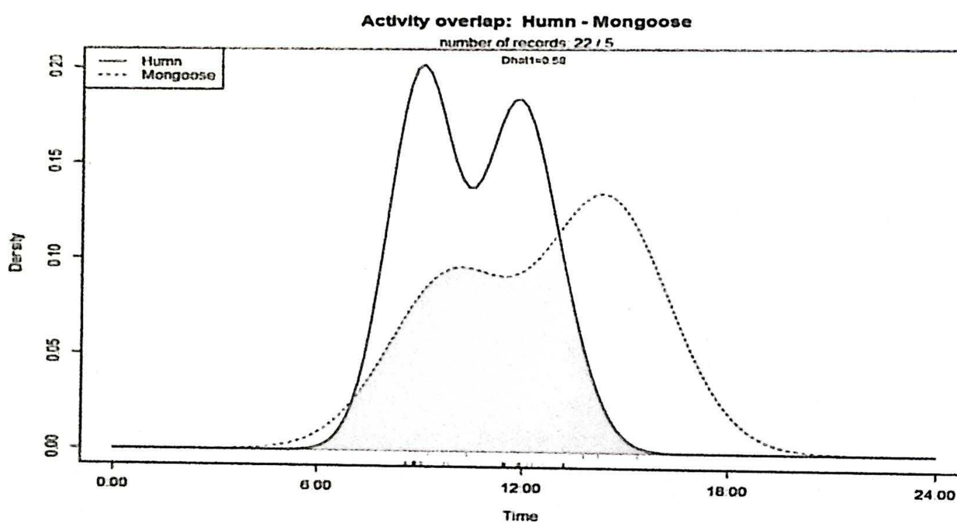


Figure. 10.35. - Activity overlaps of Mongoose with Human

Activity pattern of galliformes with humans in relocated village of Bhagani

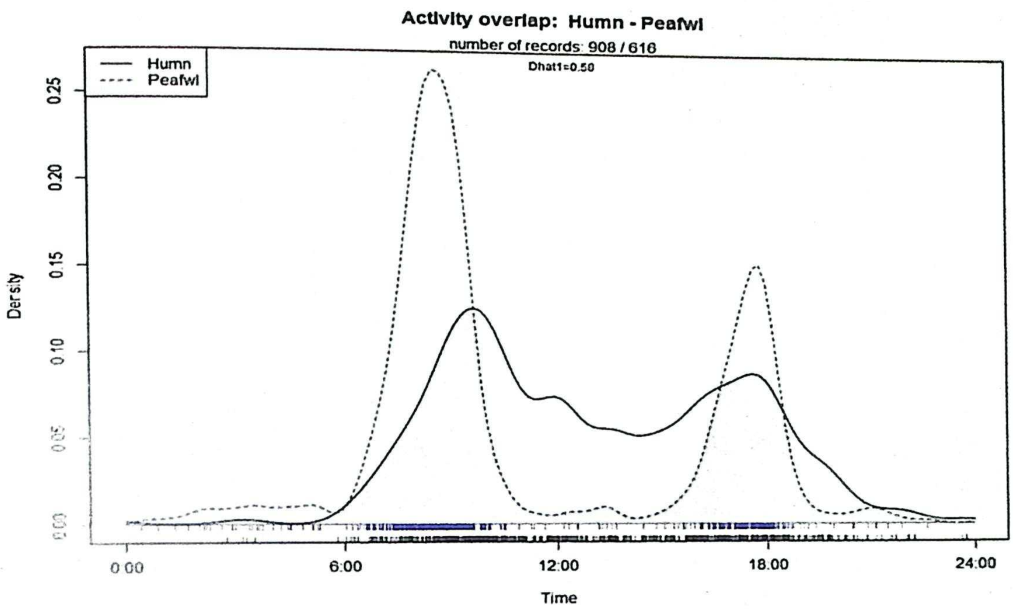


Figure 10.36: Activity overlaps of Peafowl with Humans

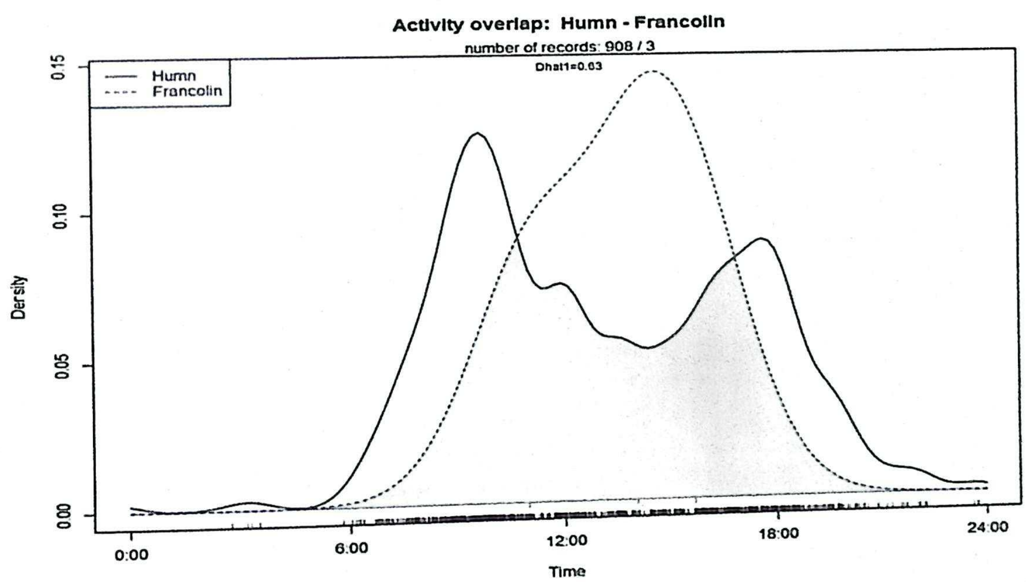


Figure 10.37: Activity overlaps of Grey francolin with Humans

Activity overlaps of Small carnivores with Human at relocated village Bhagani

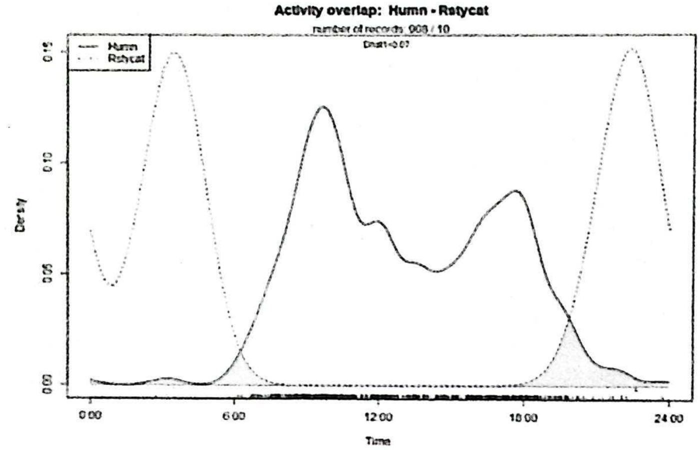


Figure 10.38: Activity overlaps of Rusty spotted cat with Human

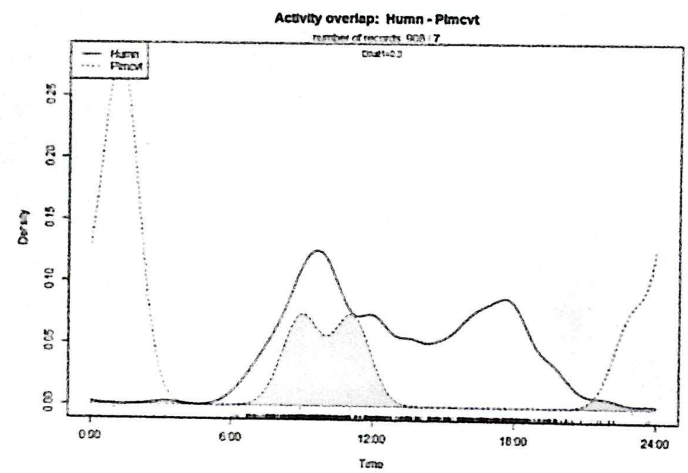


Figure 10.39.: Activity overlap of Palm civet with Human

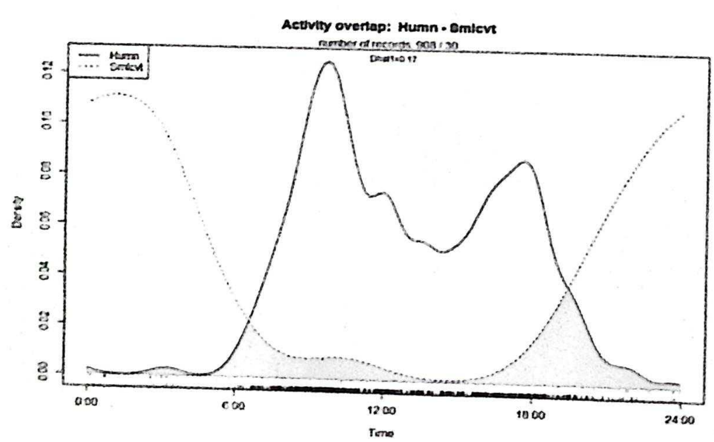


Figure 10.40: Activity overlaps of Small Indian civet with Human

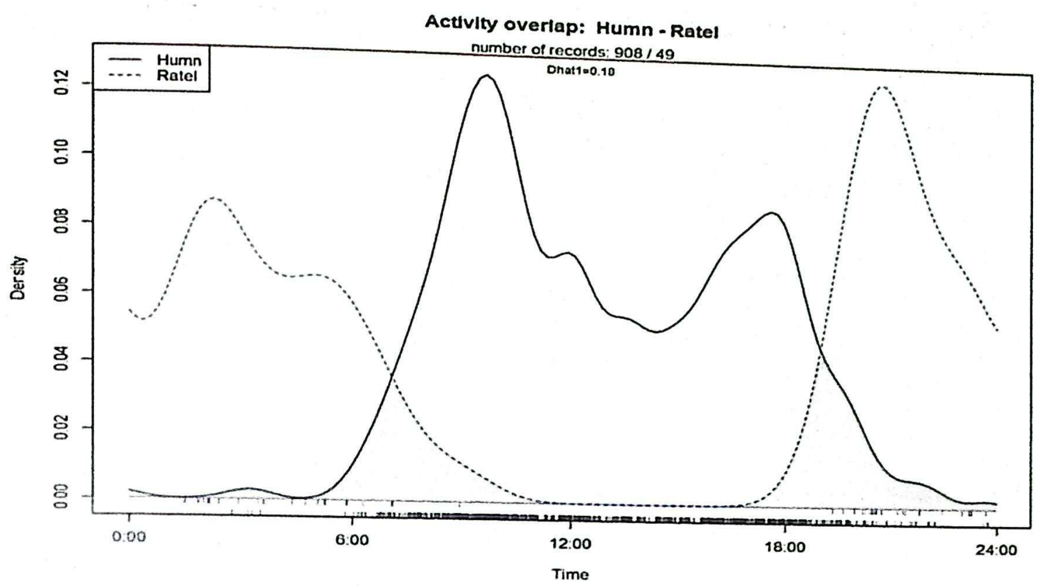


Figure 10.41: Activity Overlaps of Ratel with Human

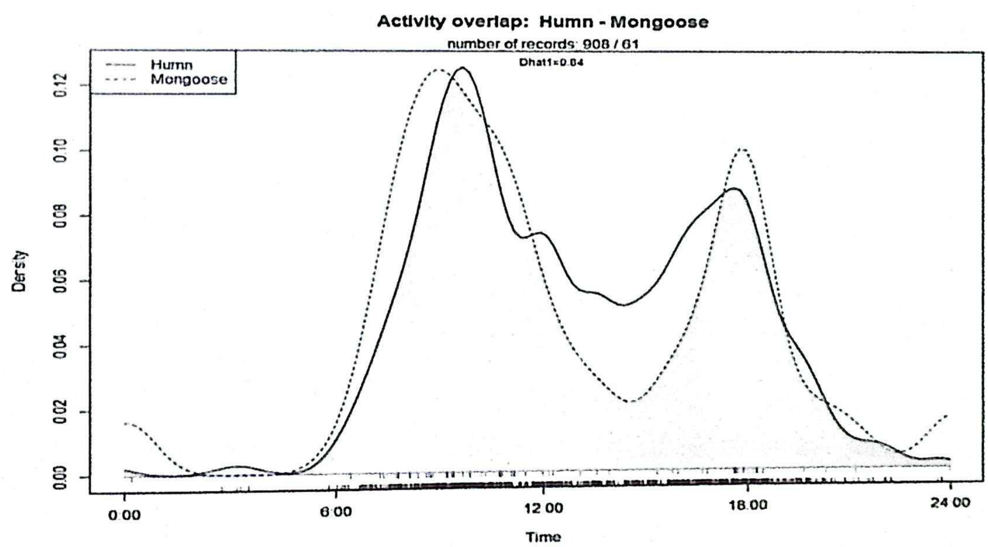


Figure 10.42: Activity overlaps of Mongoose with Human

Activity Pattern of galliformes and small carnivores in non-relocated village of Sukola

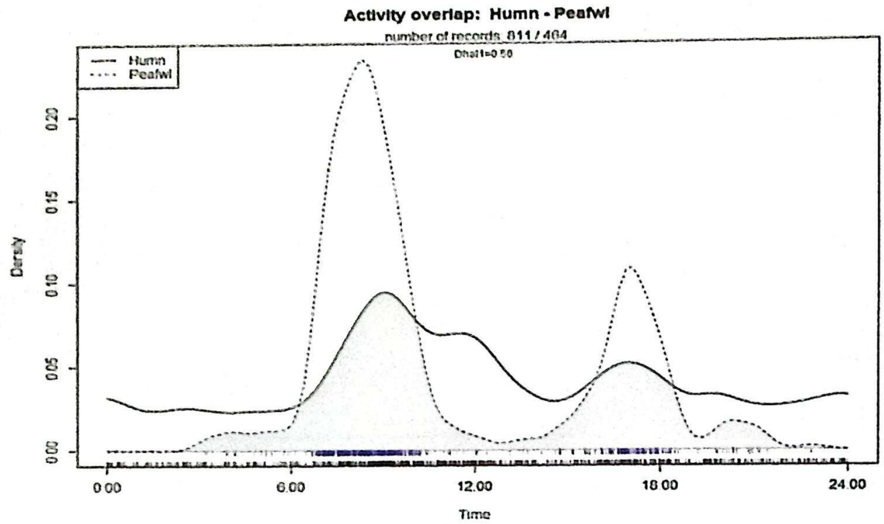


Figure 10.43.: Activity overlaps of Peafowl with Human

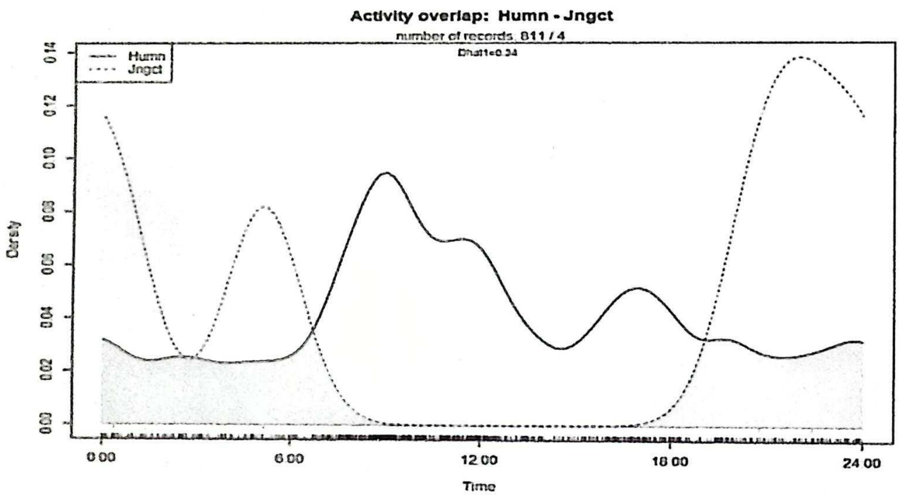


Figure 10.44: Activity overlaps of Jungle cat with Human

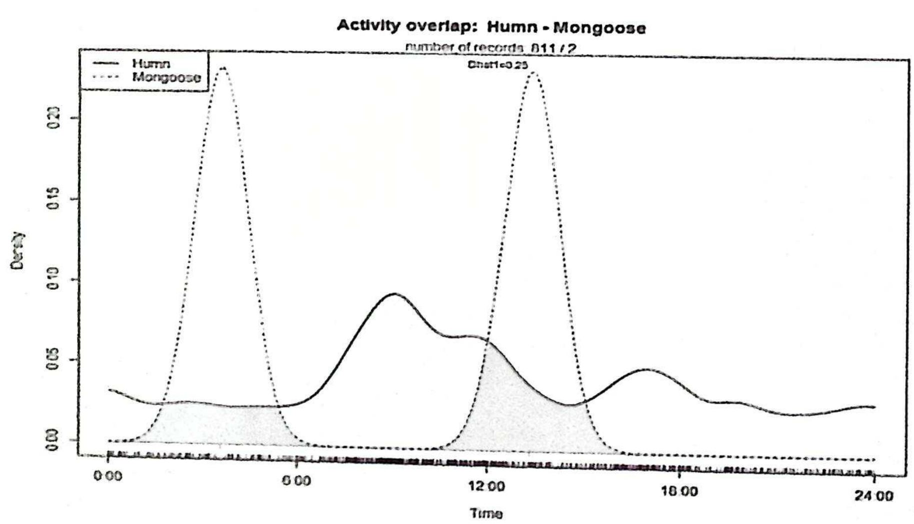


Figure 10.45: Activity overlaps of Mongoose with Human

Activity Patterns of Galliformes and Small carnivores in non-relocated village of Lilunda

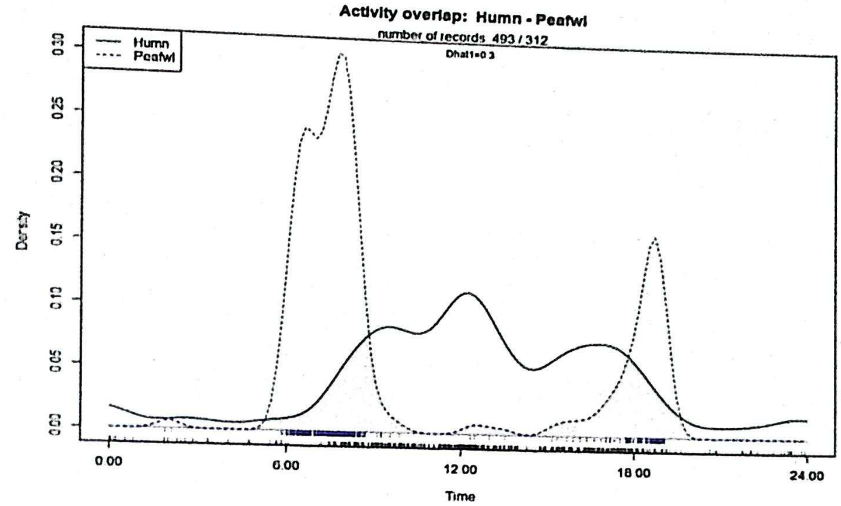


Figure.10.46: Activity overlaps of Peafowl with Human

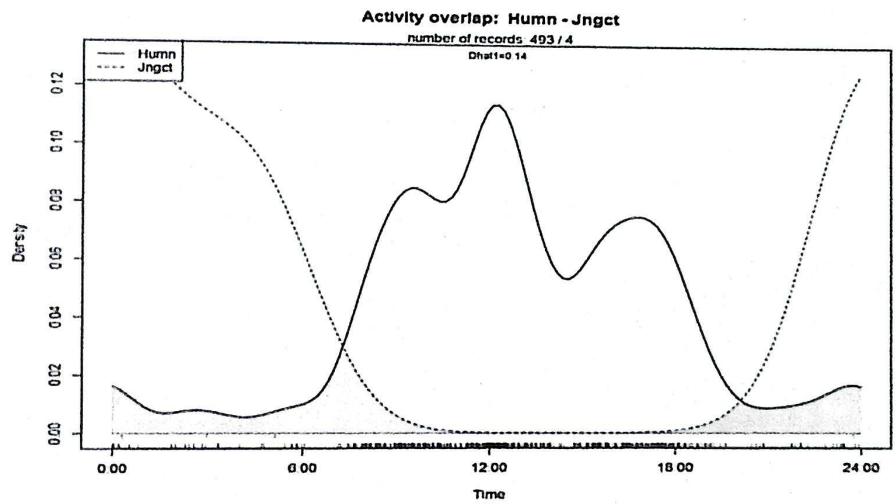


Figure 10.47: Activity overlaps of Jungle cat with Human

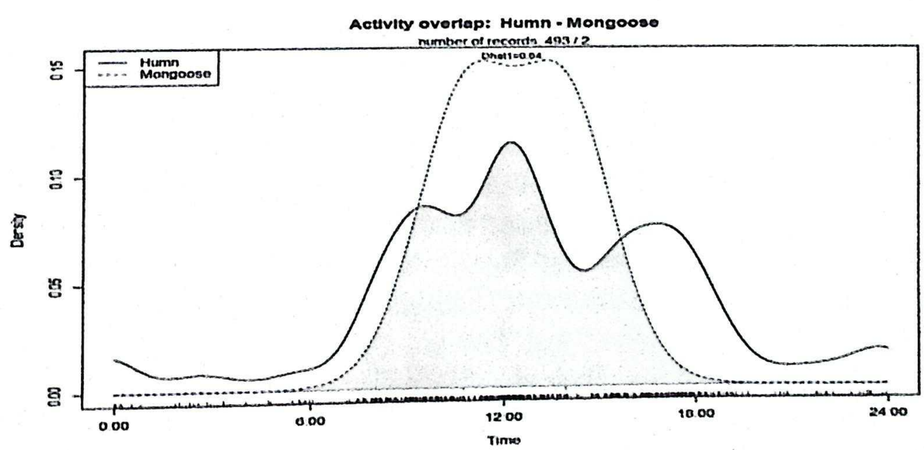


Figure 10.48: Activity overlaps of Mongoose with Human

10.4. Discussion

10.4.1. Effect on Galliformes

As for most wildlife, the single most serious threat to the survival of galliformes is habitat loss, degradation and fragmentation. In fact, they are the most important indicator species and their presence or absence in an area is a good indication of the health of the ecosystem. In this current study assessment of their population was carried out in the Sariska tiger reserve of Rajasthan. Previous studies showed that Sariska has the highest density of peafowl as well as grey francolin (Kidwai et al., 2011). But in Sariska there are 31 villages which are considerable threat for all wildlife as well as ground birds. This reserve has faced high disturbance as form of human presence, biological extraction and grazing pressure. Most of the studies shows that presence of human and livestock has negative impact on galliformes (Bhattacharya et al., 2007). This study was carried out in the relocated and non-relocated villages of Sariska to see the abundance and habitat use of galliformes with respected to disturbance.

The density of ground bird was estimated highest (331.4 ± 75.5) in the village Bhagani which has been relocated 10 years before followed by Slopka (240.4 ± 56 .5), relocated more than 40 years ago. The other two non-relocated sites were Sukola which is partially relocated has the density of 180.7 (± 48.7) birds per sq. Km. The density of galliformes estimated to be 181.3 (± 43.9) per sq km in the village Lilunda. It shows that there is a significant difference in density of ground birds (galliformes) with relocated village to non-relocated village and very less difference among non-relocated villages. But two relocated village has obvious difference in ground bird density. We also compute the peafowl density for each village sites. The density of peafowl found to be highest in Bhagani (158.72 ± 45.6) followed by Lilunda (124.7 ± 38.2), Sukola (115.05 ± 27.4) and Slopka (108.89 ± 32.17). In case of peafowl two non-relocated villages has the highest density than the relocated villages of Slopka. It can be explained by species biology and their specific habitat uses in the study site. In case of galliformes the highest density was observed in two relocated villages because grey francolin (n=23, 20), painted Spurfowl (n=6, 4) and red Spurfowl (n=3, 1) constitute most of the sighting other than peafowl. Where in case of non-relocated site most of sighting made on peafowl. This difference can be observed in encounter rate of each species at different habitat types in different village site. The encounter rate of grey francolin is 4.62 & 4.72/ km in Butea mixed forest and 2.57 & 2.87/Km in Ziziphus mixed forest in Slopka and Bhagani respectively. But in non-relocated village site amount of Butea mixed forest and Ziziphus mixed forest is very less compare to relocated villages. The abundance of grey francolin is also affected by shrub cover and ground cover layer where painted Spurfowl and red Spurfowl both are mostly restricted to riverine forest and bamboo forest. Since, peafowl is a large bodied species; it occupies wide forest areas i.e. open forest, bushland, thorn forest (Madge and Mc Gowan, 2002). Because of human encroachment into their natural territories, peafowl and humans have come into increasing contact (Madge & Mc Gowan, 2002). Peafowl is a disturbance tolerant species; mostly prefer open scrubland, degraded areas than dense forest. Previous studies show that Sariska has the highest galliformes density, peafowl (174/km^2) followed by grey francolin (40.8 /Km^2) and jungle bush quail (20 /km^2) (Gupta et al., 2011). Earlier studies on galliformes showed that they occupy non- overlapping habitats due to their preference to different habitat types. Their abundance also depends on a variety of habitat factors like tree cover, shrub cover, anthropogenic pressures etc. (Kidwai et al., 2011). Non-relocated village may have good densities of galliformes but it is mostly comprises of peafowl density. Because it fails to provide different habitat types, the abundance of other galliformes species is very less which causes low species diversity. While relocated villages has the highest densities of galliformes because it provides different habitat type which is very crucial for maintaining species diversity. As they form a significant prey base, their presence or absence can affect the abundance small carnivores.

10.4.2. Effect on Rodents

Various studies have shown important roles of rodent in the diet of many small and medium sized carnivores. They are found to play an important role by contributing 4.4% in the diet of golden jackal and 34.3% in jungle cat (Gupta et al., 2011). Some of them are the indicator of habitat quality as they mostly depend upon ground layer cover for food and shelter. Sampling of rodent was carried out at four different villages' sites of Sariska tiger reserve to investigate their diversity and abundance. Different type of habitat was selected for rodent trapping at relocated and non-relocated villages of Sariska tiger reserve. The highest density was recorded from the fourteen-year-old relocated village Slopka (13.08 ±0.31) followed by Bhagani (9.72 ±1.38), Sukola (9.12 ± 0.42) and Lilunda (3.21 ± 0.71). Previous study on rodent shows an overall rodent density in winter was (22.92 ±4.65) animals/ha, and 7.81 ±2.25 (SE) animals/ha in summer. Most number of individual was captured in the village Slopka (n=12) followed by Sukola (n=10), Bhagani (n=9) and Lilunda (n=3).Most number of species was captured from the relocated village Bhagani (n=4) followed by Slopka (n=3).Earlier studies suggest that different species of rodents are restricted to specific habitat types for example *Vandeleuria oleracea* was captured only in *Anogessius* dominant forest; and *Millardia meltada* were found in *Butea* mixed forest; *Millardia gleadowi* was captured only in *Butea- Ziziphus* mixed forest; and *Golunda ellioti* was largely captured in open scrubland (Gupta et al., 2011). In this study highest number of rodents were captured in Scrubland (n=10) followed by Ziziphus mixed forest (n=9) and Butea mixed forest (n=8). Relocated village has the highest density of rodents because it provides different types of habitat which is essential for species diversity. Density of rodents might be same in Sukola (partially relocate) with Bhagani (Relocated) but the species composition is different. In Sukola most number of capture species was House mouse (*Mus musculus)* which is known to live near human habitation. While in Bhagani soft furred rat (Milardia meltada) as well as Indian gerbil (*Tatera indica*) and little Indian field mouse (*Mus booduga*) was caught from the forested areas. Only Brown rats (*Rattus norvegicus*) were capture from the non-relocated village Lilunda. It suggests that non-relocated villages might have high density of rodents but their composition was totally different. Both brown rats and house mouse are known to reside near human habitation and indicator of disturbed habitats. While in case of other species like Indian bush rat, Little Indian field mouse and soft furred rat which caught in the relocated village sites, are known to affect negative relation with disturbance. All of this indicates that presence of villages has considerable effect on species composition of small mammals and their abundance. As they are the major prey species, they can affect the abundance of small carnivore locally.

10.4.3. Effect on Vegetation structure

Vegetation sampling was carried out for evaluation of canopy cover, shrub layer and ground layer cover. In each plot amount human disturbance was also recorded. The proportion of the total number of trees showing signs of lopping was recorded. The lopping score for each tree was additionally measured on a scale of 0–4 as follows: 0, no lopping; 1, rudimentary signs of lopping; 2, up to half of the main branches lopped; 3, more than half of the main branches lopped; 4, the tree reduced to a stump. Among all four study sites Lilunda found to be the most habitat followed by Sukola. Sukola was found one of least disturb site.

Computation of vegetation structure shows that Slopka has the highest amount of Boswellia mixed forest (63.0/ ha.) followed by Anogeissus mixed forest (56.9/ha.) Butea mixed forest (53.7/ ha.) and Ziziphus mixed forest (41.4/ha) while Bhagani has most of the area as riverine forest (55.8/sq km) and Anogeissus mixed forest (55.5/ha). The other forest was mostly comprising of butea mixed forest (50.4 /sq.km) and Ziziphus mixed forest (46.7/ha.). The partially relocated village Sukola has most of its area as scrubland (40.07/ha.) followed by Anogeissus mixed (40.4/ha), Butea mixed (25.0/ha.) and acacia mixed forest (20.0/ha.). Lilunda was mostly dominated by Scrubland (45.8/ha), Anogeissus mixed (20.05/ha), acacia mixed (20.0 /ha.) and Ziziphus mix (12.2 /ha) forest. Both of the village sites show the mark difference in terms of vegetation type with relocated village. Slopka and Bhagani both the site has very good amount of Anogeissus mixed forest. Both the non-relocate village site has most of it area as scrubland due to presence disturbance by human and their livestock. Among all across study sites Anogeissus pendula was found to be most dominant tree species (12.67/ha) followed by Butea monosperma (4.08/ha) ,Ziziphus mixed forest (4.95/sq km) and Boswellia mixed forest. The tree density of each village site was also estimated. Slopka has the highest tree density (29558 /ha). Amount shrub cover was also computed for four different sites. Slopka has the dense shrub cover (43/ha) followed by Bhagani (26.37/ha), Sukola (20.37/ha) and Lilunda (12.93/ha). Amount of shrub cover suggest that relocated village site has very minimum disturbance.

Abundance of invasive species was estimated. The results showed that Slopka has very invasive species (14.42/ha) followed by Bhagani (17.72/ha) Sukola (24.06/ha) and Lilunda (19.6/ha). These results showed that presences of human and their livestock cause considerable disturbances in different sites. Amount of human disturbance is also measure in study sites. Slopka has the least affected sites followed by Bhagani. Lilunda has the highest disturbance among all village sites. Lopping pressure was highest in Lilunda (2.84/ha) followed Sukola (2.42/ha) Bhagani. (0.31/ha) and Slopka (.0.15/ha).

10.4.4. Effect on Small carnivores

Photographic capture rate of each species was computed for all across the study site. Livestock has the highest number of capture rate followed by human, chital and peafowl. The camera trap pictures of each sites were analysed in CamtrapR to see the activity overlaps of galliformes species and small carnivores with human.

Slopka: (relocated more than 40 years ago)

In Slopka activity overlap between peafowl and human is found to be 0.38%. The most active time of peafowl was at the 8:00 AM in the morning and 2:00PM in the afternoon. The overlap between grey francolin with human was 0.71 % and most activity time grey francolin was at 10:00 AM in the morning.

The activity pattern of Jungle cat shows very less overlap with human (0.21%) and most activity time period for jungle cat is 10:00 AM in the morning which also indicate the less disturbance in the area. There is no activity overlap between palm civet with human. Being a nocturnal creature palm civet was active mostly at mid night (12:00 AM). Small Indian civet also shows very less, only 0.01% overlaps with human and it was mostly active at 8:00 PM at night. Being highly nocturnal creature ratel shows very less overlap (0.05%) and mostly active after 8:00 PM to through midnight. Mongoose shows activity overlap 0.58% with human and mostly active from 10:00 AM to 1:00PM. Because of very less disturbance animals in Slopka are active according to their biological clock.

Bhagani: (relocated 10 years ago)

In Bhagani peafowl shows 0.58% activity overlap with human and mostly active in the 8:00 AM in the morning and 5:00 PM in the evening. Grey francolin shows 0.63% activity overlap with human and mostly active after 12:00AM in the morning to 5:00 PM in the evening. Activity overlap of Rusty spotted cat with human is very less (0.07%) and show activity after 8:00PM in the evening. Being a highly nocturnal creature palm civet shows very less activity overlap (0.03%) and starts their activity after 12:00 AM. The overlap between activity patterns with human was 0.17% in case of small Indian civet and they start showing activity after 6:00PM in the evening to throughout the night. The activity overlap of Ratel with human is only 0.18% and mostly they start active after 6:00 PM in the evening to throughout the night. Mongoose shows high activity overlap of 0.84% with human and most active at the 10:00 AM in the morning and 5:00 PM in the evening. Activity pattern of animals in Bhagani shows very less affected by human presence or disturbance.

Sukola (Partially relocated)

Sukola was partially relocated and people are still living in these villages and causing a considerable amount of disturbance to the wild animals. The activity overlap of peafowl with human was 0.56% and they are mostly active at 8:00AM in the morning and 5:00PM in the evening. The activity overlap of jungle cat was found to be 0.34% with human and they are most active after 6:00 PM in the evening to till 12:00 PM in the night. Activity overlap between mongoose with human was 0.25% and they show most activity at 6:00 AM in the morning and 1:00 PM at the noon. In Sukola peafowl and jungle cat seems like not so affected by human disturbance but other species of small carnivores are highly affected by the disturbance. Peafowl and jungle cat both are tolerant to human disturbance and reside mostly near to human habitation for easy available food sources. Mongoose is a versatile predator with high adaptability of human disturbances. In fact, they live very close to human habitation. But other wildlife species like Small Indian civet, Palm civet and ratel are known to affect by disturbances.

Lilunda (Not relocated)

Village lilunda is located inside the national park and causes significant disturbances to the wildlife of the park. The activity pattern of peafowl has very less (0.3%) overlap with human because they actively avoid human presence. Their activity time shows two peaks, one at the 7:00AM in the morning and another one is the 6:00 PM in the evening. The activity pattern of jungle cat with human shows minimum overlap of 0.15% by actively avoiding human presence. They start active at 12:00 AM in the night and stop activity before 5:00AM in the morning. The activity pattern of mongoose shows very high overlap (0.64%) with human. They are the most active at the 12:00 PM in the afternoon. The village lilunda seems to have very high amount disturbance since most of the species which are known to tolerate some amount of disturbance (e.g. –Peafowl, Jungle cat) are also actively avoid human presence by sliding their temporal activity. Except mongoose which are mostly active during day time and shows significant overlap with human activity pattern. Presence of villages inside the protected areas not only causes disturbance to that area but also to the surrounding areas, which makes the whole area unsuitable for many species. This can lead to local extinction of species from a particular area.

CHAPTER 11
POLICY IMPLICATIONS

Approximate mean age of first reproduction of reintroduced tigers in Sariska was comparatively higher (65.33 months) than reported tiger populations from Indian sub-continent. Mean time of first reproduction after reintroduction (31.33 months) was comparatively higher than reintroduced population of Panna. This may be due to scarce availability of inviolate areas suitable for raising cubs. Sariska tigress have taken comparatively longer time to explore and identify areas suitable for breeding resulting in larger home ranges and higher time of first parturition.

11.1 Creation of Inviolate Core

It would be crucial to relocate the prioritized villages in Sariska to create an inviolate core (national park area) for long term conservation of tigers in this landscape. Creation of inviolate core (national park, approximately 400 sq. km) free from disturbance may act as a source for the entire greater Sariska tiger population and would be crucial to maintain source-sink dynamics in this landscape (Figure 11.1).

Moreover, our simulations suggest that the existing small tiger population may crash within 40 years even under highly managed scenario, if the current birth rate continues. Village relocation is essential to create more inviolate space to accelerate the birth rate. Small isolated population without any natural connectivity or without natural dispersal of tigers such as Sariska are vulnerable to extinction even if they have good prey base. Active population management such as supplementation at regular interval is necessary for long term persistence of tigers in Sariska.

11.2 Management Actions Required for Formation and Maintenance of Inviolate Core

Our long-term research indicates recovery of wild ungulate and tiger population following relocation of 565 families from the reserve. Three of the five reintroduced tigresses in Sariska littered after a gap of 4-6 years of reintroduction and have been effectively utilizing the inviolate areas created after village relocation. Currently the population have grown to 14 individuals in Sariska. This have been possible due to the relentless persuasion and efforts of the forest department in relocating about 565 families until now resulting in creation of more inviolate space for tiger breeding. Our long-term study on reintroduced tigers in Sariska documented signs of herbivore population recovery following the relocation and consequently reducing livestock grazing pressure in forest land. Livestock density have decreased by more than 50% over last seven years. Earlier scientific studies have documented recovery of tiger and their prey population following relocation and removal of livestock from major tiger habitats.

However, there are still 7 villages with an estimated 5000 livestock inside the national park, the best available tiger habitat. Although, the livestock density has decreased, the current livestock density is really high (~70-80 livestock/ sq. km). Heavy livestock grazing is not only detrimental to the habitat, but also creates competition for wild ungulates and can cause human-animal conflict. Tigers require inviolate space free from human disturbance for breeding. Presence of villages are an impediment for tiger breeding inside the core area.

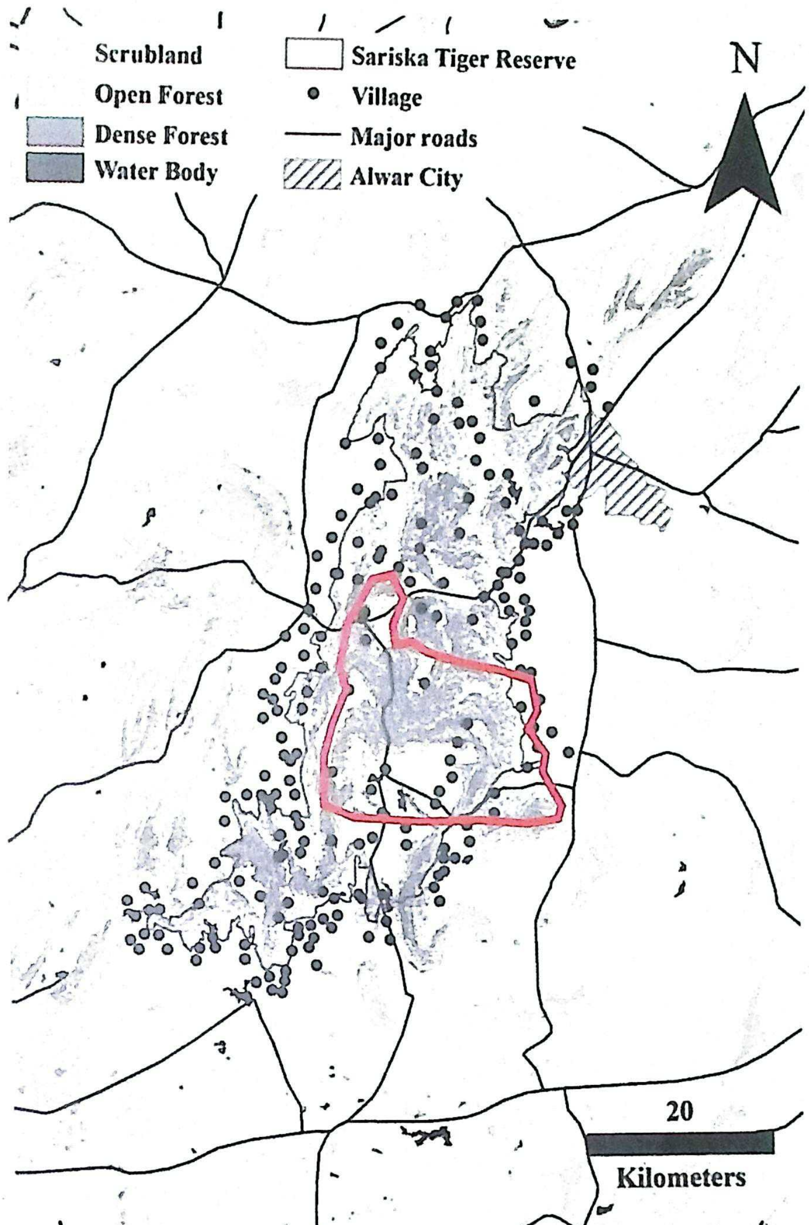


Figure 11.1. Red line indicates the potential highly managed inviolate core

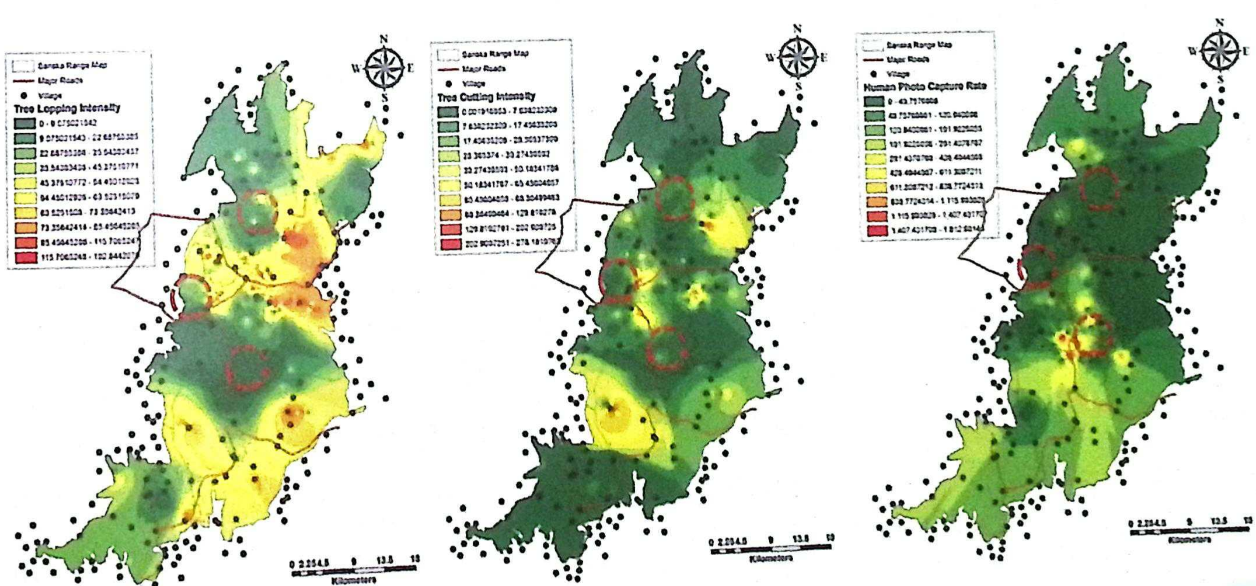


Figure 11.2. Litter spots of reintroduced tigresses against anthropogenic disturbance shows tigresses choose sites with minimal disturbance

11.3 Village relocation

Once, these six prioritized villages are relocated, management should concentrate on complete removal of livestock from these areas and increase man power in at least four chawki (Rotkala, Sukola, Kankwadi and Bana) for further management of these newly created inviolate areas.

11.4 Weed eradication

Eradication of weed is extremely crucial, especially *Cassia tora* and *Lantana camara* from the national park. Sukola offers complex terrain, however, is infested with *Lantana sp. Lantana sp.* should be removed from Sukola following the relocation of Sukola village. There has been an invasion of *Cassia tora* in the Sariska valley resulting in low growth of grass. It is recommended to manually remove *Cassia tora* from the valley.

11.5 Supplementation

Sariska's tiger population is vulnerable to extinction due to its isolation and small size even if it is highly managed. Supplementation in a highly managed scenario with no prey loss and human induced tiger mortality will be crucial for long term survival of the population. Although, ecological carrying capacity of tigers based on prey abundance is comparatively higher, our findings suggest it may be a gross over estimate as suitable breeding area are less to accommodate these many tigers in Sariska.

11.6 Active Population Management

Since most of the individuals belonging from the founder population are old, supplementation with special consideration to age-sex dynamics should be undertaken in future. Sariska's tiger population holds great potential but necessarily calls for adaptive management in future years.

Table 11.1: Age-sex structure and status of individual tigers as of 31.06.2018

Tiger ID	Age (as on June.2018)	No. of litters produced	Current Status (as on June 2018)
ST1 (M)			Dead
ST2 (F)	~ 14.3 yrs	2	Alive
ST3 (F)	~ 11.8 yrs		Alive
ST4 (M)	~ 13.3 yrs		Alive
ST5 (F)	~ 10.8 yrs		-
ST6 (M)	~ 11.8 yrs		Alive
ST7 (F)	~ 6.3 yrs		Alive
ST8 (F)	~ 6.3 yrs		Alive
ST9 (F)	~ 7.3 yrs	1	Alive
ST10 (F)	~ 7.3 yrs	1	Alive
ST11 (M)	~ 4.3 yrs		Dead
ST12 (F)	~ 4.3 yrs		Alive
ST13 (M)	~ 4.3 yrs		Alive
ST14 (F)	~ 4.3 yrs	1	Alive
ST15 (M)	~ 2.8 yrs		Alive

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