

Monitoring tiger and its prey in Chilla Range, Rajaji National Park, Uttaranchal, India

**Abishek Harihar,
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भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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Summary

The Rajaji National Park along with the adjoining Corbett Tiger Reserve forms the north-western limit for the distribution of the Tiger and Elephant in the Indian Subcontinent. Most parts of this landscape are under anthropogenic influence. Following the notification of the earlier sanctuaries (Rajaji, Motichur & Chilla) to a National Park (Rajaji National Park) in 1983, voluntary relocation of human (Gujjar community) settlements is underway (since 2002). The Chilla Range of Rajaji National Park is presently void of human settlements (Gujjars) and is showing very healthy resurgence of vegetation indicating promising signs of recovery with respect to utilization of the area by wildlife. This study carried out across two years (2004-2005 to 2005-2006) aimed at monitoring the tiger population within Chilla range following a human resettlement program. Photographic capture-recapture analysis (450 trap nights each year) was used to estimate the density of tigers. Ecological density of wild ungulate prey species was estimated using line transects in conjunction with distance sampling. A total of nine permanent transects were laid and sampled eight times each, every year (102.8 km of walk each year). Food habits of tiger were determined by analysing field collected scats. Our results indicated that Chilla range supports a high ungulate prey density (76.5 individuals km⁻² in 2005; 70.98 individuals km⁻² in 2006) and has the highest reported sambar density (25.67 individuals km⁻² in 2005; 24.69 individuals km⁻² in 2006). Though we photographed 12 different individuals during our study (2004-06), the tiger density was found to be low (3.01 tigers 100km⁻² in 2005; 2.54 tigers 100km⁻² in 2006). The current wild prey biomass off take by tigers was estimated to be 2.78%. However, a predicted ~14 tigers 100km⁻² can be supported within Chilla range given a 10% biomass off take (following the model developed by Karanth et al., 2004b). Past anthropogenic pressures have probably caused a downward trend in the tiger densities. From the photographs obtained during this study, it is clear that tigers are breeding in Chilla range. Given adequate protection Chilla can serve as a major source population from where tigers will breed and disperse into neighbouring forests within the Shivalik landscape. A continuous monitoring program is envisaged to document this recovery of predators, prey and their habitat.



1. Introduction



Conservation initiatives such as Project Tiger and Project Elephant have helped save India's declining population of tigers, elephants and a wide range of species that live along side them. However, with about 69% of India's protected areas being inhabited by people (Saloni, 1996) and the recent crisis of vanishing tiger populations, the fact that most reserves are faced with severe anthropogenic pressures is increasingly becoming a cause of concern. Vast tracts of forested landscape that once housed large mammals have now been lost to human habitation. This has caused a sharp decline in animal populations and confined many of the remaining populations to small, isolated, less productive forests. A major problem in conserving and managing large mammal species is the relative lack of reliable quantitative information regarding their distribution, abundance and habitat requirements, using which, the effectiveness of management practices can be assessed and goals set for the future.

Rajaji National Park (RNP) along with Corbett Tiger Reserve (CTR) and its adjoining forests are one of the largest contiguous patches of forest (7500 km²), and forms the north western limit of the tiger (*Panthera tigris* L.) and elephant (*Elephas maximus* L.) distribution in India (Johnsingh & Negi, 2003). Known as the Rajaji Corbett Tiger Conservation Unit (RCTCU, Johnsingh & Negi, 2003) it is a level I Tiger Conservation Unit (TCU I, Wikramanayake *et al.*, 1998) identified for the long term persistence of the species. Most parts of this landscape are however under severe anthropogenic pressure. Following the notification of the earlier sanctuaries (Rajaji, Motichur & Chilla) to a National park (RNP) in 1983, voluntary relocation of human (*Gujjar* community) settlements is underway. As a pilot programme in 2003, 74 *gujjar* settlements have been shifted out from the Chilla range along the eastern part of RNP, making the area relatively free from anthropogenic influence. Presently void of human settlements, the study area has shown a very healthy resurgence of vegetation indicating promising signs of recovery with respect to utilization of the area by wildlife (Pandav *et al.*, 2004). However, our understanding of habitat recovery in Chilla will only be possible if we can monitor the habitat over years. Considering the need to monitor the changes after relocation of *gujjars* the present study was formulated with the following objectives:

- I. To estimate the tiger population inhabiting the study area using photographic capture recaptures,
- II. To estimate ecological density and biomass of the wild ungulate prey species (sambar, chital, wild pig and nilgai) and
- III. To study food habits of the tiger.

Estimating populations to monitor habitats

Population estimation of wild animals is of prime importance to ecologists and managers. In most situations the goals of managing natural animal populations are expressed in terms of population size. For the purpose of monitoring habitats, it would be of interest to estimate the population size from the same place over years to better explain the status of the population and thus the habitat. A population estimate is an approximation of population size (N) derived from a sample of the population (C), accounting for the fact that not all the animals in the study area are counted but assuming that the sample represents the entire population to which we wish to draw



our inferences. The estimate of the population size is thus computed by estimating the proportion of animals of the entire population that have been sampled.

$$\hat{N} = C / \hat{p}$$

\hat{N} - The estimate of the population size, \hat{p} - detection probability or capture probability

While estimating the populations of tigers and other individually identifiable animals, (primarily carnivores) camera trapping within a capture-recapture framework has been found reliable (Karanth, 1995, Karanth & Nichols 1998, 2000, 2002, O'Brien *et al.*, 2003, Trolle & Kery 2003, Karanth *et al.*, 2004a). The use of cameras to capture individually marked or identifiable animals and photographically recapture them has aided in estimating population parameters. The capture-recapture theory requires that all animals be identified with surety. By estimating the capture probability an estimate of the population size is arrived at (Nichols 1992) for each sampling period (primary period) and estimates of survival (s), emigration ("?) and immigration ("?) aid monitor populations across sampling periods (Kendall, Nichols & Hines, 1997).

Since ungulates make up the major part of tigers' diet (Schaller 1967; Seidensticker 1976; Karanth & Sunquist 1995), understanding herbivore populations and their distributions serve as an important part of studies on predator ecology (Karanth & Sunquist 1995). Estimation of ungulate population has largely been carried out by using distance sampling methods (Anderson *et al.*, 1979; Burnham, Anderson & Laake, 1980; Buckland *et al.*, 1993) through repeated monitoring on line transects (Karanth & Nichols 1998; Biswas & Sankar 2002; Bagchi, Goyal & Sankar, 2003; Jathanna, Karanth & Johnsingh, 2003). Distance based methods estimate the detection probability as a function of distance measured from the line-to-object, thereby estimating the population as a function of area (A).

$$\hat{D} = \hat{N} / A$$

[\hat{D} = Density]

Estimates of density (\hat{D}) derived from each sampling period can then be compared to view trends in populations.

Understanding predator-prey relationships

The acquisition of food is a fundamental component of every organism's existence. As in the case of tiger and other large mammalian predators, prey selection is critical for understanding life history strategies (Miquelle *et al.*, 1999). Collecting data from kill sites (Johnsingh 1983, Karanth & Sunquist 1995) and scats from field (eg. Biswas & Sankar 2002, Sankar & Johnsingh 2002) has helped in our understanding of predatory ecology. Most literature on tiger food habits suggest that large bodied prey is selected over smaller size classes (Karanth & Sunquist 1995). By relating energy requirements (Carbone & Gittleman 2002, Karanth *et al.*, 2004b) of predators to that supported by habitats, responses of predator populations to prey density and biomass has been better understood. It is thus important to note that understanding relationships of energy requirements and associated costs and benefits is crucial to ecological studies and conservation practices alike.



The study of animal abundance across the Indian sub-continent reveals that ecological densities of ungulate species range from a total of 10 individuals/km² (Jathanna *et al.*, 2003) to 90.3 individuals/km² (Biswas & Sankar 2002). This range of values brings to notice that habitat types across the subcontinent support varied densities of ungulate species (Karanth *et al.*, 2004b). On comparing biomass 1064 kg/km² (Jathanna *et al.*, 2003) to 7638 kg/km² (Karanth & Nichols 1998), it is evident that variations in prey biomass and densities between habitat types exist, thus bringing to our notice that tiger populations would also vary in response to these changes (Karanth *et al.*, 2004b).

Study area

The Rajaji National Park (RNP, 820 km²) is divided by the Ganges into an eastern half comprising of Chilla (148 km²) and Gohri Ranges and Motichur, Hardwar, Dholkhand East and West, Kansrao and Chillawali Ranges on the western half (Fig. 1). Both these parts of the RNP are connected by the narrow Chilla-Motichur corridor (Johnsingh, Prasad & Goyal, 1990). This corridor along with the Rajaji-Corbett corridor maintains the contiguity with the Corbett Tiger reserve thus making this Rajaji Corbett Tiger Conservation Unit (RCTCU - Johnsingh & Negi, 2003).

The study area is characterised by rugged hills ranging from 400 m to 800 m in altitude with steep southern slopes and is drained by rivers and streams running north to south, most of which remain dry in late winter and summer. Broadly, the forests of this region can be categorized as Northern Indian Moist Deciduous Forest and Northern Tropical Dry Deciduous Forest (Champion & Seth, 1968). In addition to supporting a population of tiger and elephant, the area also supports leopard *Panthera pardus* L., sambar *Cervus unicolor* Kerr, chital *Axis axis* Erxleben, barking deer *Muntiacus muntjak* Zimmerman, nilgai *Boselaphus tragocamelus* Pallas, wild pig *Sus scrofa* L., goral *Nemorhaedus goral* Hardwicke., common langur *Semnopithecus entellus* Dufresne, Rhesus macaque *Macaca mulatta* Zimmerman, porcupine *Hystrix indica* Kerr, hare *Lepus nigricollis* Cuvier., and Indian peafowl *Pavo cristatus* L (see Other animals photographed). Domestic livestock (chiefly cattle and buffalo) are also potential prey species.

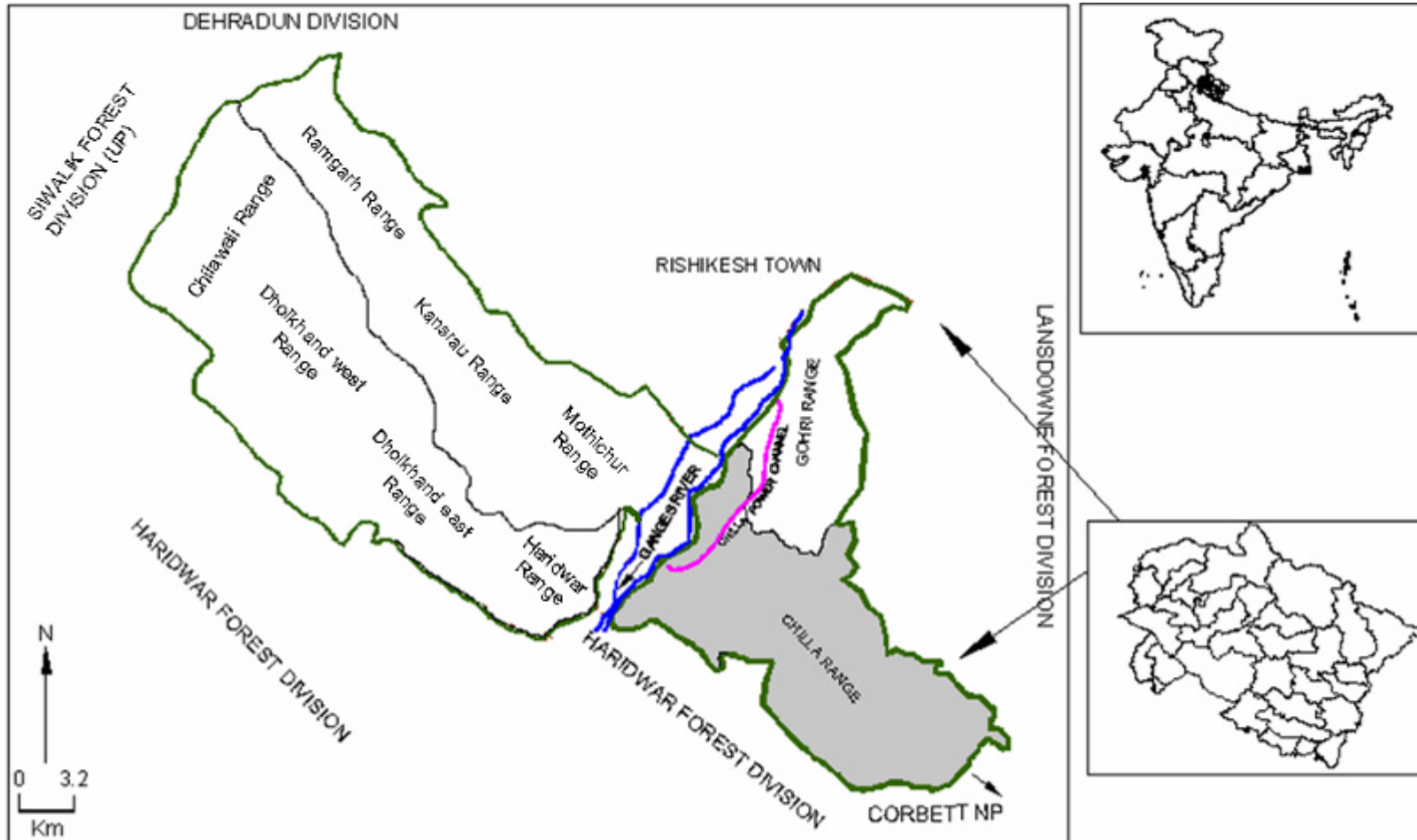


Figure 1. Chilla range – study area in Rajaji National Park.



2. Methods



Estimating tiger population

In order to monitor the population of tigers in the study area photographic capture-recapture analysis was chosen (Karanth, 1995; Karanth & Nichols, 1998). Thirty camera-trapping stations were identified (Fig. 2a & 2b, Annexure I a & b) following a reconnaissance (November – December 2004). These trapping stations were selected so as to maximise the capture probabilities of tigers (Karanth, 1995). In order to systematically sample the area, 3 sampling blocks (spatially separated) were identified within the intensive study area and the cameras were deployed in a phased manner. Each sampling block consisted of 10 trap sites run for 15 consecutive days. Thus, each sampling occasion combined captures from 1 day drawn from each block. All rolls of film used during the trapping were given a unique identity (e.g. Block1/Trap1/Roll1) so as to correctly note the date, time and location of the captures. Every tiger captured was given a unique identification number (e.g. RT-001) after examining the stripe pattern on the flanks, limbs and forequarters (Schaller, 1967; McDougal, 1977; Karanth, 1995).

Following the identification of tigers, capture histories (X matrix) were developed and analysed using program CAPTURE (Otis *et al.*, 1978; White *et al.*, 1982; Rexstad & Burnham, 1991). It was assumed that the sampled population was demographically and geographically closed (Otis *et al.*, 1978; Karanth, 1995; Karanth & Nichols, 1998) during the short sampling period (45 days) repeated twice each year and demographically and geographically open across the two primary sampling periods (2004-2005 & 2005-2006). The density of tigers in the study area was estimated as the population size divided by the effective sampled area, which is estimated by creating a polygon over the trapping stations (A) and a buffer width (\hat{W}) estimated as half the mean maximum distance moved ($\frac{1}{2}$ MMDM) by recaptured tigers added to A (Karanth & Nichols, 1998).

$$\hat{D} = \hat{N} / (A (\hat{W}))$$

\hat{D} - Estimated density, \hat{N} - Estimated population size, $(A (\hat{W}))$ - Effectively sampled area

Vital rates (survival and migration probabilities across the two primary sampling periods) were estimated using Pollocks' Robust Design (Pollock, 1975). This design estimates parameters of concern by viewing long term studies of an open population as a sequence of short term studies of closed populations. Program MARK (Kendall *et al.*, 1997) estimates survival and migration probabilities across primary sampling periods and population size within primary sampling periods under models incorporating heterogeneity and varying probabilities of capture and recapture. Akaike Information Criterion (AIC) was used to select the best model.

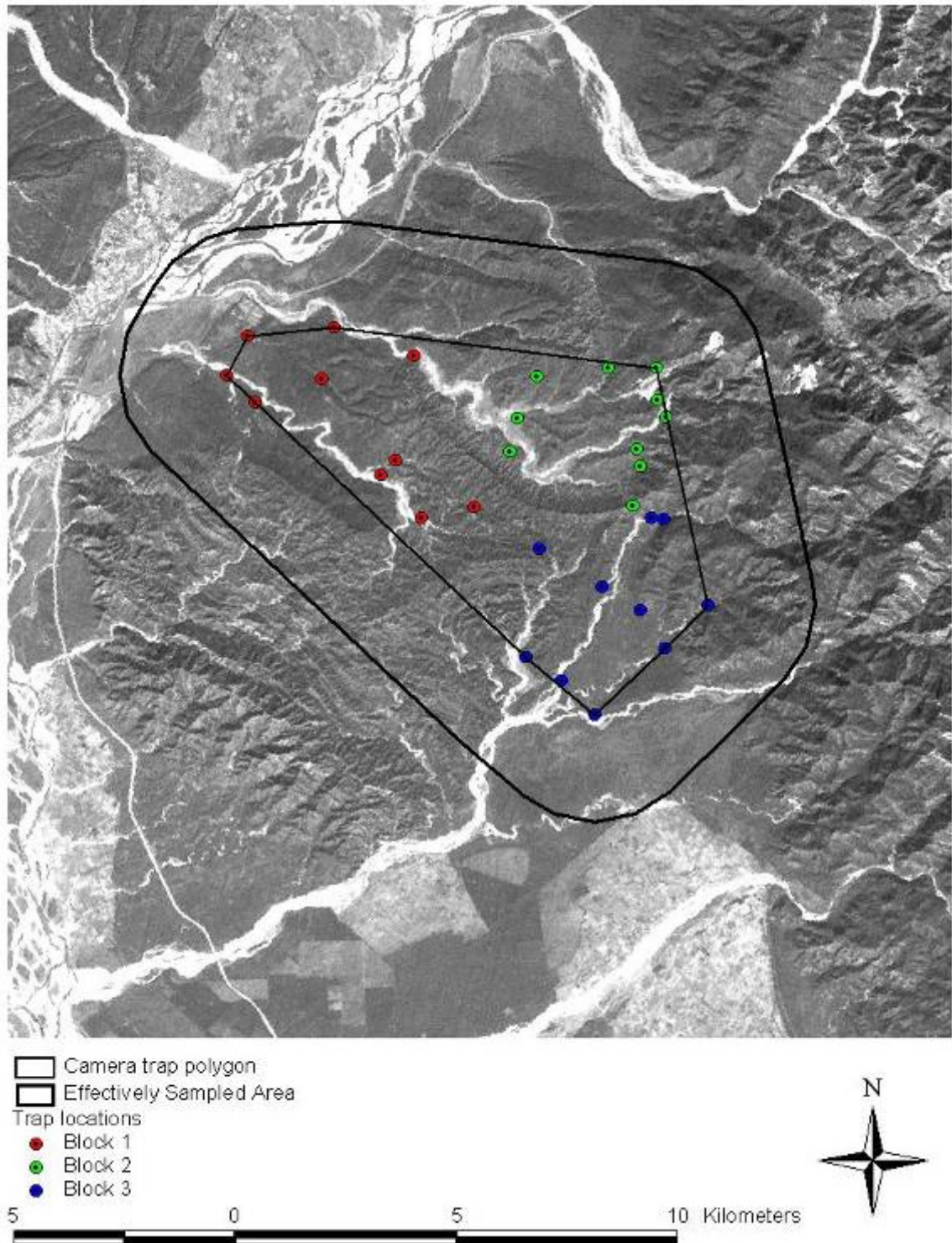


Figure 2a. Camera trap locations and the effective sampled area (2004 – 2005).

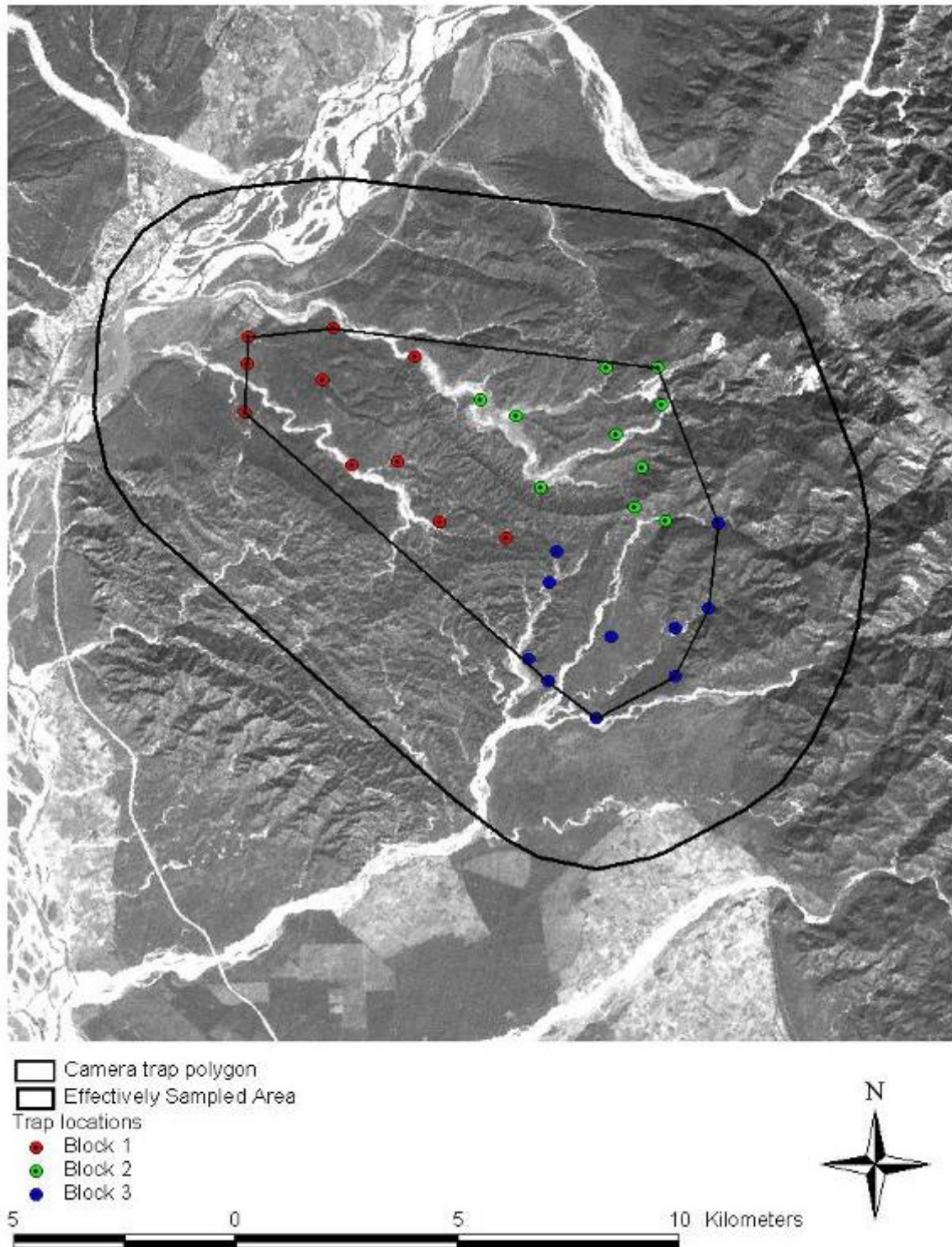


Figure 2b. Camera trap locations and the effective sampled area (2005 – 2006).



Estimating prey species density and biomass

Densities of the wild prey species were estimated using line transects in conjunction with distance sampling (Anderson *et al.*, 1979; Burnham, Anderson & Laake, 1980; Buckland *et al.*, 1993). A total of 9 line transects were cut and marked in 2004 (Fig. 3). The total length of line transects were 12.85 km. Each line transect was walked 8 times each thus the total effort amounted to 102.8 km of walk for each sampling period (January – April 2005 & December 2005 – March 2006). Line transect data were collected between 0615 hrs and 0930 hrs by two observers. On every walk, species, group size, sighting angle using a hand held compass (KB 20, Suunto, Vantaa, Finland) and sighting distance using a laser range finder (Yardage Pro 400, Bushnell, Overland Park, Kansas USA) were noted.

The data was analysed using program DISTANCE 4.1 Release 2 (Buckland *et al.*, 1993, 2001; Thomas *et al.*, 2004). In order to model detection functions so as to estimate species density, the data was examined for signs of evasive movement and peaking at great distance from the line of walk. The best model was selected based on the Akaike Information Criteria (AIC). Using the selected model, estimates of group density (D_g), group size (GS) and animal density (D_i) were derived by pooling data for all walks for a given transect and treating each transect as a true spatial replicate.

Density estimates obtained from distance sampling were used to estimate the biomass density of prey species in the area. The average body weight of individual wild prey species were taken from Schaller (1967) and Karanth & Sunquist (1992).

Reconstructing the food habits of tigers

Scat samples were collected from roads, trails and paths opportunistically. Since leopards also existed in the study area the distinction between leopard and tiger scats was made from the size of scats and signs (pug marks and scrapes) present in the area. During the collection of scats from the field, the GPS locations were also noted (Fig. 4). The samples were then sun dried in the field, individually labelled (e.g. TT1) and brought to the laboratory for further analysis. The contents of the scats were sieved and prey remains such as bones, hooves, teeth and hairs separated. By using features such as medullary and cuticular structure (Mukherjee, Goyal & Chellam, 1994) from the hair in the scats, individual species were identified by comparing it to reference samples from the Wildlife Institute of India. Relative numbers of individual prey species killed by tigers using scats was analysed using the Ackerman regression equation (Ackerman, Lindzey & Hernker, 1984) developed for puma (*Puma concolor*). Assuming that the digestive system and degree of utilization of carcass by the Tiger is comparable to that of the puma (Karanth & Sunquist, 1995)

$$Y = 1.98 + 0.035 (X)$$

where, X represents the live weight of the prey species represented in one collectable tiger scat Y . The average number of collectable scats (λ_i) produced by a tiger from an individual animal of each prey species ($\lambda_i = X/Y$) and the relative biomass and numbers of each prey killed were computed (Ackerman *et al.*, 1984). Prey selectivity and annual wild prey off take was calculated based on availability of the prey species derived from density estimates using line transects. Under the null hypothesis that the prey killed is in proportion to availability a comparison between the observed



proportions in scats to the expected proportions was carried out by constructing Bonferroni's simultaneous confidence interval. The annual biomass off take of wild prey was calculated with the assumption that the scats collected during the study represent biomass off take during the six months of the study.

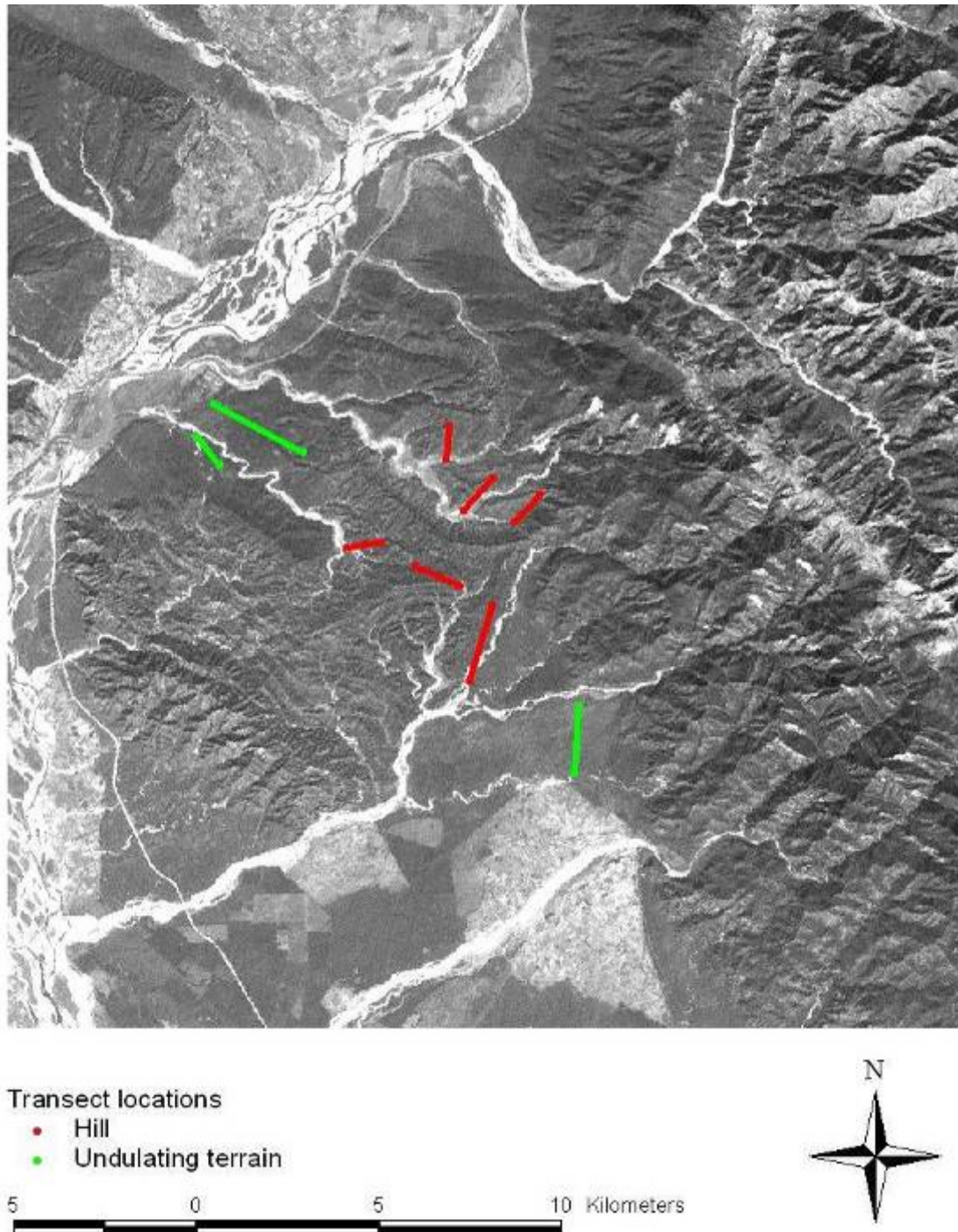
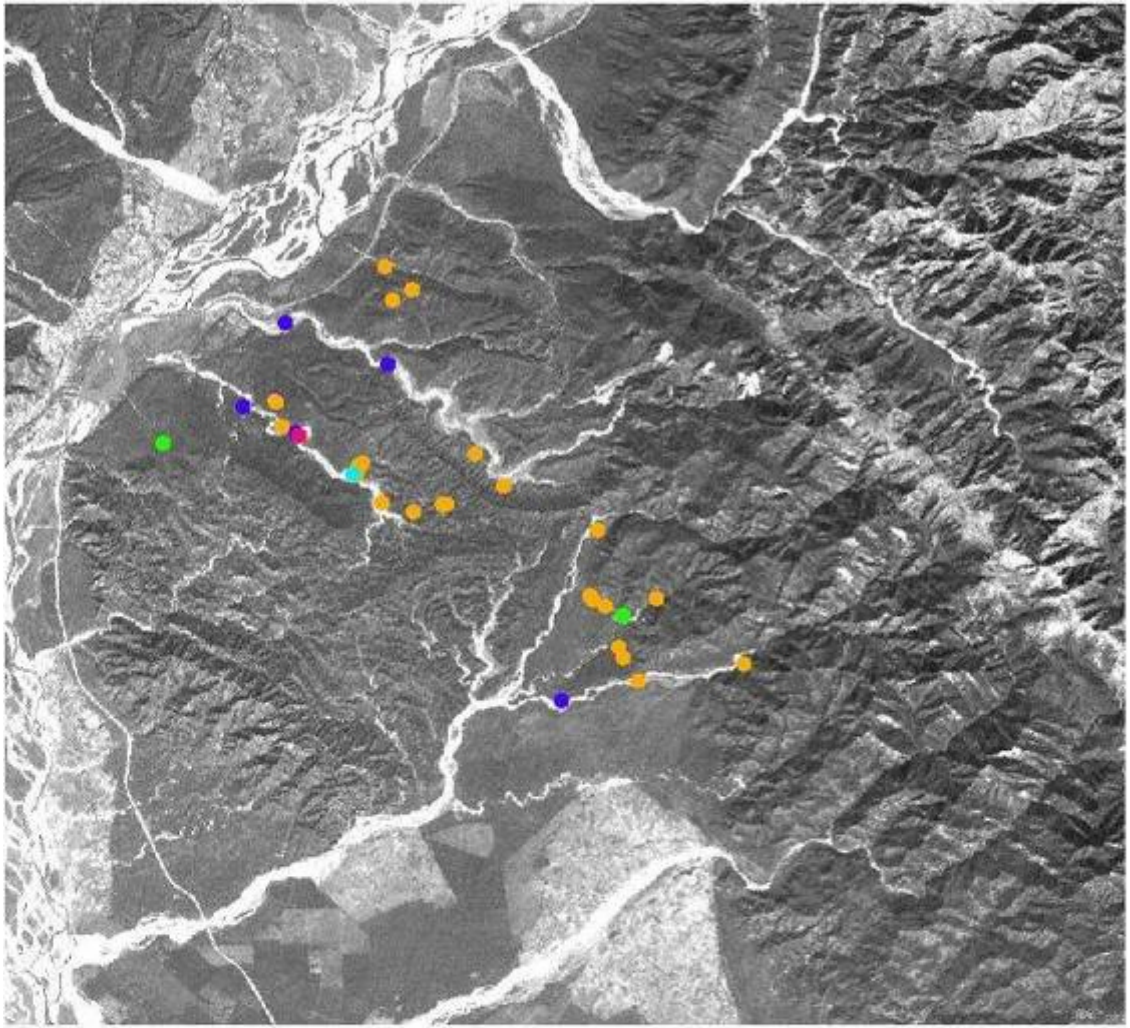


Figure 3. Location of transects in Chilla range of RNP.



Scats

- Buffalo
- Cattle
- Chital
- Sambar
- Wild Pig



Figure 4. Location of collected tiger scats indicating the predominant prey species found in the scat.



3. Results



Estimates of tiger population

2004-2005

The total sampling effort amounted to 449 trap nights (January-February 2005). A total of 11 tiger photographs of four individual tigers (Fig. 5a). The statistical test for population closure in CAPTURE (Otis *et al.*, 1978; Rexstad & Burnham, 1991) supported the assumption that the sampled population was closed for the 45-day study interval ($\hat{\zeta} = -0.390$, $P = 0.34809$). The model selected by program CAPTURE was M_0 (null model), the capture probability (p) was estimated as 0.1833 and the estimated population size N (SE $[N]$) was 4(0.49). The camera trap polygon (A) formed using periphery camera traps measured 52.65 km². The boundary strip width W (SE $[W]$) was estimated as 2.41 (0.39) km and the effective sampled area A (W) (SE $[A(W)]$) was 132.90 (20.42) km². Thus, the estimated female tiger density D (SE $[D]$) for Chilla range of RNP is 3.01 (0.38) per 100 km². The second sampling effort (February-April 2005) amounted to 450 trap nights during which a total of 11 tiger photographs of four individual tigers (Fig. 5b) were documented. The statistical test for population closure in CAPTURE supported the assumption that the sampled population was closed for the 45-day study interval ($\hat{\zeta} = 2.3530$, $P = 0.994$). The model selected by program CAPTURE was M_0 (null model), the capture probability (p) was estimated as 0.1833 and the estimated population size N (SE $[N]$) was 4(0.49).

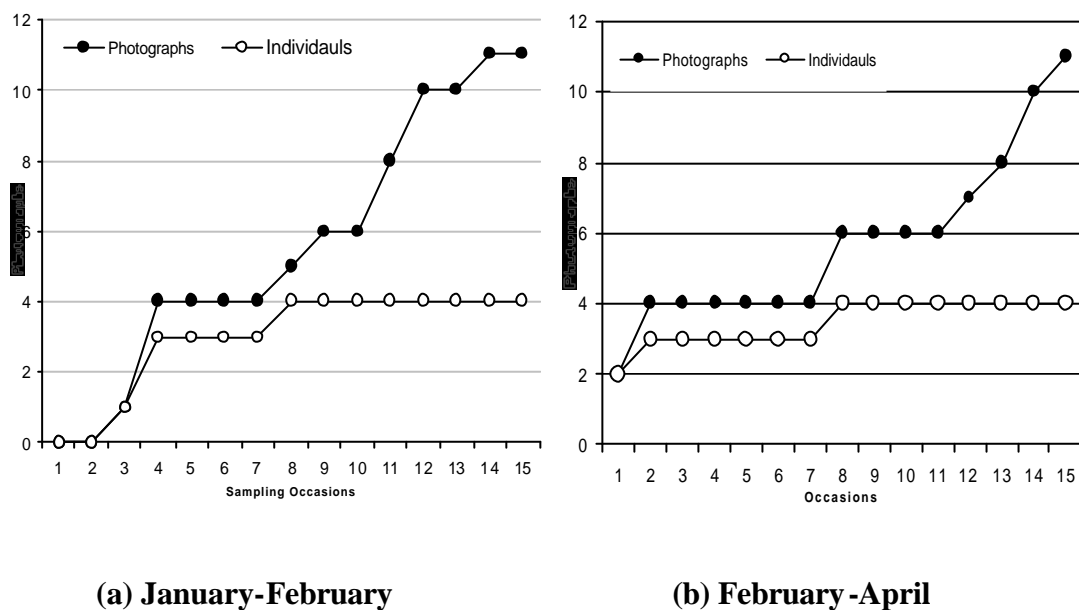


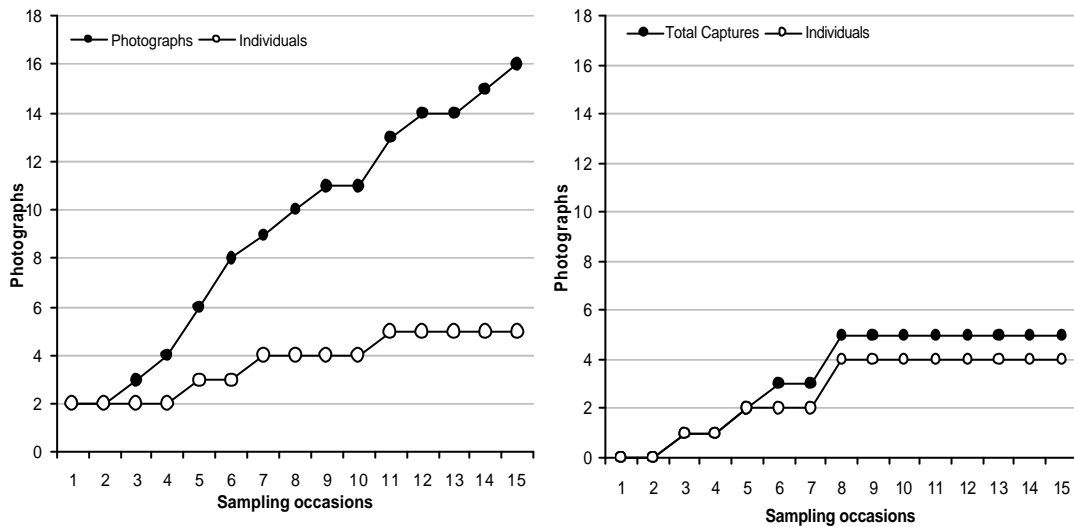
Figure 5. Cumulative number of tiger photographs indicating the number of individual tigers captured with increasing sampling occasions during 2005.

2005-2006

The total sampling effort amounted to 450 trap nights (December 2005-February 2006). A total of 16 tiger photographs of five individual tigers (Fig. 6a). The statistical test for population closure in CAPTURE (Otis *et al.*, 1978; Rexstad & Burnham, 1991) supported the assumption that the sampled population was closed for the 45-day study interval ($\hat{\zeta} = 0.445$, $P = 0.67170$). The model selected by program CAPTURE was M_0 (null model), the capture probability (p) was estimated as 0.2133



and the estimated population size N (SE [N]) was 5(0.39). The camera trap polygon (A) formed using periphery camera traps measured 56.25 km². The boundary strip width W (SE [W]) was estimated (by the recapture of two females and one male) to be 3.38(1.1) km and the effective sampled area $A(W)$ (SE [$A(W)$]) was 196.26(47) km². Thus, the estimated tiger density D (SE [D]) for Chilla range of RNP is 2.54(0.71) per 100 km². However, the density of females for the second sampling period was estimated as 2.98(0.60) per 100 km². The strip width W (SE [W]) was estimated (by the recapture of two females) to be 2.35(0.7) with the effective area sampled $A(W)$ (SE [$A(W)$]) totaling to 134.03(21) km². The second sampling effort (February-April 2006) amounted to 450 trap nights during which a total of 5 tiger photographs of four individual tigers (Fig. 6b) were documented. The statistical test for population closure in CAPTURE supported the assumption that the sampled population was closed for the 45-day study interval ($\hat{z} = 0.68$, $P = 0.246$). The model selected by program CAPTURE was M_0 (null model), the capture probability (p) was estimated as 0.0426 and the estimated population size N (SE [N]) was 8(5.5). Across the two sampling sessions it was of interest to note that the male (RT-006) which was captured on six occasions during the previous session was not captured even once during the second session. This temporal variation in captures could be as a result of temporary immigration out of the study area. We feel this could be as a result of the increase in temperature and the reduced availability of water in the study area.



(a) December-February

(b) February-April

Figure 6. Cumulative number of tiger photographs indicating the number of individual tigers captured with increasing sampling occasions during 2005-06.



Monitoring the tiger population

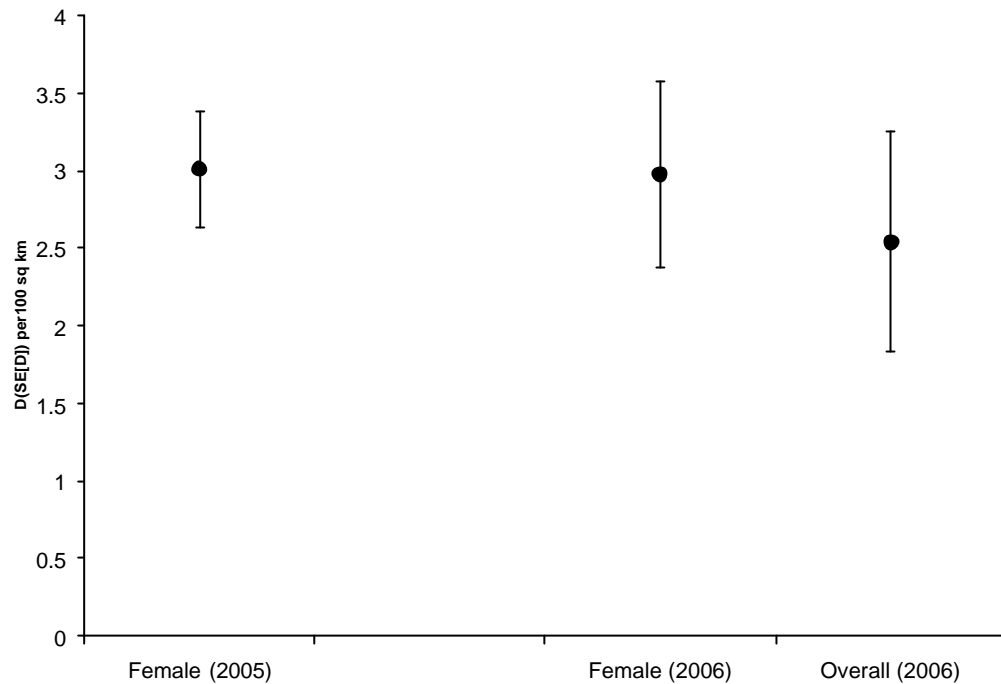


Figure 7. Comparison of female and overall tiger density ($D(SE[D])$ per 100 km²) across the two primary sampling sessions (2004-2005 and 2005-2006).

Of the four tigers captured during the first primary session, three had recaptures. The estimated W was 2.15 km and the resulting $A(W)$ was thus 132.9 km². During the second sampling period, three (two females and one male) of the five individuals captured had recaptures. Thus, the estimated W involving all recaptured individuals was 3.38 km and the resulting $A(W)$ was 196.2 km². It was noticed that there was no significant difference between the estimated W across the two sampling periods for females (2.15±0.4 km in 2005; 2.35±0.5 km in 2006). As the movement of one male (5.5±5.5 km) influenced the estimate of W in 2006, the estimated $A(W)$ was higher by ~25 % (196.2 km² given $W=3.38$ km; 145.8 km² given $W=2.35$ km). The estimates of tiger density arrived at during the primary sampling session (2004-2005) was essentially the number of female tigers per 100 km². However during the second sampling session (2005-2006), the female tiger density was computed as a sub sample of the overall tiger density. The comparison reveals that there is no significant overlap in density of tigers over the years (Fig. 7).

The estimates of survival probability (s) and immigration rate (γ) using Pollocks robust design (Pollock, 1975) across two primary periods (2004-2005 and 2005-2006) indicate a low survival probability ($s = 0.25$) and high immigration rate ($\gamma = 0.57$).



Estimates of prey density

Prey density estimates 2004 – 2005

Though a total of 13 species were detected on transects, density estimates for six potential prey species was computed (Table 1). Estimates of density could not be computed for the remaining seven species due to sample size constraints (Buckland *et al.*, 1993). Though langur, wild pig and nilgai had fewer than the recommended 60-80 detections, it conformed to the underlying assumptions of model fitting (Buckland *et al.*, 1993; Laake *et al.*, 1993). Estimates of prey density derived here are high (105.31 animals km⁻²), with the estimated ungulate density being 76.5 animals km⁻². In terms of densities of groups sambar was the most abundant followed by chital, peafowl, wild pig, langur and nilgai. Chital was found to be the most abundant in terms of individual densities, followed by sambar, peafowl, langur, wild pig and nilgai. Of the groups 17.3% were of small bodied animals (peafowl and langur, <20 kg); 33.8% were of medium sized animals (chital and wild pig, 20-50 kg) and 46.9% were of large bodied animals (sambar and nilgai, above 50 kg). The total biomass was estimated as 6158.48 kg km⁻² with 97% being contributed by the four ungulate species.

Prey density estimates 2005 – 2006

Though a total of 11 species were detected on transects, density estimates for six potential prey species was computed (Table 2). Estimates of density could not be computed for the remaining seven species due to sample size constraints (Buckland *et al.*, 1993). Though langur, peafowl, nilgai and wild pig had fewer than the recommended 60-80 detections, it conformed to the underlying assumptions of model fitting (Buckland *et al.*, 1993; Laake *et al.*, 1993). Estimates of prey density derived here are high (93.11 animals km⁻²), with the estimated ungulate density being 70.98 animals km⁻². In terms of densities of groups sambar was the most abundant followed by chital, nilgai, langur, peafowl and wild pig. Chital was found to be the most abundant in terms of individual densities, followed by sambar, langur, peafowl, nilgai and wild pig. Of the groups 12.1% were of small bodied animals (peafowl and langur, <20 kg); 36.3% were of medium sized animals (chital and wild pig, 20-50 kg) and 51.6% were of large bodied animals (sambar and nilgai, above 50 kg). The total biomass was estimated as 6008.99 kg km⁻² with 97% being contributed by the four ungulate species.

Table 1. Prey species densities in Chilla range (2004 - 2005). (Total effort, 102.8 km.)

Species	<i>n</i>	D_g (km^{-2})	$CV D_g$ (%)	$GS \pm SE$	D_i (km^{-2})	$CV D_i$ (%)	Body weight* (kg)	Biomass (kg km^{-2})
Chital	101	7.54	21.6	5.79±0.57	43.61	24.5	47	2049.67
Sambar	137	12.6	12.6	2.03±0.28	25.67	19.6	134	3439.78
Wild pig	20	2.04	42.0	2.71±0.56	5.52	33.6	32	176.64
Nilgai	19	0.68	23.9	2.50±0.44	1.70	38.9	181	307.70
Ungulates	-	22.86	-	-	76.5	-	-	5973.79
Peafowl	59	3.93	20.3	3.79±0.51	14.92	27.3	4	59.68
Langur	22	1.51	37.2	9.19±1.01	13.89	38.6	9	125.01
Total	-	28.3	-	-	105.31	-	-	6158.48

Table 2. Prey species densities in Chilla range (2005 - 2006). (Total effort, 102.8 km.)

Species	<i>n</i>	D_g (km^{-2})	$CV D_g$ (%)	$GS \pm SE$	D_i (km^{-2})	$CV D_i$ (%)	Body weight* (kg)	Biomass (kg km^{-2})
Chital	87	7.97	12.7	5.14±0.70	41.03	19.7	47	1928.41
Sambar	101	10.9	11.9	2.26±0.07	24.69	12.9	134	3308.46
Wild pig	6	1.13	75.1	2.16±0.47	2.44	81.6	32	78.08
Nilgai	11	2.03	50.6	1.39±0.21	2.82	55.6	181	510.42
Ungulates	-	22.03	-	-	70.98	-	-	5825.37
Peafowl	13	1.36	48.6	1.74±0.39	3.11	55.6	4	12.44
Langur	16	1.68	31.2	11.3±3.20	19.02	40.8	9	171.81
Total	-	25.07	-	-	93.11	-	-	6008.99

n, total number of groups detected; D_g , density of groups (groups km^{-2}); $CV D_g$ (%), coefficient of variation of density of groups; $GS \pm SE$, group size and associated standard error; D_i , density of individuals ($\text{individuals km}^{-2}$); $CV D_i$ (%), coefficient of variation of density of individuals.

Body weight* - Adopted from Schaller (1967) and Karanth & Sunquist (1992).



Food habits of tiger

The results presented here are with reference to the data collected during November 2004 to April 2005. In total 46 scats were collected from field. Two scats were not used for analysis owing to a doubt in their origin. However from the remaining 44, 77.27 % had remains of only one prey species, while 20.45 % of the scats had remains of 2 species and the remaining 2.27 % containing 3 prey species. Remains of sambar, cattle, chital, wild pig and buffalo were identified. The highest frequency of occurrence being that of sambar (60%), followed by cattle (20%), chital (9%), wild pig (5.45%) and buffalo (5.45%) (Table 3).

Table 3. Estimated average number of field collectable scats produced from individual prey animals, relative numbers of prey species killed and Biomass off take by tigers in six months.

Species	Presence in number of scats	Frequency occurrence	Correction factor (Y)	Relative biomass consumed	Relative number of individuals consumed	Percentage off take by tigers (six months)
Sambar	33	75	6.77	65.51	54.57	2.204
Cattle	11	25	6.18	19.92	18.94	-
Chital	5	11.3	3.62	5.31	12.89	0.225
Wild pig	3	6.8	3.31	2.91	8.73	1.756
Buffalo	3	6.8	7.23	6.36	4.83	-
Total						1.395

During the study period estimates of domestic animal (cattle, buffalo) densities could not be computed. Owing to the placement of line transects in the study area only estimates of wild ungulate prey could be derived. Thus for the purpose of analysis of prey selection only wild prey species are considered (sambar, chital and wild pig). On comparing densities of wild prey species and their representation in tiger diet (Fig. 8) it is evident that sambar and wild pig are being over represented, whereas chital selected less than availability. On constructing the 95% Bonferroni's confidence intervals (Fig. 8) on the expected proportions of wild prey species in tiger diet it is evident that sambar and wild pig are significantly selected more than availability in the diet of the tiger. Therefore it was evident that tigers in Chilla range are selectively consuming prey species.

Estimated annual biomass off take of wild ungulate prey by tigers in the study area was calculated to be 2.78%. With an assumption that the scats collected during the study represent only six months of biomass off take by tigers in the study area the estimate of yearly off take was calculated by multiplying the derived estimate into two (Table 3). It is generally noted that tigers crop from 8 – 10% of the ungulate



biomass (Karanth *et al.*, 2004b). However the estimated annual biomass off take is low, suggesting that much higher densities of tigers could be attained in Chilla range.

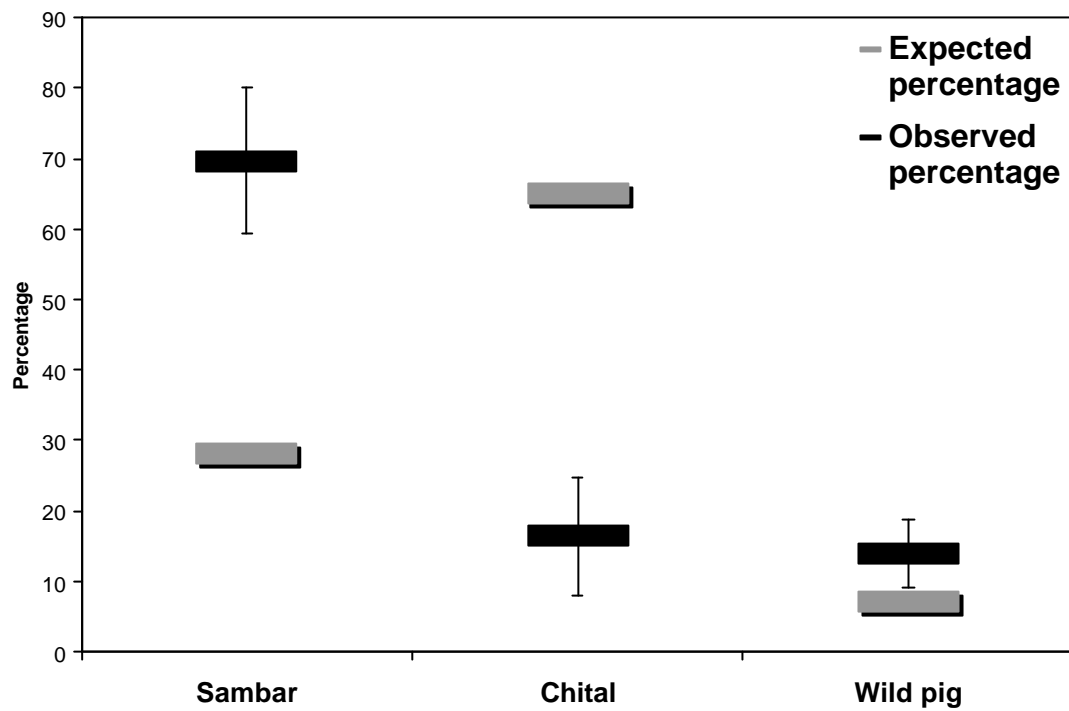


Figure 8. Comparing prey availability to prey consumption by tiger.



4. Discussion



Tigers radiated throughout Asia. They inhabit a wide variety of habitats. Miquelle *et al.*, (1999) and Karanth & Stith (1999) show that prey distribution and density determine first order and second order habitat selection by tigers. Recent studies suggest that abundance of carnivores is closely related to biomass (Carbone & Gittleman, 2002) and that tigers respond numerically to the densities of ungulate prey species (Karanth *et al.*, 2004b) and seem to avoid areas of human disturbance (Johnsingh *et al.*, 2004). The estimates of prey density arrived at in this study shows that Chilla range of RNP harbours a high density of prey species (105.31 individuals km⁻² in 2005; 93.11 individuals km⁻² in 2006), with no significant difference in density across the years. Tigers being obligate carnivores primarily prey upon ungulates in all the ecosystems in which they occur (Seidensticker, 1997). Although they can prey on a wide variety of prey species it has been noticed that the average prey size is around 60 kg. This is obtained predominantly from deer species, which contribute up to 75% of the prey biomass requirement of tiger (Sunquist, Karanth & Sunquist, 1999). Chilla range supports a high density of ungulates (76.5 individuals km⁻² in 2005; 70.98 individuals km⁻² in 2006), primarily contributed by chital and sambar (90.6 – 92.6%). The overall estimates of individual density derived from this study (Table 1 & 2) shows that chital is the most abundant of all ungulate species (43.61 individuals km⁻² in 2005; 41.03 individuals km⁻² in 2006) followed by sambar (25.67 individuals km⁻² in 2005; 24.69 individuals km⁻² in 2006). Nilgai (Table 1 & 2) and Domestic prey (Cattle & Buffalo; density not estimated due to sample size constraints) seen more commonly in open areas along the south eastern part of the study area were probably underestimated since; these habitats were poorly represented by the spatial replicates.

On comparing the estimates of ungulate density across various study areas (Table 4) it is evident that Chilla range of RNP supports a high density of prey species. Of the animal groups detected on the transect surveys, 46.9% were of large prey (sambar & nilgai) as compared to 40.5% in Ranthambore (Bagchi *et al.*, 2003; sambar & nilgai), 8.5% in Pench Tiger Reserve (Biswas & Sankar, 2002; sambar & nilgai) and 7.25% in Nagarhole (Karanth & Sunquist, 1995; sambar, gaur *Bos gaurus* L. & elephant). This high availability of large bodied prey in the study area could influence prey selection by tiger (Johnsingh, 1983; Karanth & Sunquist, 1995; Biswas & Sankar, 2002). As noted in this study (Table 3; Fig. 8) sambar seems to be preyed upon in much higher levels than expected. Though estimates of cattle density could not be arrived at from this study (for reasons explained above) there seems to be a high off take (Table 3). The estimated prey biomass density (6158.48 kg km⁻² in 2005; 6008.99 kg km⁻² in 2006) reveals that Chilla range of RNP is a high biomass density area (Table 5), with 60.9% being contributed by large (sambar & nilgai), 36.1% by medium (chital & wildpig) and 3% by small (peafowl & common langur) bodied prey species. However, prey biomass off take by tigers (estimated from scats collected in 2005) show that only an approximate 3% of the standing ungulate biomass is being cropped by tigers. This is suggestive of the fact that Chilla range of RNP can support higher densities of tigers. As high prey biomass correlates to higher chances of persistence of predator populations (Carbone & Gittleman, 2002), such areas will have to be protected so as ensure the long term survival of the species.

Table 4. Comparison of ungulate prey species densities (individuals km⁻²), tiger densities (individuals 100km⁻²) and predicted tiger densities (following the model developed by Karanth *et al.*, 2004b).

Location	Forest type	Rainfall (mm)	Ungulate Density ± Standard error (individuals km⁻²)	Tiger Density ± Standard error (individuals 100km⁻²)	Predicted Tiger Density
Ranthambore	Dry forest	800	60.6 ± 3.44	11.97 ± 3.71	12.12
Melghat	Dry forest	1100	5.3 ± 0.76	3.27 ± 0.59	1.04
Panna	Dry forest	1100	30.9 ± 1.49	6.94 ± 3.23	6.18
Tadoba	Dry forest	1175	13.1 ± 1.41	3.42 ± 0.84	2.61
Bandipur	Moist and dry forest	1200	35.2 ± 7.55	7.29 ± 2.54	7.04
Pench-MR	Moist forest	1400	16.2 ± 2.72	4.94 ± 1.37	3.24
Pench-MP	Moist forest	1400	63.8 ± 3.14	16.76 ± 2.96	12.76
Nagarahole	Moist forest	1500	56.1 ± 3.95	11.46 ± 4.20	11.22
Kanha	Moist forest	1500	57.3 ± 4.07	11.70 ± 1.93	11.46
Chilla (2005)	Moist and dry forest	2000	76.5 ± 4.1	3.01 ± 0.48	15.30
Chilla (2006)	Moist and dry forest	2000	70.9 ± 6.4	2.54 ± 0.71	14.19
Bhadra	Moist forest	2200	16.8 ± 1.75	6.67 ± 1.85	3.36
Kaziranga	Alluvial grassland	3000	58.1 ± 6.51	11.92 ± 1.71	11.62



Table 5. Comparison of ungulate prey biomass density across different habitats in the Indian subcontinent.

Location	Prey biomass density (kg km ⁻²)
Ranthambore (Kumar, 2000)	4937
Ranthambore (Bagchi, Goyal & Sankar, 2004)	6263
Gir (Khan <i>et al.</i> , 1996)	3292
Bandipur (Johnsingh, 1983)	3382-3619
Pench TR (Biswas & Sankar, 2002)	6013.25
Nagarhole (Karanth & Sunquist, 1992)	7638
Kanha (Schaller, 1967)	3902.3-4805.7
Chilla (Present study 2004-2005)	6158.48
Chilla (Present study 2005-2006)	6008.99
Bardia (Dinerstein, 1980)	2842-3120
Chitwan (Eisenberg & Seidensticker, 1976)	2933
Kaziranga (Karanth & Nichols, 1998)	4252

Karanth *et al.*, (2004b) show that tigers respond numerically to ungulate prey densities. Supporting the general trend that higher prey densities correspond to increased tiger numbers. Though Chilla range supports a high ungulate prey density (76.5 individuals km⁻² in 2005; 70.98 individuals km⁻² in 2006) the tiger density is low (3.01 tigers 100km⁻² in 2005; 2.54 tigers 100km⁻² in 2006) as opposed to a predicted ~14 tigers 100km⁻² given a 10% biomass off take (following the model developed by Karanth *et al.*, 2004b). The prolonged anthropogenic disturbance caused over many years prior to the study by a recently relocated resident community of pastoralists (*Gujjars*) in Chilla range of RNP is possibly the reason for this low tiger density. During the first primary period (2004-2005) a total of four individual tigers (all females) were captured in the sampling area of 52 km². During the second primary session (2005-2006) five individual tigers were captured (three females and two males) within the same area. However, the estimated density of tigers (2.54 tigers 100km⁻² in 2006) was lower since the first estimate (3.01 tigers 100km⁻² in 2005), it is important to note that this is a sampling artifact. Density (*D*) is derived by dividing the estimated population size (*N*) by the effective sampled area (*A* (*W*)). Since (*W*) is an estimate based on ½ MMDM by recaptured individuals the effectively sampled area (*A* (*W*)) is dependent on the movement of the recaptured tigers. Radio tracking studies have shown that adult males occupy large home ranges often encompassing two to three females and move as much as 4km between locations on successive days, whereas female home ranges are smaller and they move only about 1.5km (Chundawat, Gogate & Johnsingh, 1999). Therefore we feel that the estimate of female density (resident number of females in area) is a better measure for comparison across years.

The use of cameras to individually identify tigers has greatly aided in monitoring the tiger population. With only one individual being common to both years (RT-005) the estimated survival probability (*s*) was 0.25. It was also noted that one of the individually identified tigers (RT-002) captured during the first primary period was



confirmed dead in November 2005 prior to the sampling carried out from 2005-2006 (see Hilltop tigers). However, we also noticed a high turnover in population. The emigration probability (?) was estimated to be 0.57 across the two primary sampling periods, we feel that the relatively safer habitat provided by Chilla range could be the reason as to why these high rates of migration by tigers from adjoining areas is occurring. In an earlier study on pumas it was noticed that when the hunting of pumas was closed high migration rates of females was noticed. Over years of monitoring the population the turn over rates lowered and the resident females started maintaining territories (Seidensticker pers. com.). We feel that continuous monitoring of the tiger population over the years could aid our understanding of the social organization of tigers within this landscape.

Chilla range of RNP is a very important forest area. It is part of one of the most intact and extensive habitat units of the Terai Arc Landscape (Tiger Habitat Block II) (Johnsingh *et al.*, 2004) and forms connectivity to THB I (Simbalbara to Ganges) across the Ganges. Although a population of tigers do persist on the west of the Ganges very little connectivity is said to exist between the two areas. Johnsingh *et al.*, (2004) recorded no evidence tiger along the east bank of the Ganges. However, this study (2005-2006) documented two individuals (RT-011 & RT-012) in the riverine forests along the east bank of the Ganges, using part of the Chilla-Mothichur corridor. Though it is noticed that tigers inhabit a variety of habitats (Seidensticker, 1997; Miquelle *et al.*, 1999), human activity has caused considerable degradation (Karanth & Stith, 1999; Karanth *et al.*, 2004a). Given the fact that most tiger habitats are part of larger landscape matrices under multiple uses (Karanth & Stith, 1999) and the scarcity of resources for conservation of tigers, it is essential to identify areas where the probability of the tiger's survival is highest (Wickramanayake *et al.*, 1998). From the present study it is evident that Chilla range of RNP with its high-density prey population has the potential to support a higher tiger density. Thus, protecting the habitat along with regular monitoring of the tiger and prey population in this area could ensure the recovery and long-term persistence of tigers within this landscape.

Management Implications

Although the present population density of tiger in Chilla range is low, our study clearly indicates that the area has potential to house much higher density of tigers. Chilla currently supports a very high density of tiger prey species (wild, >70 per sq. km). With this high prey density, Chilla has the potential of harboring approximately 14 tigers per 100 sq. km. With the increased evidence of breeding tigers obtained during our study, Chilla range can certainly act as a source population for tigers along the east bank of Ganges. Tigers being territorial are known to disperse from the source area and establish territories in adjoining forested habitats. It is thus imperative that forested habitats adjoining Chilla range (Shyampur and Chidiyapur ranges of Haridwar Forest Division and Gohri Range of RNP) need immediate attention for long term persistence of tiger along east bank of Ganges. Relocation of gujjars from Gohri range is currently under progress. However, gujjars of Shyampur and Chidiyapur ranges exert enormous pressure on some of the potential tiger habitats south of Chilla range. Sincere efforts are required to free these two ranges of gujjars as well as other encroachments. This will ensure an area of roughly around 400 sq km along the eastern bank of Ganges from Rishikesh to Chidiyapur which has the potential to support a healthy population of tiger and its prey species.



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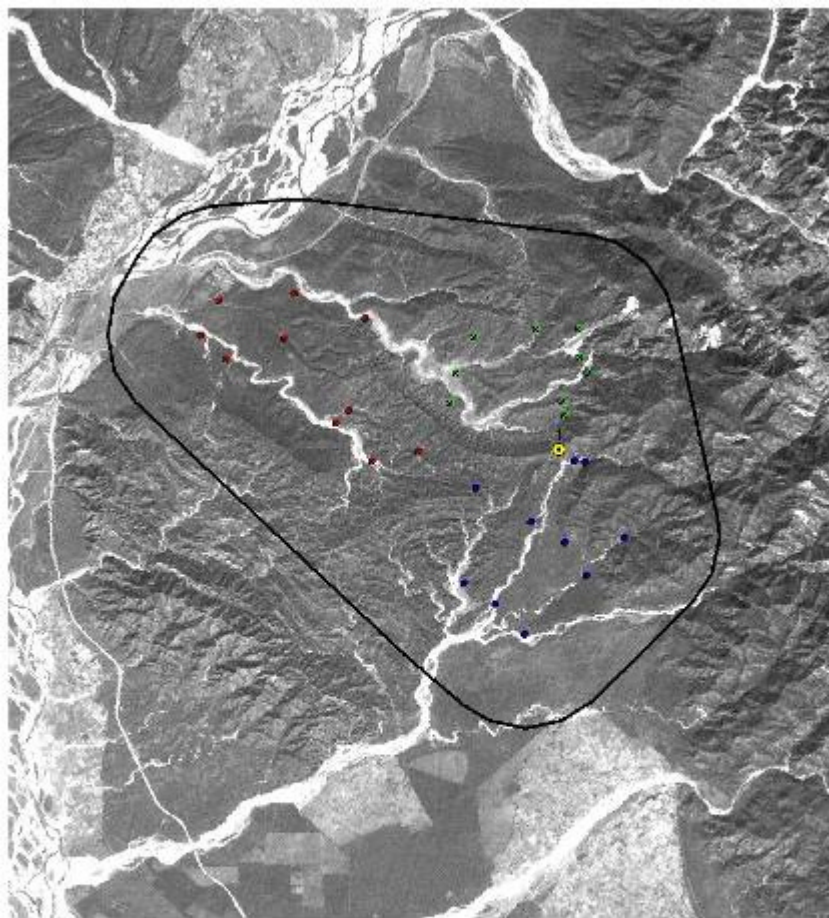
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Individual tigers (2004 – 2005)



Hilltop Male (RT – 001)



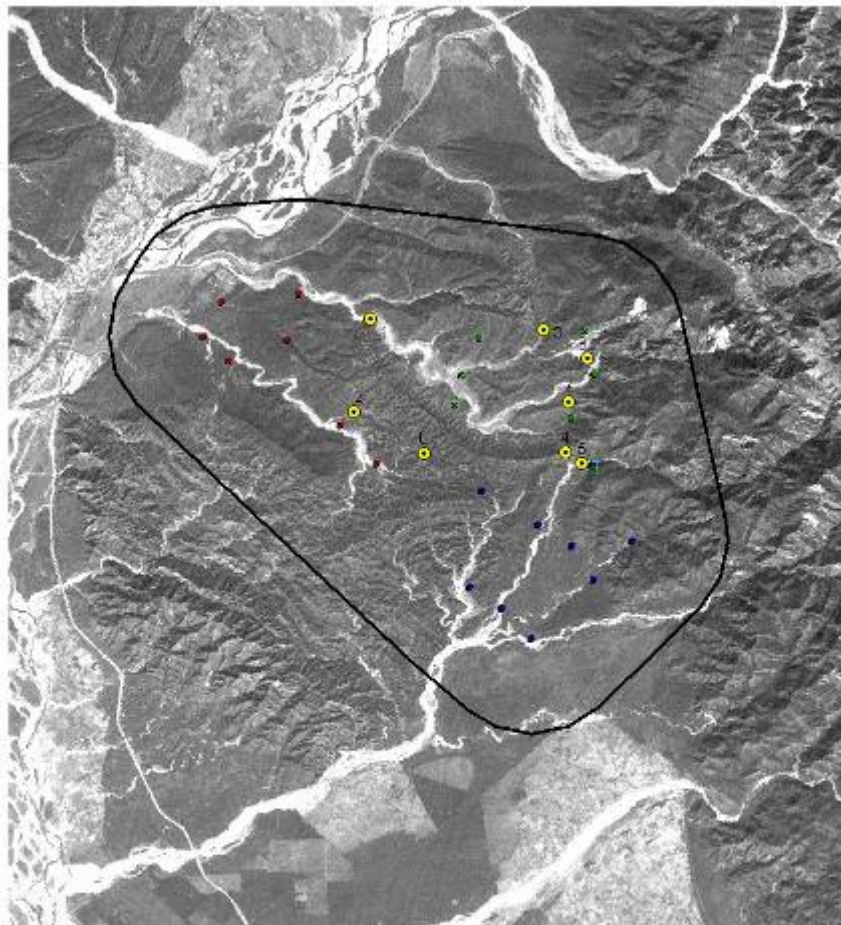
Location & Date

- 1. Hill Top (B2CT01) 27/05/04

This male was photographed during *ad hoc* camera trapping carried out in 2004.



Hilltop Female (RT – 002)



Capture location
 Effectively Sampled area
 Trap locations
 Block 1
 Block 2
 Block 3

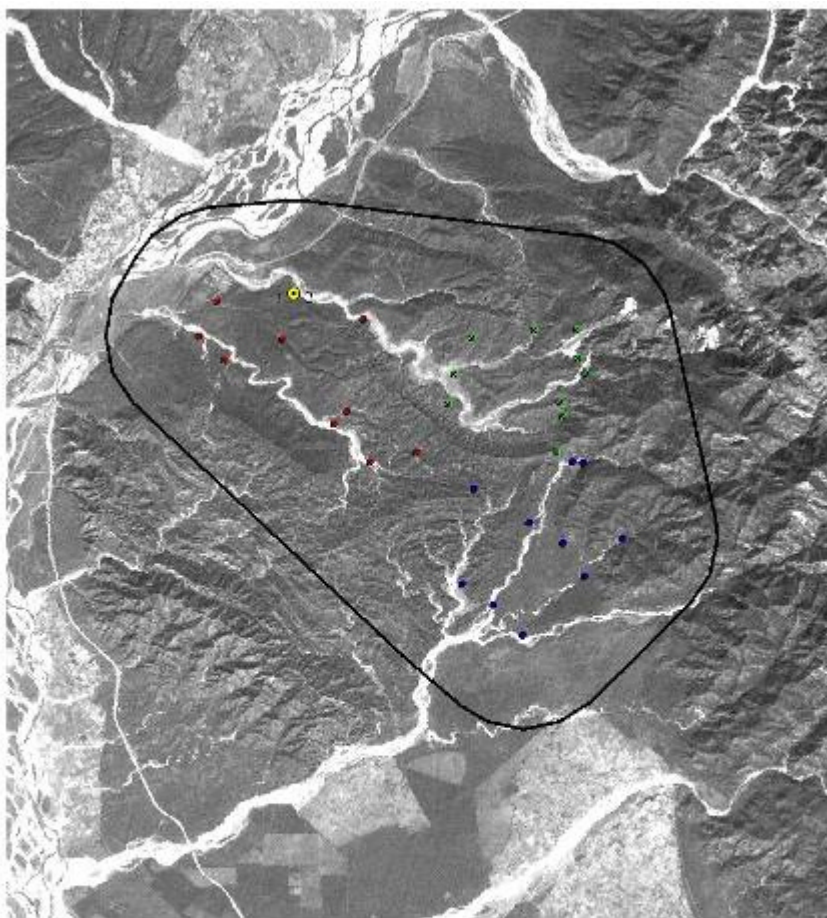


Location & Date

1. Mundal rau
(B1CT01)
06/01/05
2. Gau Sot
(B1CT10)
13/01/05
3. Mehnderghati
(B2CT07)
31/01/05
4. Hill Top
(B2CT01)
02/02/05
5. Mithawali
(B3CT10)
09/02/05
6. Beri Sot
(B1CT06)
22/02/05
7. Upstream Amgadi
(B2CT03)
25/03/05
8. Gara sot
(B2CT05)
27/03/05
9. Mithawali
(B3CT10)
13/04/05



Mundal Female (RT – 003)



● Capture location
□ Effectively Sampled area
Trap locations
● Block 1
● Block 2
● Block 3

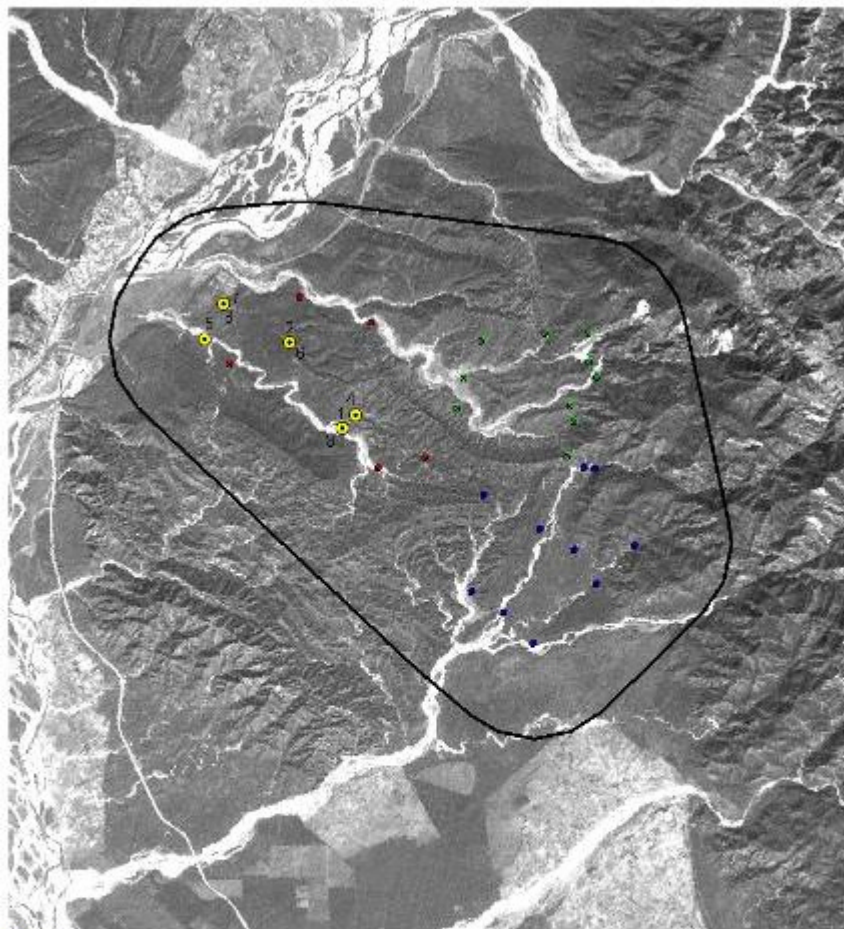


Location & Date

1. Mundal
(B1CT02)
06/01/05
2. Mundal
(B1CT02)
03/03/05



Hazara Female (RT – 004)



Capture location
 Effectively Sampled area
 Trap locations
 Block 1
 Block 2
 Block 3



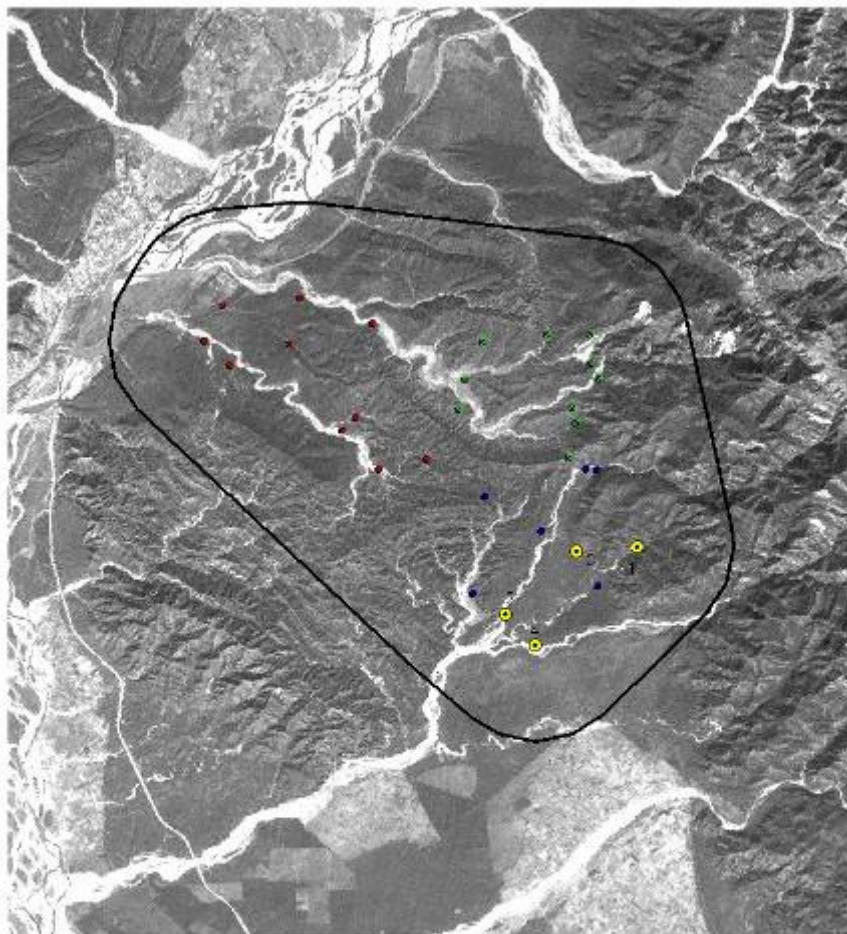
5 0 5 10 Kilometers

Location & Date

1. Ghasiram
(B1CT09)
06/01/05
2. Gamera sot
(B1CT04)
11/01/05
3. Ghasiram
(B1CT09)
13/01/05
4. Gau sot
(B1CT10)
22/02/05
5. Teak plantation
(B1CT06)
23/02/05
6. Gamera sot
(B1CT04)
03/03/05
7. Chilla gate
(B1CT03)
08/03/05
8. Chilla gate
(B1CT03)
08/03/05



Sarkada Female (RT – 005)



☉ Capture location
□ Effectively Sampled area
Trap locations
• Block 1
• Block 2
• Block 3



Location & Date

1. Sarkada
(B3CT04)
13/02/05
2. Mithawali
Downstream
(B3CT07)
16/02/05
3. Sarkada Downstream
(B3CT03)
31/03/05
4. Luni Downstream
(B3CT06)
10/04/05

Photographs of tigers captured during 2004 - 2005 in Chilla Range, Rajaji National Park



RT-001 - 27.05.2004 (B2/T01)



RT-002 - 13.06.2004 (B2/T01)



RT-002 - 01.07.2004 (B2/T4)



06.07.2004 (B2/T4)



RT-002 - 05.01.2005 (B3/T01)



RT-004 - 06.01.2005 (B3/T09)



RT-004 - 06.01.2005 (B3/T09)



RT-003 - 06.01.2005 (B3/T03)



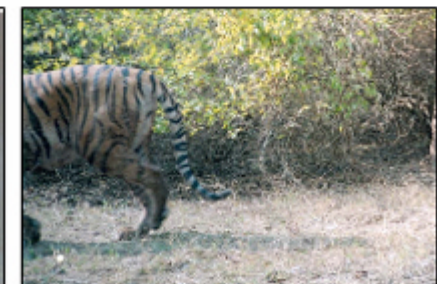
RT-002 - 13.01.2005 (B1/T10)



RT-004 - 13.01.2005 (B1/T09)



RT-004 - 13.01.2005 (B1/T09)



RT-002 - 31.01.2005 (B2/T07)

Photographs of tigers captured during 2004 - 2005 in Chilla Range, Rajaji National Park



RT-002 - 02.02.2005 (B2/T01)



RT-002 - 09.02.2005 (B3/T10)



RT-005 - 13.02.2005 (B3/T04)



RT-005 - 16.02.2005 (B3/T07)



RT-004 - 22.02.2005 (B1/T10)



RT-002 - 22.02.2005 (B1/T06)



RT-004 - 23.02.2005 (B1/T07)



RT-004 - 03.03.2005 (B1/T05)



RT-003 - 03.03.2005 (B1/T03)



RT-005 - 08.03.2005 (B1/T04)



RT-005 - 08.03.2005 (B1/T04)



RT-002 - 25.03.2005 (B2/T03)

**Photographs of tigers captured during 2004 - 2005 in Chilla Range,
Rajaji National Park**



RT-002 - 27.03.2005 (B2/T05)



RT-002 - 13.04.2005 (B3/T10)



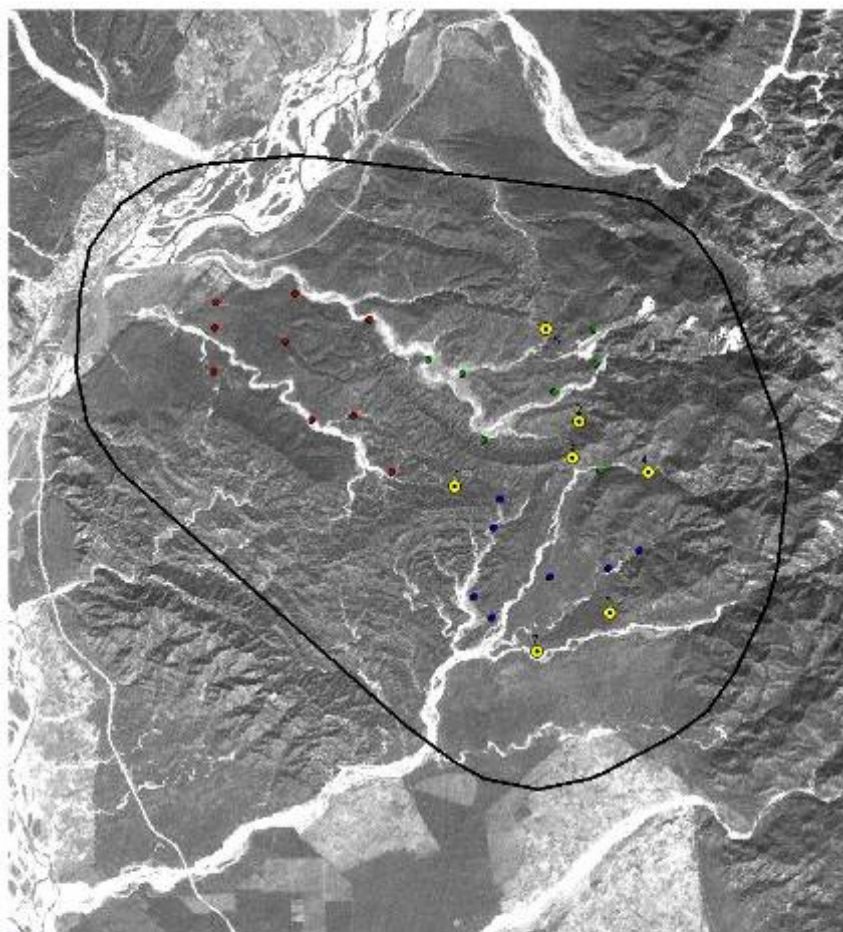
RT-005 - 09.04.2005 (B3/T03)








Individual tigers (2005 – 2006)



Sarkada Female (RT – 005)



 Capture location
 Effectively Sampled area
 Trap locations
 Block 1
 Block 2
 Block 3

5 0 5 10 Kilometers

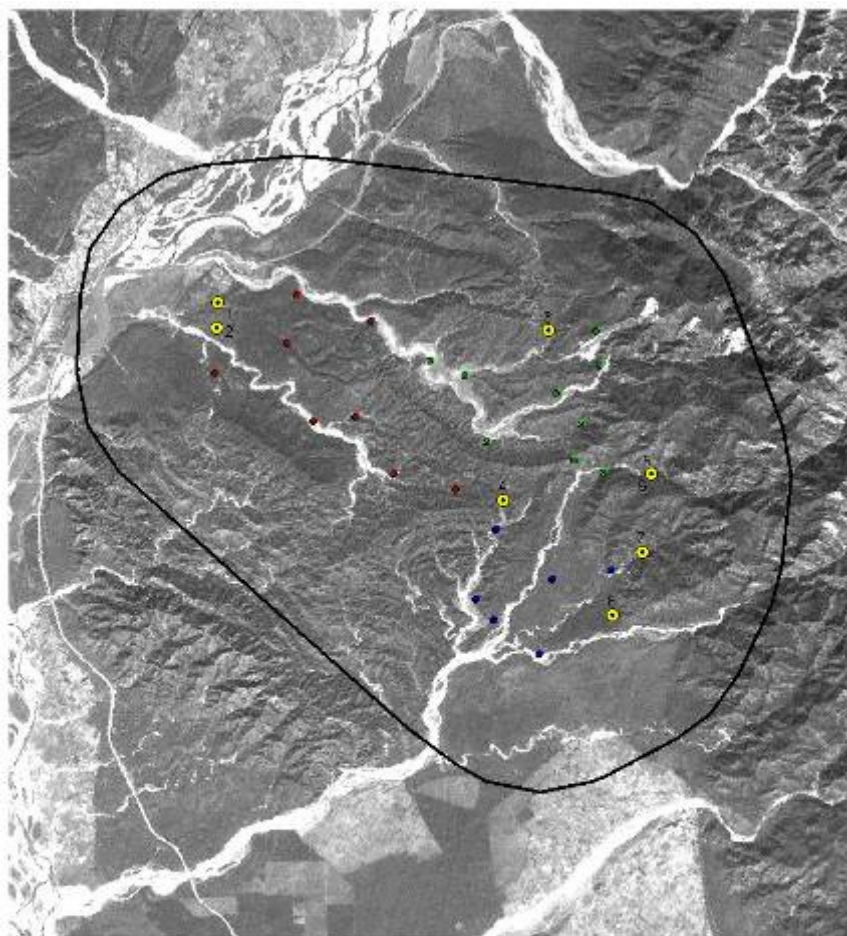


Location & Date

1. Delghati
(B1CT10)
08/01/06
2. Karondi Sot
(B2CT08)
09/01/06
3. Hill Top
(B2CT09)
18/01/06
4. Upstream Mithawali
(B3CT10)
30/01/06
5. Luni
(B3CT07)
31/01/06
6. Mehnderghati
(B2CT04)
28/02/06
6. Lalghati
(B3CT05)
19/03/06



Chilla Male (RT – 006)



Capture location
 Effectively Sampled area
 Trap locations
 Block 1
 Block 2
 Block 3

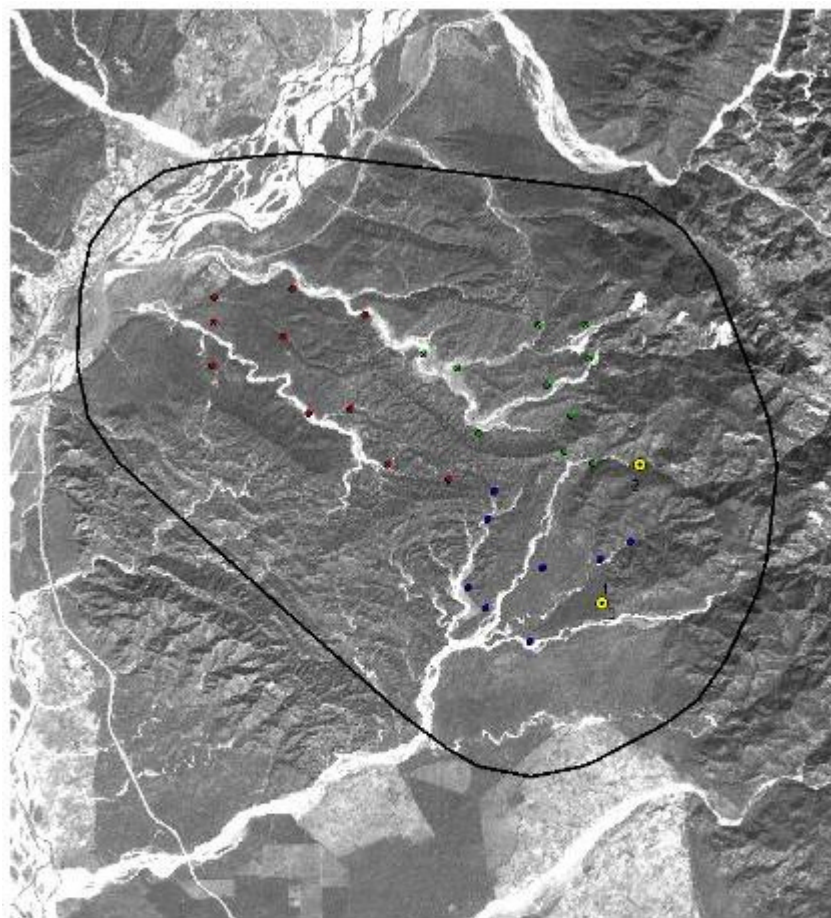


Location & Date

1. Near Chilla gate (B1CT03) 27/12/05
2. Machaan Road (B1CT04) 27/12/05
3. Mehnderghati (B2CT04) 14/01/06
4. Sain Sot (B3CT01) 25/01/06
5. Upstream Mithawali (B3CT10) 29/01/06
6. Upstream Mithawali (B3CT10) 01/02/06
7. Sarkada (B3CT09) 07/02/06
8. Luni (B3CT07) 11/02/06



Luni Female (RT – 007)



● Capture location
□ Effectively Sampled area
Trap locations
● Block 1
● Block 2
● Block 3

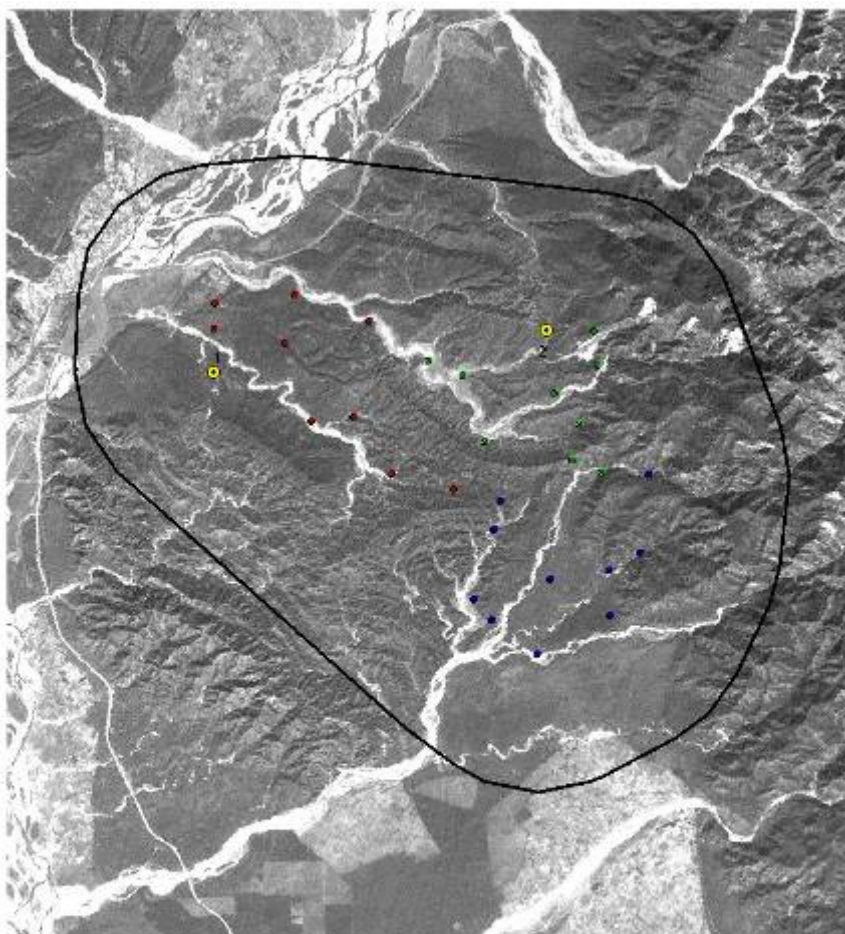


Location & Date

1. Luni
(B3CT07)
01/02/06
2. Upstream Mithawali
(B3CT10)
03/02/06
3. Luni
(B3CT07)
09/02/06



Nastarvali Female (RT – 008)



● Capture location
□ Effectively Sampled area
Trap locations
● Block 1
● Block 2
● Block 3



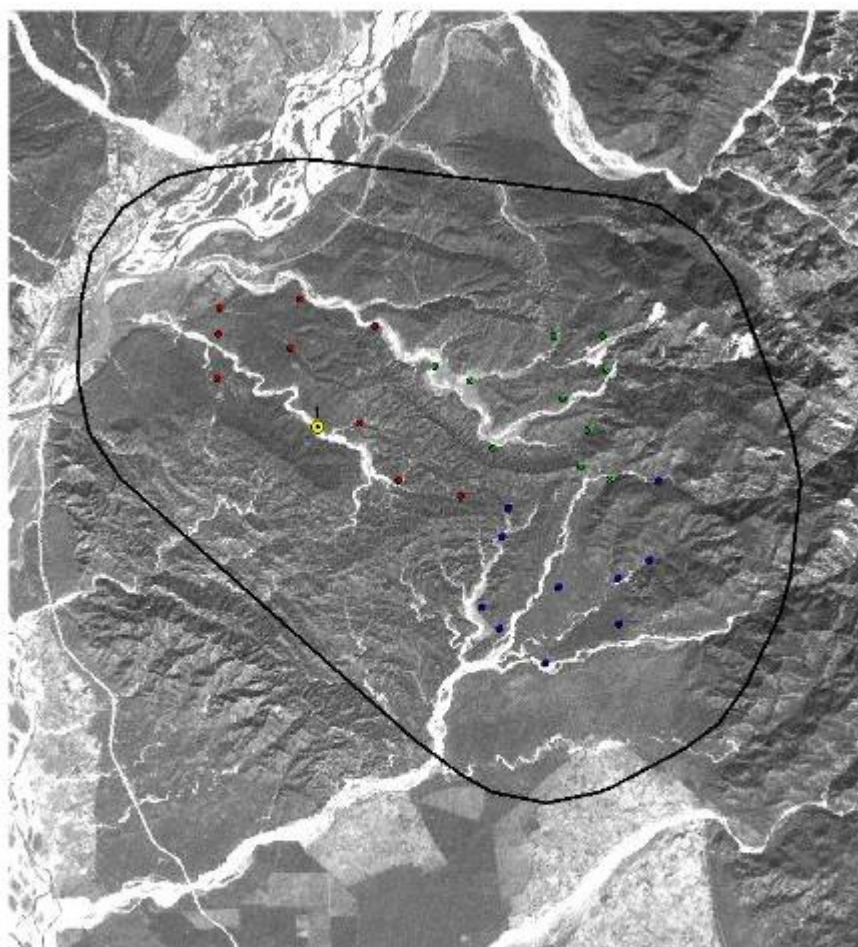
5 0 5 10 Kilometers

Location & Date

1. Nastarvali
(B1CT05)
29/12/05
2. Mehnderghati
(B2CT04)
02/03/06



Ghasiram Individual (RT – 009)

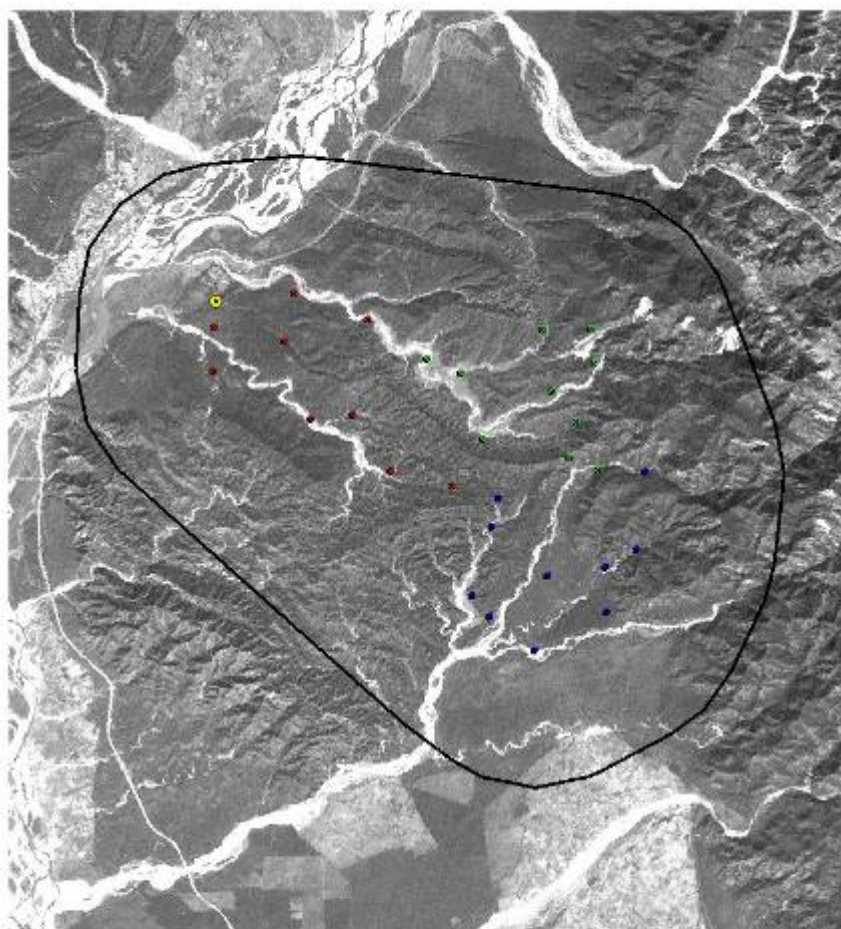


Location & Date

- 1. Ghasiram rau
(B1CT07)
04/01/06



Chilla gate Individual (RT – 010)



● Capture location
□ Effectively Sampled area
Trap locations
● Block 1
● Block 2
● Block 3

5 0 5 10 Kilometers

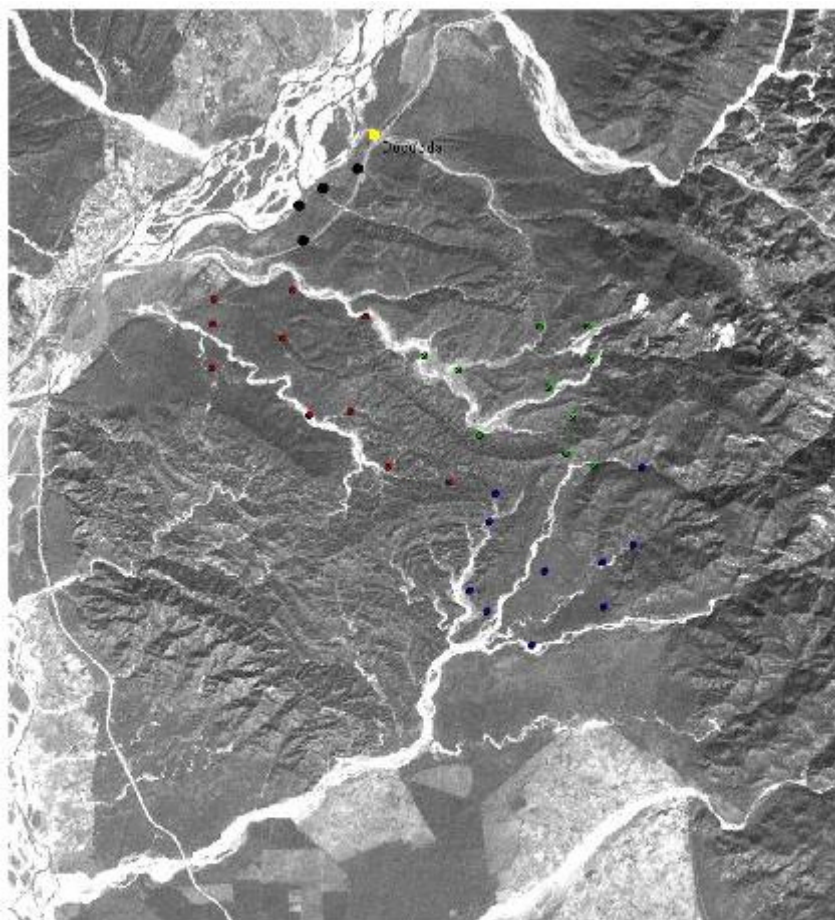


Location & Date

- 1. Chilla gate
(B1CT03)
18/02/06



Dogudda Female (RT – 011)



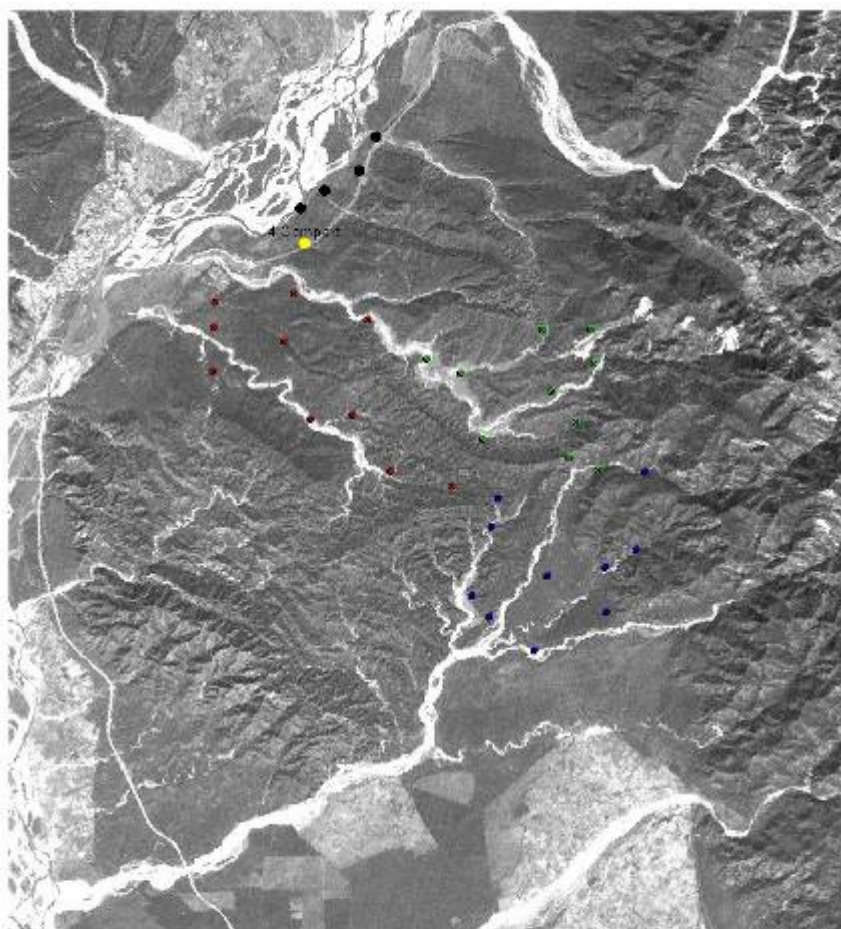
Location & Date

Dogudda
(Dogudda)
06/04/06

Captured during 15 days of sampling along the riverine forests of the east bank of the Ganges (Individual not included in analysis).



Ganga male (RT – 012)



● Capture location

Trap locations

- Block 1
- Block 2
- Block 3

5 0 5 10 Kilometers



Location & Date

4 Compartment nullah
(4 compart)
10/04/06

Captured during 15 days of sampling along the riverine forests of the east bank of the Ganges (Individual not included in analysis).

Photographs of tigers captured during 2005 - 2006 in Chilla Range, Rajaji National Park



RT-006 - 27.12.2005 (B1/T4)



RT-006 - 27.12.2005 (B1/T3)



RT-008 - 29.12.2005 (B1/T5)



RT-009 - 04.01.2006 (B1/T7)



RT-005 - 08.01.2006 (B1/T10)



RT-005 - 09.01.2006 (B2/T8)



RT-006 - 14.01.2006 (B2/T4)



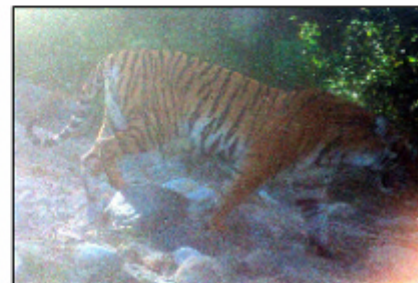
RT-005 - 18.01.2006 (B2/T9)



RT-006 - 25.01.2006 (B3/T1)



RT-006 - 29.01.2006 (B3/T10)



RT-005 - 30.01.2006 (B3/T10)



RT-005 - 31.01.2006 (B3/T5)

Photographs of tigers captured during 2005 - 2006 in Chilla Range, Rajaji National Park



RT-006 - 01.02.2006 (B3/T10)



RT-007 - 01.02.2006 (B3/T7)



RT-007 - 01.02.2006 (B3/T7)



RT-007 - 03.02.2006 (B3/T10)



RT-007 - 03.02.2006 (B3/T10)



RT-006 - 04.02.2006 (B3/T7)



RT-006 - 07.02.2006 (B3/T7)



RT-007 - 09.02.2006 (B3/T7)



RT-010 - 18.02.2006 (B1/T3)



RT-005 - 28.02.2006 (B2/T4)

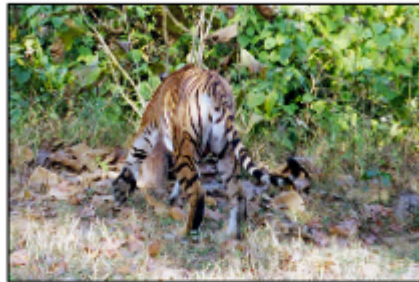


RT-008 - 02.03.2006 (B2/T4)



RT-005 - 19.03.2006 (B3/T7)

Photographs of tigers captured during 2005 - 2006 in Chilla Range, Rajaji National Park



21.03.2006 (B3/T7)



RT-011 - 06.04.2006 (Dogudda)



RT-011 - 06.04.2006 (Dogudda)



RT-012 - 10.04.2006 (4 no. nullah)



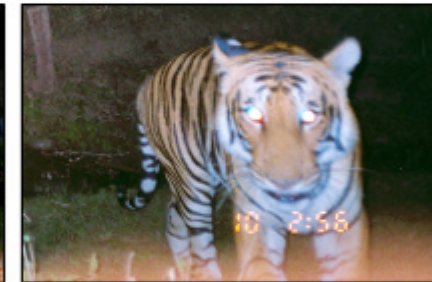
RT-012 - 10.04.2006 (4 no. nullah)



RT-012 - 10.04.2006 (4 no. nullah)



RT-012 - 10.04.2006 (4 no. nullah)



RT-012 - 10.04.2006 (4 no. nullah)



Hilltop Tigress



In June-July 2004, following the first phase of relocation of the *Gujjar* settlements in Chilla range of Rajaji National Park, adhoc camera trapping was carried out. During this period two to three camera locations were selected wherein our surveys indicated high probability of capturing tigers. One of these locations was on the road passing over the hills that separate the Mundal valley from the Mithawali valley. This narrow portion on the hill top provided us an ideal opportunity to place a camera trap and monitor animal movements. On the 13th of June 2004 (Fig. 1a) we obtained a capture of a tigress (see Hilltop female RT-002). By examining the stripe patterns we identified that this individual was characterized by a fork shaped stripe and a dot at the base of the tail (highlighted by circles in the photographs). A month later she was again photographed at a trap site located diagonally opposite the Mundal forest chowki, 6 km east of the hill top. At that time the tigress had a taut belly and appeared to be healthy.



Figure 1a. Hilltop - 13th June 2004



Figure 1b. Mundal – 1st July 2004



Figure 1c. Mundal – 5th January 2005



Figure 1d. Gau sot – 13th January 2005



Figure 1e. Hilltop – 2nd February 2005



Figure 1f. Mithawali - 9th February 2005



On the 2nd of January 2005 we resumed systematic camera trapping within a large part of Chilla range. Within 5 days of our sampling in the Chilla and Mundal forest beats, we captured the hill top tigress at one of our trap stations (Fig 1c). Although we could not get a complete photograph of the individual, the stripe patterns on her body clearly indicated that she was the same tigress earlier captured on the hill top in June 2004. Instead of a taut belly she had developed clear underwools on her belly. A photograph taken a week later made it clear that the tigress was pregnant (Fig. 1d). Subsequently we photographed her twice during February 2005 and all her photographs clearly indicated that she was lactating (Fig. 1e & 1f). The last photograph of her was obtained on the 13th of April 2005, during our last sampling session. A tigress with three cubs was sighted by our field assistant and the forest guard of Kasan beat (Imam Hussain and Nathiram respectively) in June 2005 within the same area where we had earlier captures of hill top tigress. We presume that it could be the hill top tigress. Following the direct sighting, pug marks of this family were encountered in many areas of Mundal and Kasan beats of Chilla range by the forest guards. However, in November 2005 the body of this female (Fig. 2) was recovered on the Ghasiram rau (along the southern boundary of the national park).



Figure 2. The two identifying features of the hilltop tigress.

Though this particular individual did not survive even one year after littering, we have photographed at least three other individuals (RT-003, RT-007, RT-008) in a span of two years which clearly show signs of breeding. Records of tigers breeding in Chilla range were sporadic during the presence of gujjars. The fact that tigers have started breeding in Chilla range clearly demonstrates the success of relocation of gujjars from the area.



**Daytime Photographs & Direct
Sightings of tiger**



Tigers are mostly crepuscular to nocturnal. Thus most photographic capture studies (Karanth & Nichols, 1998) are carried out from late evenings to early mornings. During our study however, we placed camera traps in some locations throughout the day. It was interesting to note that photographs of tigers were obtained even during the day (0700hrs-1700hrs). During the first primary period (2004-2005) 8.7% of all the photographs obtained of tigers were during the day where as 13.04% of all tiger photographs were during the day in the second primary session (2005-2006). Assuming that the time of photographic capture is indicative of the activity patterns of tigers it is of interest to note this change (Fig. 1). Increased daytime photographic captures of tigers in Chilla range is possibly because of the disturbance free environment following the relocation of *Gujjar* settlements.

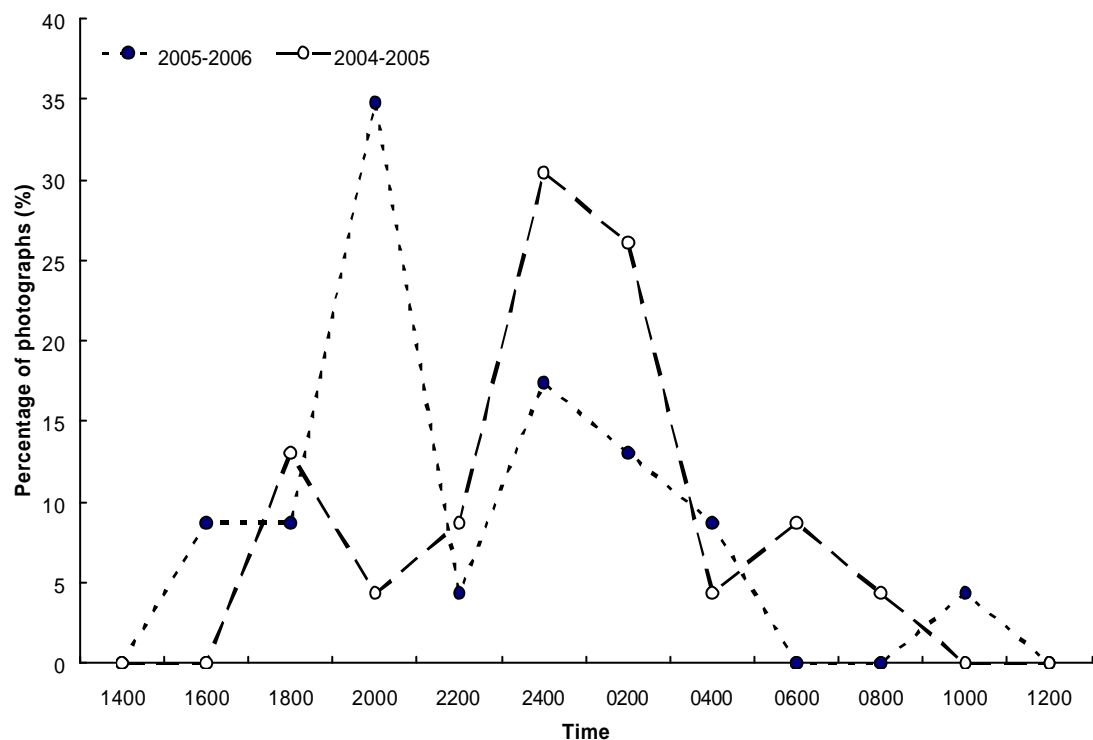


Figure 1. Percentage captures of tigers across time.

Day time photographs of tigers (2004-2005)



RT-002 – 30.01.06 – B3CT10



Day time photographs of tigers (2005-2006)



RT-005 – 30.01.06 – B3CT10



RT-006 – 01.02.06 – B3CT10



21.03.06 – B3CT07

During the course of the study three direct sightings of tigers were made. On 17 November 2004, the very first day when we started our systematic work on tiger and its prey population in Chilla, a tigress was sighted in the Mithawali valley along the Mithawali-Khara road. The sighting was at about 1725hrs. Though the individual was observed at close proximity we were unable to note any features of the stripe pattern that could help us identify the individual. However, following the systematic trapping we feel that it could have been the female using Mithawali-Sarkada areas (RT-005).

On our routine checking of camera traps during the systematic sampling (second run of block 2) on 18 March 2005 at 1100hrs we encountered a fresh sambar kill in the Amgadi sot (approximately 50m from the tourist road crossing the Amgadi sot). As is our routine to document kills made by tigers, we (A.H & Imam Hussain) approached the kill and sighted a tigress (probably RT-002) lying besides the kill.

After completing the sampling of the earlier designated three sampling blocks within Chilla range, we placed camera traps at five sites in the riverine forest along the eastern bank of the Ganges in order to document the tiger use of the area. On the evening of 03 April 2006, as we (A.H & Imam Hussain) were going to set up our camera trap at one of the trapping stations, we encountered a female (RT-011) on the road in front of the trap station. Following the 15 nights of sampling within this area we documented two individual tigers (RT-011 & RT-012) using the riverine patch of



forest along the east bank of the Ganges. Pugmark sets in the direction of Mothichur range on the west bank of Ganges have been documented. Though we do not have evidence of Chilla tigers using habitats along the west bank of the Ganges, it is important to note that tigers from Chilla range have started using the Chilla-Mothichur corridor. A record by *Gujjars* of a Buffalo kill on the islands in the Ganges suggests use of the area by tigers. In comparison to a survey of the Chilla-Motichur corridor done in 2001 (Johnsingh *et al.*, 2004), it seems that the area is now (following the relocation of *Gujjars*) being used frequently by tigers. Given the fact that the recent census report (2005, Uttaranchal Forest Department) records no evidence of breeding tigers in the western part of Rajaji National Park, dispersal of tigers from Chilla through Chilla-Motichur corridor could be very important in ensuring the long term survival of tigers within the Shivaliks.



Other animals photographed



With the help of remote photography the elusive lives of cryptic animals have been better understood. Since previously all other information regarding cryptic animals, carnivores in particular, were derived either from direct observations or indirect signs, remote photography studies have proved more successful (Kucera and Barrett 1993). From the times of Champion (1928) photographing cryptic animals such as the tiger in the Indian sub-continent using remote photographic techniques has sought popularity. During the course of our study we have photographed a large number of non target species. The presence of two species of bears (Sloth bear *Melursus ursinus* and Black bear *Ursus thibetanus*) using similar habitats in Chilla was confirmed by the use of remote cameras. This is probably one of the very few areas in the Indian subcontinent where both sloth and black bear coexist. It is also of interest to note that during our sampling both species were photographically captured at the same trap station on the same night. The presence of the Himalayan palm civet *Paguma larvata* was also confirmed. Other than just providing us information regarding presence of animal species insights into habitat use are also obtained. The striped hyena *Hyaena hyaena* documented only along the western boundary of Chilla range during our first sampling period (2004-2005) was found in the interior regions (Upstream of Ghara sot and Amgadi sot of Kasan beat) during our second sampling period (2005-2006).



Leopard
Panthera pardus

Sloth bear
Melursus ursinus





Black bear
Ursus thibetanus

Jackal
Canis aureus



Striped hyena
Hyaena hyaena



Small Indian civet
Viverricula indica



Himalayan palm civet
Paguma larvata

Porcupine
Hystrix indica





Indian pangolin
Manis crassicaudata



Common langur
Semnopithecus entellus



Asian elephant
Elephas maximus



Sambar
Cervus unicolor



Chital
Axis axis



Barking deer
Muntiacus muntjak



Nilgai
Boselaphus
tragocamelus



Wild pig
Sus scrofa

Hare
Lepus nigricollis





Annexure I

a

Location (GPS) of camera traps placed during the first primary session (2004-2005) in Chilla range of RNP.

Camera trap ID	Latitude	Longitude	Sampling block
B1CT01	29.96449	78.24834	1
B1CT02	29.97023	78.23193	1
B1CT03	29.96859	78.21454	1
B1CT04	29.95978	78.22960	1
B1CT05	29.93403	78.26034	1
B1CT06	29.96069	78.21025	1
B1CT07	29.95519	78.21614	1
B1CT08	29.93177	78.24976	1
B1CT09	29.94038	78.24142	1
B1CT10	29.94347	78.24455	1
B2CT01	29.93408	78.29273	2
B2CT02	29.94211	78.29409	2
B2CT03	29.94570	78.29341	2
B2CT04	29.95218	78.29931	2
B2CT05	29.95560	78.29770	2
B2CT06	29.96035	78.27321	2
B2CT07	29.96222	78.28771	2
B2CT08	29.96202	78.29734	2
B2CT09	29.95183	78.26905	2
B2CT10	29.94503	78.26763	2
B3CT01	29.93141	78.29892	3
B3CT02	29.91761	78.28642	3
B3CT03	29.91287	78.29412	3
B3CT04	29.91404	78.30778	3
B3CT05	29.90534	78.29908	3
B3CT06	29.89172	78.28483	3
B3CT07	29.89886	78.27803	3
B3CT08	29.92539	78.27372	3
B3CT09	29.90356	78.27099	3
B3CT10	29.93160	78.29629	3

b

Location (GPS) of camera traps placed during the second primary session (2005-2006) in Chilla range of RNP.

Camera trap ID	Latitude	Longitude	Sampling block
B1CT01	29.96462	78.24822	1
B1CT02	29.97029	78.23186	1
B1CT03	29.96859	78.21454	1
B1CT04	29.96301	78.21428	1
B1CT05	29.95331	78.21386	1
B1CT06	29.95976	78.22963	1
B1CT07	29.94259	78.23560	1
B1CT08	29.94346	78.24462	1
B1CT09	29.93110	78.25325	1
B1CT10	29.92787	78.26680	1
B2CT01	29.95591	78.26132	2
B2CT02	29.95274	78.26872	2
B2CT03	29.96233	78.29746	2
B2CT04	29.96233	78.28694	2
B2CT05	29.95488	78.29817	2
B2CT06	29.93818	78.27362	2
B2CT07	29.94888	78.28892	2
B2CT08	29.94215	78.29414	2
B2CT09	29.93405	78.29271	2
B2CT10	29.93148	78.29891	2
B3CT01	29.92518	78.27684	3
B3CT02	29.91893	78.27541	3
B3CT03	29.90360	78.27115	3
B3CT04	29.89901	78.27507	3
B3CT05	29.89157	78.28482	3
B3CT06	29.90798	78.28780	3
B3CT07	29.89994	78.30084	3
B3CT08	29.90978	78.30075	3
B3CT09	29.91382	78.30748	3
B3CT10	29.93083	78.30952	3
Ganga	29.98913	78.23302	4
Dogudda	30.00480	78.24984	4
4 Compart	29.98119	78.23401	4
Lal Sot	29.99735	78.24608	4
Sen Sot	29.99289	78.23832	4

C

Location (GPS) of Start and end points of the nine permanent transects laid in Chilla range of RNP.

Transect ID	Length (m)	Longitude	Latitude	Sampling block
B1LT1start		78.21518	29.96775	
B1LT1end	2490	78.23721	29.95588	1
B1LT2start		78.21106	29.95957	
B1LT2end	930	78.21668	29.95258	1
B1LT3start		78.25647	29.93346	
B1LT3end	1000	78.24807	29.93200	1
B2LT1start		78.27250	29.95410	
B2LT1end	910	78.27327	29.96246	2
B2LT2start		78.27672	29.94141	
B2LT2end	1160	78.28403	29.94946	2
B2LT3start		78.28940	29.93841	
B2LT3end	960	78.29557	29.94537	2
B3LT1start		78.27571	29.92266	
B3LT1end	1230	78.26480	29.92740	3
B3LT2start		78.27821	29.89867	
B3LT2end	2190	78.28380	29.91775	3
B3LT3start		78.30395	29.87567	
B3LT3end	1980	78.30518	29.89257	3

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