Density of leopards (Panthera pardus) in the Chilla Range of Rajaji National Park, Uttarakhand, India

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Panthera

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Short Note

Density of leopards (*Panthera pardus*) in the Chilla Range of Rajaji National Park, Uttarakhand, India

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In the Indian subcontinent, tigers (*Panthera tigris* Linnaeus) occur sympatrically with leopards (*P. pardus* Linnaeus) over most of their range. While considerable conservation investment is primarily targeted towards recovering the dwindling populations of tigers (Dinerstein et al. 2007), our understanding of the potentially cascading effects of human-induced changes to populations of one carnivore species on the entire carnivore community (Smith et al. 2003) remains poor. Though leopards may not be as adversely affected as tigers under deteriorating habitat conditions (Ramakrishnan et al. 1999), the continual loss of habitat and intense poaching for illegal trade in body parts (Environmental Investigation Agency (EIA) and Wildlife Protection Society of India (WPSI) 2006) has caused a decline in their population. However, the lack of estimates of population size makes it difficult to make an objective assessment of their status.

The Chilla forest range (148 km^2) of Rajaji National Park (RNP, 820 km^2) has witnessed signs of recovery with respect to utilization of the area by tigers (Pandav et al. 2004) following the resettlement of 193 *gujjar* (a pastoralists community) families. This program, initiated by the Uttarakhand Forest Department in 2003, was aimed at reviving the declining population of tigers. The current tiger density in the Chilla range is 3/100 km^2. However, the range with a prey density of 91 per km^2 (Harihar 2005) has potential for supporting a far higher number of tigers, i.e., ~14 tigers/100 km^2, according to a model of the relationship between tiger and prey density (Karanth et al. 2004). It is in this context that the present study estimates the population density of leopards in the Chilla forest range in order to establish a baseline for monitoring the response of the predators to minimization of anthropogenic disturbances.

This study was carried out from January to February 2005 in the Chilla forest range. Generally, the forests of this region can be categorized as Northern Indian Moist Deciduous Forest and Northern Tropical Dry Deciduous Forest (Champion and Seth 1968), with the major associations being mixed forests on the southern slopes and Sal (*Shorea robusta*; Dipterocarpaceae) -mixed and Sal-dominated forests on the northern slopes. The area supports a high ungulate prey density of which ~90% is contributed by chital (41.5±10.7 SE) and sambar (21.3±4.1 SE). Of the groups encountered in line transect surveys (Harihar 2005), 18.3% were of small-bodied animals (peafowl *Pavo cristatus* Linnaeus and common langur Dufresne, <20 kg), 40.6% were of medium-sized animals (chital *Axis axis* Erxleben and wild pig *Sus scrofa* Linnaeus, 20–50 kg) and 40.9% were of large-bodied animals (sambar *Cervus unicolor* Kerr and nilgai *Boselaphus tragocamelus* Pallas, >50 kg). Though livestock densities were not estimated, they are found bordering the range and also constitute potential prey species for both tiger and leopard.

To estimate the population density of adult leopards in the study area, we used photographic capture-recapture analysis. Previously developed for tigers (Karanth 1995, Karanth and Nichols 1998), this method has been found effective for the estimation of population sizes of many rare and elusive large cats (Karanth and Nichols 1998, Trolle and Kery 2003, Silver et al. 2004). We used a total of 10 camera trap units (TRAILMASTER TM 1550, Goodson and Associates, Lenexa, KS, USA), each of which was equipped to photograph only 1 flank of the leopard at every capture.

In total, 30 camera-trapping locations were identified (Figure 1) in the Chilla range. These trapping locations were selected in order to maximize the capture probabilities of leopards. To systematically sample the area, three sampling blocks (spatially separated) were identified. Each of the three blocks consisted of 10 camera trap sites with a mean inter trap distance of 1.82 km (ranging from 1.33 to 2.44 km) run for 15 consecutive days. Thereby, the total sampling period amounted to 45 days (450 trap nights) and each sampling occasion combined captures from 1 day drawn from each block. One trap night was a 14-h period (17:00–07:00 h) during which a camera was functional. To ensure effective performance of the cameras (replenish film rolls and batteries), the 10 trapping sites in a block were checked on a daily basis. All rolls of film used during the trapping were given a unique identity (e.g., Block1/Trap1/Roll1) in order to correctly note the date, time, and location of the captures. Every leopard captured was given a unique identification number (e.g., RL-001) after examining the

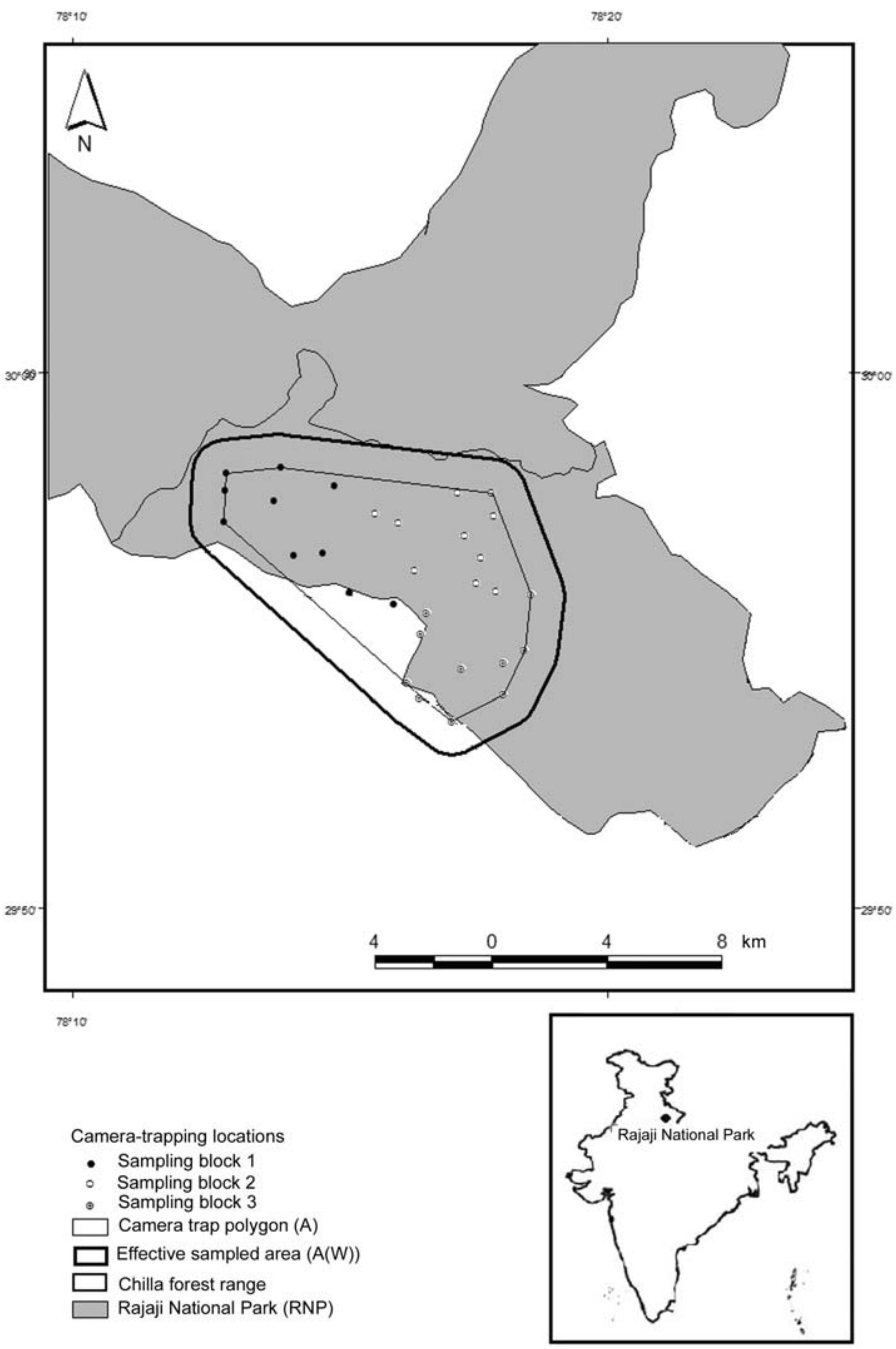

Figure 1 The 30 camera-trapping locations within three spatially separated blocks, camera trap polygon (A) and the effective sampled area [A(W)] used to estimate leopard density within the Chilla forest range of Rajaji National Park during January–February 2005.

rosette pattern on the flanks, limbs, and forequarters (Figure 2). Following the identification of leopards, capture histories (X matrix) were developed.

As estimating population sizes using closed capture models require the population under investigation to be both demographically and geographically closed, we tested for population closure using the Pradel (1996) model incorporated in the MARK program (White and Burnham 1999). We estimated the apparent survival (Φ), recruitment (f), and recapture probability (p) in order to test for population closure with regard to entry and exit into or out of the sampling grid, under the assumption that the population of leopards was demographically closed during these 45 days. As apparent survival is given by the product of true survival (S) and fidelity (F) for the sampled area (Φ=SF), violation of closure could only be as a result of changes in fidelity (F) as true survival was assumed to be equal to 1 (S=1). Because there were no births during the course of the study, f was an estimate of the number of immigrants into the sampling grid. In all, we tested eight competing models with Φ, p, and f estimated as either constant (•) or varying with time

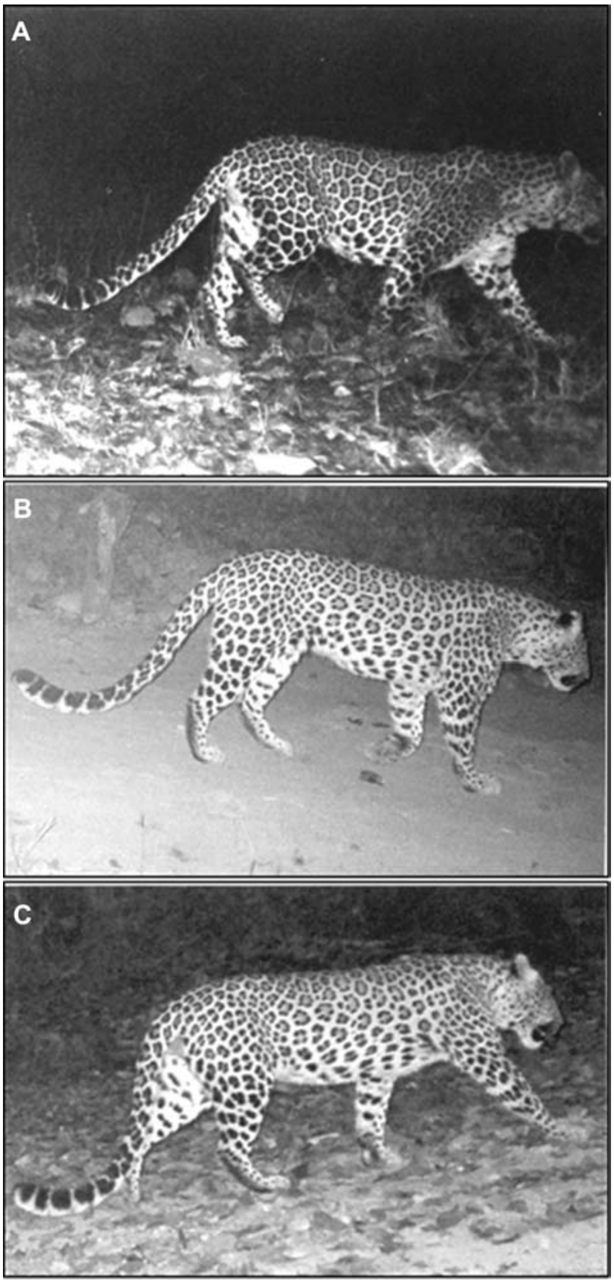

Figure 2 Photographs of two individual leopards, (A) RL-008 and (B, C) RL-007, showing differences in rosette patterns which allow for individual identification.

(t). The model with the lowest Akaike Information Criterion (AIC_c) was considered as the most parsimonious (Burnham and Anderson 1998).

The population size ($\hat{N}$) was estimated using the MARK program by modeling for variations in capture (p) and recapture (c) probabilities. Finite mixture models (two mixtures; Pledger 2000) were used to investigate the effect of heterogeneity. Fit of models was again evaluated using AIC_c (Burnham and Anderson 1998). The density ($\hat{D}$) of leopards in the study area was estimated as the population size ($\hat{N}$) divided by the effective sampled area [A ($\hat{W}$)], where A ($\hat{W}$) was 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 leopards added to the camera trap polygon (A) (Karanth and Nichols 1998).

The total sampling effort amounted to 449 trap nights (January–February 2005). The intensive trapping resulted in a total of 11 photographs of eight individual leopards identified using the right flank profile (Table 1). In addition, seven photographs of five individual leopards identified using the left flank profile were obtained. As the number of individuals identified from the right flank profile was higher, we only used these data for further analysis. Apparent survival Φ [SE(Φ)] was estimated at 0.97 (0.11) and the recruitment rate f was estimated to be <0.001 using the best model [$\Phi(\cdot)$ p(t) f($\cdot$); K=16], therefore, providing less evidence for the violation of closure.

The model selected by the AIC_c score [M_o p($\cdot$) N($\cdot$); Table 2] estimated capture probability ($\hat{p}$) as 0.0531 and population size $\hat{N}$ [SE ($\hat{N}$)] as 13 (6.02). The camera trap polygon (A) formed using periphery camera traps measured 52.65 km^2. The boundary strip width $\hat{W}$[SE ($\hat{W}$)] was estimated as 1.16 (0.8) km and the effective sampled area A($\hat{W}$) [SE(A ($\hat{W}$))] was 86.72 (3.4) km^2. Thus, the estimated leopard density $\hat{D}$[SE($\hat{D}$)] for Chilla range of RNP was 14.99 (6.9) leopards/100 km^2.

Although photographic capture-recapture sampling methodology has been used to estimate the density of tigers in many protected areas throughout India (Karanth and Nichols 1998, Karanth et al. 2004), similar density estimates of leopards are only available from Sariska Tiger Reserve (Chauhan et al. 2005). Our estimate based on the capture-recapture framework is lower than the density estimated from the dry forests of Sariska (23.5

Table 1 Capture histories of individual leopards identified using the right flank profile in Chilla range of Rajaji National Park, across 15 samplings undertaken in three sampling blocks in a phased method during the 45 days of sampling (January–February 2005).

Leopard ID	Sampling occasions														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RL-001	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
RL-002	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
RL-003	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
RL-004	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
RL-005	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
RL-006	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RL-007	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0
RL-008	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Table 2 Closed population model selection by the MARK program for leopards in Chilla range of Rajaji National Park, Uttarakhand, India, 2005, using Akaike Information Criterion (AIC_c), the difference in AIC_c between the ith model and the model with lowest AIC_c value (Δi), Akaike weights (w_i), and number of parameters (K).

Model	AIC_c	Δi	w_i	K
M_o p(•) N(•)	53.174	0.000	0.527	2
M_b p(•) c(•) N(•)	55.024	1.850	0.209	3
M_h π(•) p(g) N(•)	55.278	2.104	0.184	3
M_{bh} π(•) p(g) c(g) N(•)	57.165	3.991	0.072	4
M_t p(t) N(•)	62.121	8.947	0.006	16
M_{th} π(•) p(t) N(•)	64.839	11.665	0.002	17
M_{tb} p(t) c(t) N(•)	93.743	40.569	<0.00	28
M_{tbh} π(•) p(g,t) c(g,t) N(•)	97.230	44.056	<0.00	29

Capture probability (p) and recapture probability (c) were modeled either as varying over time (t), constant over time (•), varying across mixtures (g) or varying both across mixtures and time (g,t). Model structure not incorporating c implies that p=c. The heterogeneity parameter (π) and population size (N) were estimates that did not vary across time (•).

leopards/100 km^2) following the local extinction of tigers. However, in the absence of comparable density estimates from across representative habitats within India, it is difficult to identify the regulators of relative abundance of leopards.

The issue of resettlement of local communities from wildlife areas has attracted considerable conservation attention in India (Rangarajan and Shahabuddin 2006). However, the efficacy of such conservation-induced displacement of communities in terms of recovery of wildlife habitat has not been quantitatively analyzed. The resettlement of *gujjars* from within Chilla has provided us with a unique opportunity to assess the response of predators and wild prey populations to minimization of anthropogenic pressures. Therefore, continuous monitoring of the predator population based on robust methodology as employed in this study assumes critical importance for both management and scientific reasons.

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