Understanding the response of wild ungulate prey to livestock-mediated competition in western Terai Arc Landscape, India: implications for developing management strategies to restore corridors

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Introduction

The Terai-Arc Landscape, encompassing the Shivalik hills and the Terai flood plains, is one of the five landscapes identified for tiger conservation in India. With a human population density of >500 people km^{-2} (the national average is 300 people km^{-2}; Johnsingh et al., 2004), populations of tigers occur in forest patches comprising a matrix of protected areas, multiple use forests (Forest Divisions), agricultural land and human habitation. The north-western portion of this landscape spans from the Gola River in the east to the Yamuna River in the west, forming the distributional limit of tigers in the Indian subcontinent. Encompassing the protected areas of Corbett Tiger Reserve and Rajaji National Park which cover only c. 30% of the area, it is fragmented into two disjunct units identified as Tiger Habitat Blocks, with poor or no connectivity because of anthropogenic disturbances (Johnsingh et al., 2004). Covering nearly 4,800 km^2, this hilly (*bhabar*) tract could potentially support a minimum of 150 adult tigers if corridors were established and adequate protection provided (Johnsingh et al. 2004). From west to east these Tiger Habitat Blocks include the western part of Rajaji National Park and multiple use forests covering c. 1,800 km^2 from Yamuna River to the west bank of Ganga River (Block I), and the eastern part of Rajaji National Park, Corbett Tiger Reserve and multiple use forests covering c. 3,000 km^2 from the east bank of Ganga River to the west bank of Gola River (Block II), forming the north-western population limit of tigers in the Indian subcontinent (Fig. 1).

During surveys conducted by Johnsingh et al. (2004) in western TAL, the Chilla range of east RNP which was then inhabited by *gujjars* recorded a relatively low frequency occurrence of tigers (18.3±24.1 SD%). However, following the resettlement of 193 *gujjar* families from within Chilla range of RNP, studies (Harihar et al. 2009) documented a recovery in the population of tiger and their prey. Within three years of minimization of disturbance, the frequency of occurrence of tigers increased to 60.8% (±31 SD %) and density increased from three to five tigers/100 km^2. While photographic evidence of breeding tigers (lactating females and cubs) were obtained within a year after resettlement, the increase in tiger density is presumably due to the connectivity of this area to CTR through the Lansdowne Forest Division (Rajaji-Corbett corridor). This established a new source population in eastern RNP and allowed the first known attempt in two decades by tigers to cross the adjacent 2 km riverine forest corridor and stepping stones islands where the Ganga River divides the RNP. Our study (Harihar et al. 2009) also documented a sharp increase in recruitment (5 fawns to 55 fawns per 100 adult females) among chital in three years following the minimization of disturbance. It is pertinent to note that though livestock are also potential prey, retaliatory poisoning of tigers makes it imperative to ensure higher densities of wild ungulate prey to sustain tiger populations. The immediate recovery of tiger and prey populations observed in Chilla clearly demonstrates that it is possible to sustain tigers in the face of massive land-use change and intensifying anthropogenic disturbances. However, ensuring long-term viability of tiger populations requires conservation efforts targeted at the level of the landscape. Thereby, we expect to aid the management in developing well-informed and socially responsible strategies to restore wild prey to ensure long-term viability of corridors across the landscape. Therefore the overall aim of the study

was to study the impact of livestock grazing on wild prey presence and density and assess the dependencies of local communities on habitats and resources shared with wild prey so as to develop management strategies to restore wild prey habitats.
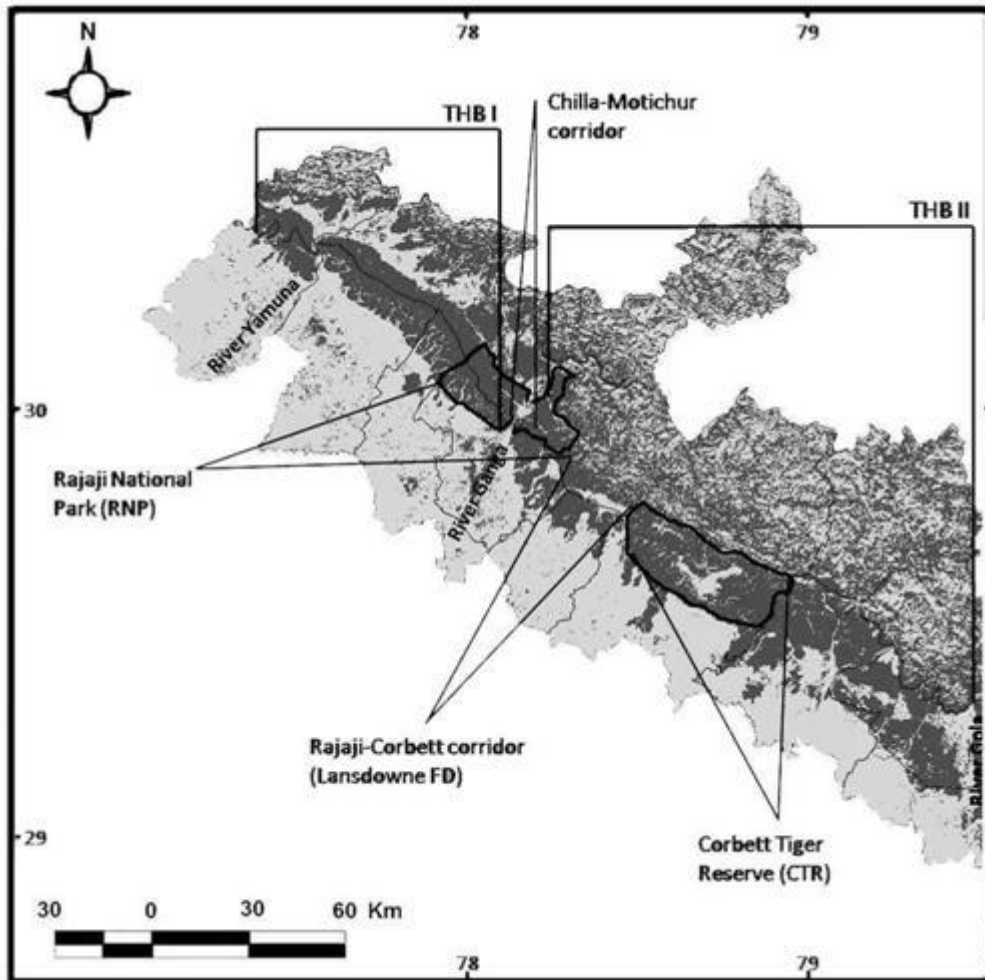

Figure 1. North-western limit of the Terai-Arc Landscape showing major rivers (Yamuna, Ganga & Gola), Tiger Habitat Blocks (THB I & II), corridors (Chilla-Motichur & Rajaji-Corbett) and the protected areas of Rajaji National Park (RNP) and Corbett Tiger Reserve (CTR).

Study area

The forest divisions (FD) and the protected area (PA) that fall in THB I (approx. 1800 km^2; Fig. 1) are Kalsi, Shivalik (Uttar Pradesh), Dehradun, Narendranagar (in part), and the western part of Rajaji National Park (Uttarakhand); and in THB II (approx. 3000 km^2; Fig. 1), are the eastern part of Rajaji NP, Haridwar, Bijnor Plantation Division (Uttar Pradesh), Lansdowne, Corbett TR, Ramnagar, Nainital, Terai West, and Terai Central Uttarakhand). The Chilla-Motichur corridor (c. 3 km^2) connecting eastern and western Rajaji National Park across the river Ganga is highly disturbed by developmental activities along the river. The expansion of Haridwar and Rishikesh townships and Raiwala village are causing disturbances along the west bank of the river Ganga. The establishment of Khand *gaon* settlements (I, II and III) for the Tehri dam evacuees, Raiwala Army camp with an ammunition dump, and the Hindustan Antibiotic Factory on the west bank of river Ganga, and the construction of the 14

km long Rishikesh-Chilla power channel on the east bank of river Ganga have further severed habitat connectivity between THB I and THB II.

Characterized by rugged hills ranging over 400–1,000 m altitude with steep southern slopes and drained by seasonal rivers and streams running north to south, the forests of this region are categorized as Northern Indian Moist Deciduous Forest and Northern Tropical Dry Deciduous Forest (Champion & Seth, 1968). The major vegetation associations are mixed forests comprising tree species such as *Terminalia alata, Anogeissus latifolia, Lagerstroemia parviflora, Holoptelia integrifolia, Ehretia laevis, Aegle marmelos,* and Sal *Shorea robusta* on the south facing slopes and Sal dominated forests on the gentle north facing slopes. Apart from the tiger, leopard also occur in this area. The prey species of the tiger in the study area are sambar *Cervus unicolor*, chital *Axis axis*, barking deer *Muntiacus muntjak*, nilgai *Boselaphus tragocamelus*, wild pig *Sus scrofa*, goral *Nemorhaedus goral*, common langur *Semnopithecus entellus*, porcupine *Hystrix indica*, hare *Lepus nigricollis* and Indian peafowl *Pavo cristatus*. Domestic livestock (chiefly cattle and buffalo) are also potential prey species.

Gujjars, a pastoralist community, inhabit many regions of the study area. With their large holdings of Buffalos (*Bubalis bubalis*), intensive grazing, lopping and firewood extraction, has led to habitat degradation (Edgaonkar 1995). Within the landscape *Gujjars* do not inhabit Corbett NP (part of Corbett TR) and parts of Rajaji NP.

Methods

Study Design

Based on prior work, we assessed the occupancy of tigers by gridding the landscape into geographical grids larger than the maximum home range size of tigers (161km^2). To estimate parameters of interest for prey species we sub-divided each 161km^2 cells into 16 sub-cells of ~10km^2 (larger than the maximum home range size of ungulate prey). Prior to sampling, a subset of these ~10km^2 cells were chosen to ensure adequate spatial coverage alongside representing a gradient of disturbance. For the assessment of the project objectives an approximate 30% (~15) of the cells were sampled (Fig. 2).

Estimation of prey density

Densities of wild prey were estimated using line transects and distance sampling (Thomas et al. 2010). A total of 92 line transects were laid, with mean lengths of 2 km and a total length of 172 km, covering all vegetation types. Each transect was walked two times by two observers over 06.00–09.30 from November 2010 to March 2011 (a total of 184 walks and 358 km). On every walk, species, group size, age-sex composition, sighting angle using a hand held sighting compass, and sighting distance measured by a laser range finder were recorded. Population density of principal prey species was estimated using the software *Distance* (Thomas et al. 2010). To model detection functions to estimate species' density the data for each species per transect was examined for signs of evasive movement and peaking at distances from the line of walk. The Akaike Information Criterion (AIC) and goodness-of-fit tests were used to judge the fit of the model. Using the model thus selected, estimates of group density, group size and individual density were derived.

Assessing wild ungulate population density and performance to livestock densities

To assess the impact of livestock grazing on wild ungulates we correlated two indicator parameters; (a) Density and (b) population performance (fawns per 100 females) of chital and sambar as they are the primary prey species present in the landscape to the number of livestock heads per household. We used estimates of density derived from our distance based sampling at the level of the grid and population performance obtained from both transects and opportunistic sightings within the sampling cell.

Assessing the dependencies of forest dwelling communities on habitats and resources shared with wild prey

Household surveys were conducted among *Gujjars* residing within the selected subset of 10km^2 cells. A semi-structured questionnaire survey was conducted in Hindi and/or *Gujjari*. The survey assessed the costs and benefits arising from livestock husbandry. In addition, the surveys also assessed the use value of the forests to the community and document the general attitudes towards relocation and compensation. In particular the key variables which were quantified during these surveys included (a) socio-economic profiles of the households surveyed, (b) profile of livestock holdings, and milk production of the surveyed households, and, (c) potential interventions that could be implemented to better living conditions.
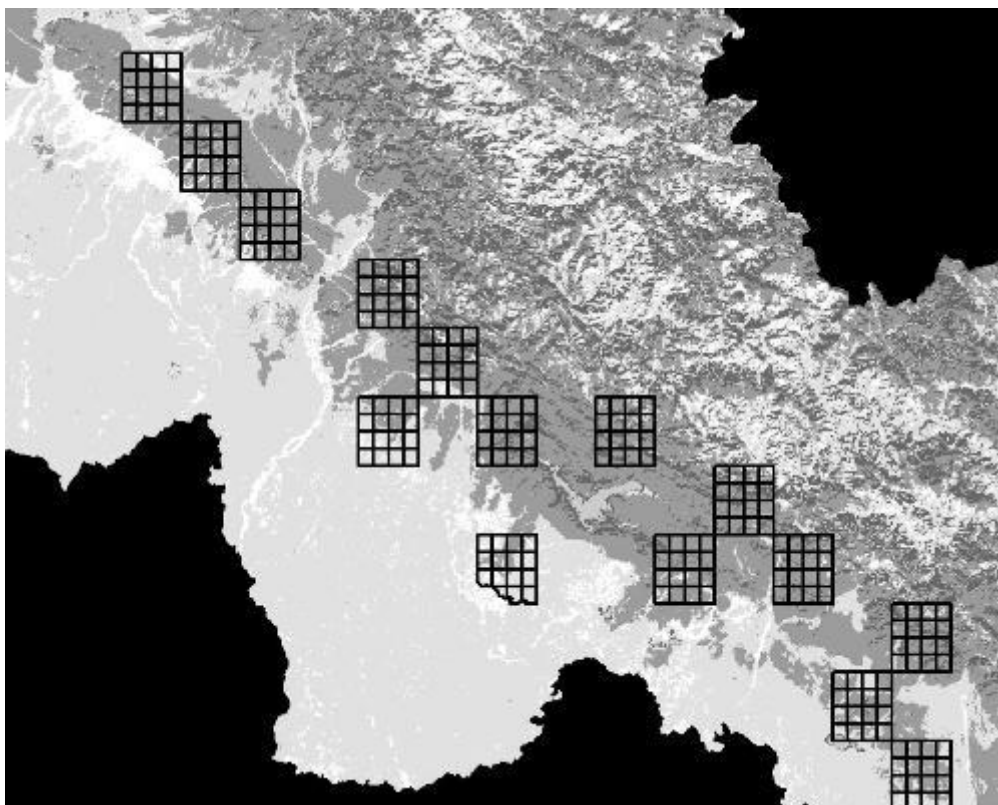

Figure 2. Selected grids (15) for the assessment of prey density and dependency of forest dwellers on habitat. Larger grids are 161km^2 and sub-cells are ~10 km^2 each.

Results and Discussion

Density of wild ungulate prey

Across the landscape we estimated densities for five (sambar, chital, nilgai, wildpig, and barking deer) of the six ungulate prey species that were detected on transects (Table 1), with an estimated overall individual density of 51.66 km^{-2} within protected areas and 21.74 km^{-2} outside of protected areas. In terms of group density within protected areas, chital was the most abundant followed by sambar, wildpig, barking deer and nilgai. Chital was also the most abundant in terms of individual density within protected areas, followed by sambar, wildpig, barking deer and nilgai. Outside protected areas, chital was the most abundant in terms of group density followed by sambar, barking deer, nilgai and wildpig. While outised protected areas, individual densities of chital was the greatest followed by sambar, nilgai, wildpig and barking deer.

The lack of well-stratified data on prey availability from outside protected has been recognized as a major impediment in extrapolating data to show conditions for tigers in corridors (Dinerstein et al. 2006). Through our assessment, we have generated data which would overcome this limitation and facilitate in evaluating the condition for tigers across forest patches in the landscape to identify source areas, dispersal corridors and potential breeding habitats. Though we had expected to analyse forage selection and dietary overlap between wild ungulates and livestock we were unable to complete this sub-objective. Though we have been broadly able to characterise the food habits of various species (using micro-histology) the inability to identify various species of family Poaceae has limited our inference.

Response of wild ungulate population density and performance to livestock

Our previous study in eastern Rajaji National Park documented a recovery in population of tigers and wild ungulate prey following resettlement of *gujjars* (Harihar et al. 2009). A notable finding of our study was the sharp increase in recruitment (5 fawns to 55 fawns per 100 adult females) among chital (*Axis* axis) in three years following the minimization of disturbance. We hypothesised that chital being ruminant grazers like cattle and buffalo were probably more affected by the presence of livestock within the area. Therefore, in this study we wished to assess the response of chital and sambar (both major prey species of tiger in the landscape) to livestock grazing.

Our results indicated that chital responded negatively to livestock grazing. With an increase in livestock densities (No./km^2), group densities (Fig. 3a), individual densities (Fig. 3b) and population performance of chital (Fig. 3c) declined significantly. In contrast, group densities (Fig. 4a), individual densities (Fig. 4b) and population performance of sambar (Fig. 4c) showed no significant change. Though we have limited data to address the issue of resource limitation and competition between ruminant grazers, we infer that the increasing proportion of fawns among chital is indicative of population recovery, which suggests improved recruitment among chital in areas where livestock densities are lower. These results have important implications for the management of livestock grazing both in our study area as well as across wildlife habitats in India.

Table 1. Group density and density of individuals wild ungulate species outside protected and within protected areas in western Terai-Arc Lanscape from November 2010 to March 2011(see text for further details)

| Non-PA/PA	Chital		Sambar		Nilgai		WildPig		Barking Deer		Overall ungulate density	
	Grp Den	Ind Den	Grp Den	Ind Den	Grp Den	Ind Den	Grp Den	Ind Den	Grp Den	Ind Den	Grp Den	Ind Den
PA	3.18	33.26	4.58	7.72	0.15	0.15	0.73	1.10	2.32	2.71	10.95	44.94
PA	8.94	38.40	9.77	16.91	0.16	0.64	2.34	4.29	0.83	0.83	22.04	61.06
PA	10.23	39.61	5.27	9.50	0.20	1.42	0.00	0.00	0.00	0.00	15.70	50.53
PA	0.00	0.00	2.76	9.45	0.00	0.00	0.00	0.00	0.61	1.21	3.36	10.66
PA	10.78	47.61	9.31	12.38	0.00	0.00	2.84	10.23	0.00	0.00	22.94	70.23
PA	9.95	19.78	2.02	2.02	0.00	0.00	4.20	16.78	2.22	2.22	18.39	40.81
PA	16.58	96.24	6.49	12.82	0.00	0.00	0.00	0.00	0.00	0.00	23.07	109.07
PA	4.16	16.89	0.00	0.00	1.84	5.12	0.00	0.00	3.98	3.98	9.98	25.99
Average	**7.98**	**36.47**	**5.02**	**8.85**	**0.29**	**0.92**	**1.26**	**4.05**	**1.24**	**1.37**	**15.80**	**51.66**
Non-PA	1.31	10.67	0.53	0.53	0.00	0.00	0.00	0.00	0.00	0.00	1.84	11.20
Non-PA	0.51	2.56	1.25	3.12	0.00	0.00	0.00	0.00	0.62	0.62	2.38	6.30
Non-PA	2.80	12.26	6.44	16.78	0.00	0.00	1.18	3.93	2.08	2.08	12.50	35.06
Non-PA	6.84	36.50	6.06	6.39	3.53	11.64	0.79	0.79	0.00	0.00	17.22	55.32
Non-PA	2.49	18.50	4.55	16.35	0.00	0.00	0.52	1.05	3.89	3.89	11.45	39.79
Non-PA	0.00	0.00	0.00	0.00	0.64	0.64	0.00	0.00	0.00	0.00	0.64	0.64
Non-PA	0.00	0.00	0.00	0.00	0.25	0.74	1.82	7.91	0.00	0.00	2.07	8.65
Non-PA	4.01	32.17	0.00	0.00	0.26	1.55	0.00	0.00	1.34	2.02	5.61	35.73
Non-PA	1.99	2.17	0.00	0.00	0.51	0.77	0.00	0.00	0.00	0.00	2.50	2.94
Average	**2.22**	**12.76**	**2.09**	**4.80**	**0.58**	**1.71**	**0.48**	**1.52**	**0.88**	**0.96**	**6.25**	**21.74**
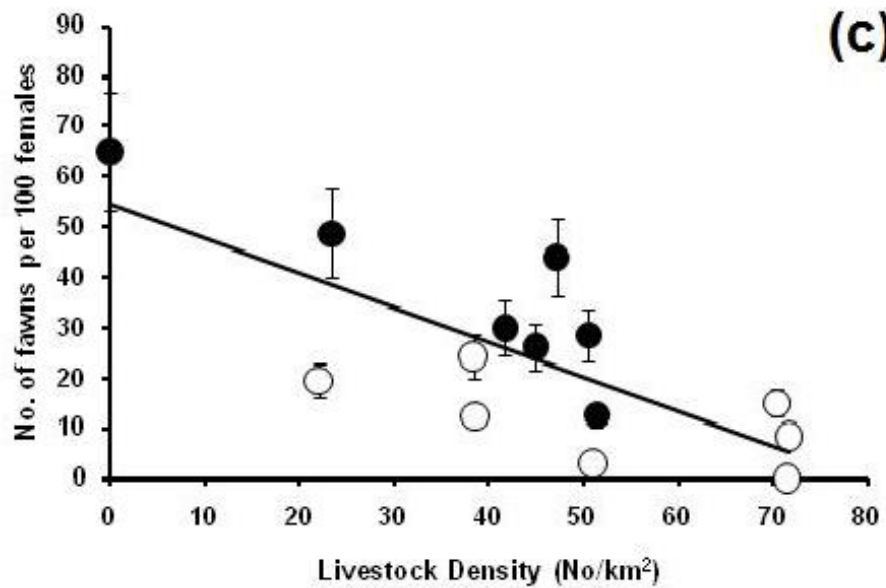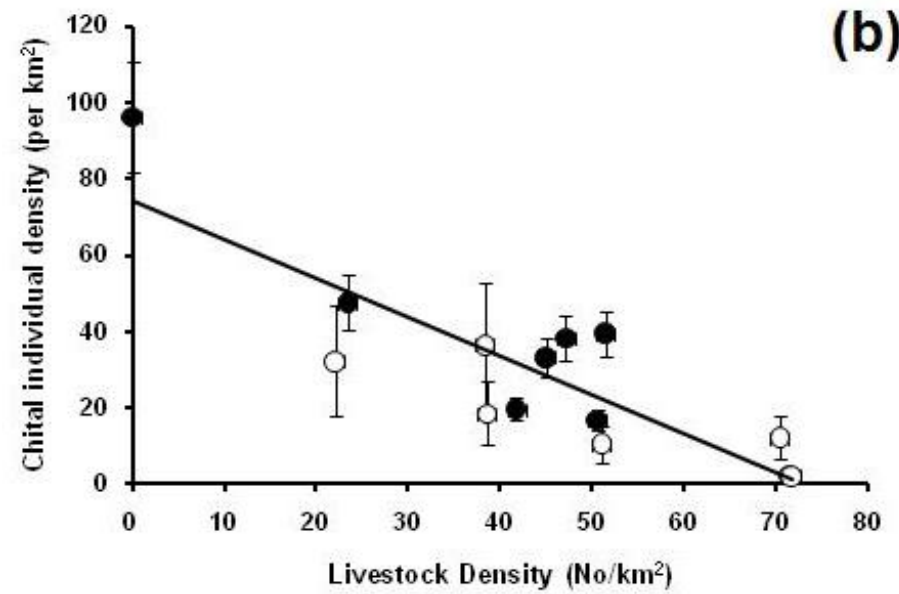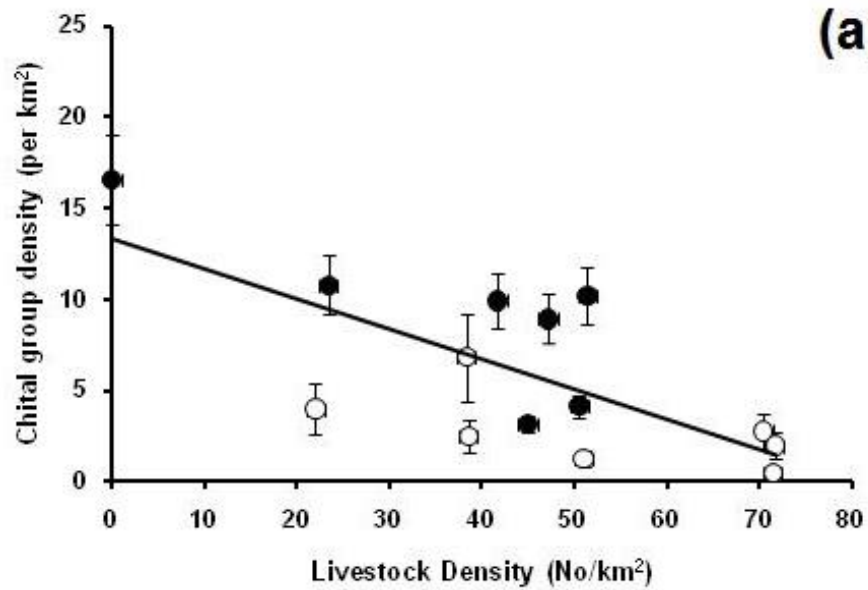
Figure 3. Decline in (a) group density (groups/km^2) *P*=0.004, (b) individual density (individuals/km^2) *P*=0.0001 and (c) population performance ratio (no. of fawns/100 females) among chital (*P*=0.001) in response to increasing livestock densities (individuals/km^2). Closed circles represent estimates from protected forests and open circles represent estimates from non-protected forests.
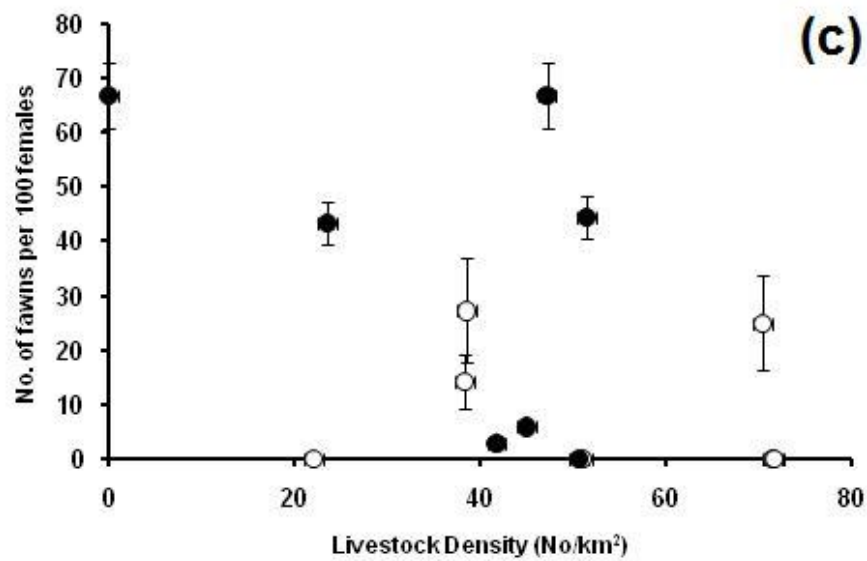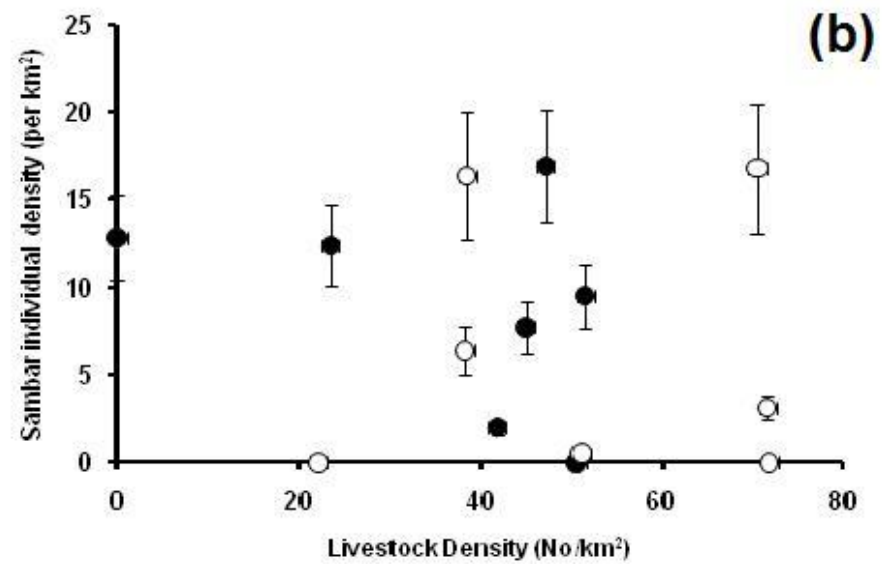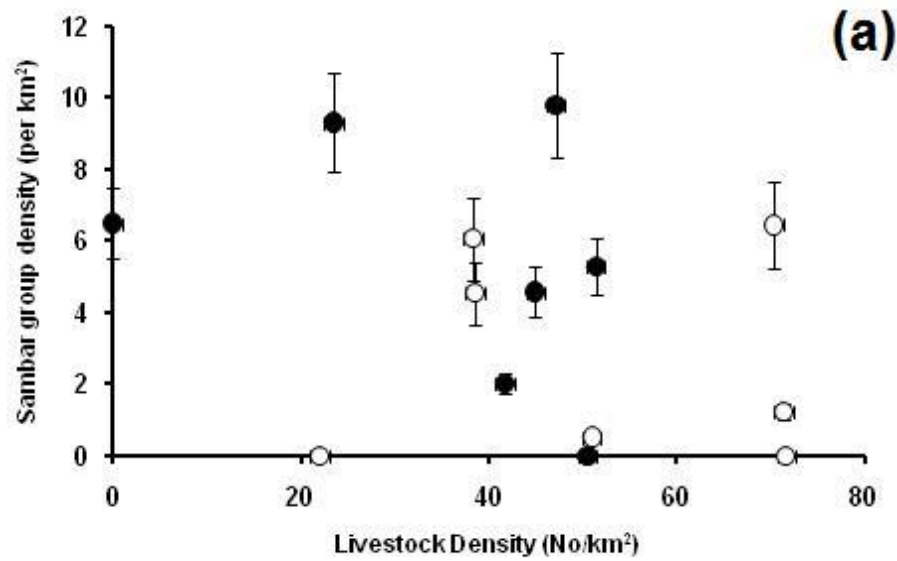
Figure 4. Changes in (a) group density (groups/km^2), (b) individual density (individuals/km^2) and (c) population performance ratio (no. of fawns/100 females) among sambar in response to increasing livestock densities (individuals/km^2). Closed circles represent estimates from protected forests and open circles represent estimates from non-protected forests.

Dependencies of forest dwelling communities on habitats and resources

  Gujjars are a pastoralist community who until recently used to migrate into the higher Himalayas with their livestock during the summer months. However, owing to many social and political reasons, such migrations are practiced only by a few households. Currently they remain in the foothills and feed their cattle mostly by lopping branches off trees. Permits are issued to families living within forests, to cut grass and lop branches off the tops of trees for leaves to provide fodder to their livestock holdings.

  During our surveys we interviewed 158 *Gujjar* households. Production and selling of milk was the primary source of income. The estimated monthly net income from livestock per adult was INR 300/-. Livestock of *Gujjars* primarily consists of buffaloes. Cattle, goats and horses/mules are also kept. During our survey, we counted a total of ~9,200 heads of livestock. Of these holdings 79.3% were buffaloes, 18.4% were cattle, 1.8% were goats and 0.5% were horses/mules. From our surveys we documented that 71% of the livestock maintained were illegal, as they exceed the number permitted by the forest department. Our findings suggest that husbandry interventions and management efforts aimed at sustainability of livestock are essential in the effort to conserve habitats for natural prey species.

  The breakdown of livestock production revenues and profits suggests that the current cattle production systems of these communities are relatively unprofitable. The estimated monthly net income varied from INR 4,200 to 66,000. When these figures are calculated in terms of income per person per day, they fall below the international poverty threshold of US $1 per person per day. Included in this figure is the revenue generated from producing and selling milk, wage earnings from both informal and formal employment, remittances from relatives and families, and income from business revenues such as selling firewood.

  During the household surveys, the respondents were asked to suggest potential interventions that could be implemented to better living conditions. Off the 158 households surveyed, 156 suggested that they would prefer to be resettled similar to *Gujjars* who were resettled by the Uttarakhand forest department from Rajaji National Park. In total, 193 *Gujjar* families from within Chilla range were resettled in the Chidiyapur range of Hardwar FD at an average cost of US$360/household (Rajaji National Park 2006). When further asked the reasons to resettle, most respondents (78%) claimed that in the forests their "children had no access to education" and were therefore illiterate. In addition, respondents (58%) also stated that the "forests are no longer productive enough to graze and raise livestock for milk".

  Based on these results, we are currently in the process of designing choice experiments to evaluate the feasibility of offering various alternatives to reduce the impact of livestock mediated completion as well as biomass extraction on wild ungulate prey and its habitat. In addition, these results have enabled us to forge collaboration with the Uttarkhand forest department towards developing a policy document on designating critical tiger habitats (as per the guidelines of the Ministry of Forest and Environment, Govt. Of India) based on sound scientific data without undermining the interests and rights of this forest community.

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