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Short communication

Population and habitat characteristics of caracal in semi-arid landscape, western India

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ABSTRACT

We studied population and ecological characteristics of caracal (*Felis caracal*) using camera traps in Ranthambhore Tiger Reserve (RTR), western India, from 2006 to 2009. We obtained 37 caracal captures over 25,156 camera-nights, with a capture success rate of 0.02–0.34 captures/100 trap-nights or 1 caracal/679.9 trap-nights over 4 years. Our results revels that caracal presence was associated with forest and undulating terrain. Caracals were more active late at night and during crepuscular hours. There was a difference in their activity between dusk and dawn. Because this is the first study in India, which generated baseline information about the ecological characteristics of the caracal it may be used for developing conservation and management plans for this species. We also suggest that the RTR and its surrounding areas could be highlighted as a global conservation region for caracal.

Caracal (*Felis caracal*) among felids is one of the mesopredators of arid and semi-arid regions of Africa and Asia (Skinner and Smithers, 1990). This cryptic carnivore is the least studied felid (Brodie, 2009) and has been placed in the Data Deficient category (IUCN, 2012). Recently, declines in populations of several data deficient species have been reported and some of them might be threatened (Morais et al., 2013). Caracal has rarely been observed in the wild, and little is known about its ecology, population status, and behaviour (Kingdon, 1977). Most of the information about its eastern most distribution has come from opportunistic sightings except for a few studies in Israel and Africa (Avenant and Nel, 1998; Marker and Dickman, 2005). The natural occurrence of the caracal at very low densities makes the species vulnerable to extinction due to change in habitat quality and land use patterns. The wild population of caracal survives in the thorn scrub forests of western India. Although exact population estimates have not been made, earlier observations report that, it is likely that <10–15 individuals survive in the Kutch region of Gujarat, India (Chavan, 1987), and that there are <50 individuals in Rajasthan, India (Sharma and Sankhala, 1984). Populations of caracals are declining throughout their range because of habitat losses (Ray et al., 2005). In fact, this rarest of the small cats of Rajasthan is confined to just in two protected areas (i.e., Sariska Tiger Reserve [STR] and Ranthambhore Tiger Reserve [RTR]; Mukherjee, 1998). Because the caracal may be approaching extinction in India, it is important to determine its status, distribution, abundance, habitat requirements, and associated threats (Sunquist and Sunquist, 2002). Understanding factors that affect existing populations and conservation threats are characteristics important for developing conservation plans at the local and regional scales (Nowell and Jackson, 1996).

Caracal, being nocturnal and elusive, is rarely seen in wild. Therefore, it is difficult to estimate abundance through direct counts, or to derive relative abundance indexes from sign surveys (i.e. tracks, scats). Camera trapping has advanced the ability to study various aspects of the ecology and biology of elusive and nocturnal animals (O'Connell et al., 2011; Rovero et al., 2013; Singh et al., 2013b, 2013a). Because information about caracal ecology are still lacking, our objective in this study was to provide baseline information about population, activity patterns, breeding periods, diets, and habitat of caracals in RTR using remotely triggered cameras and opportunistic observations. Moreover, such information will form the basis in developing conservation and management strategies and decisions.

The study was conducted in RTR (25° 54′ N to 26° 12′ N and 76° 22′ E to 76° 39′ E) and is situated in the semi-arid part of Rajasthan,

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Table 1
Efforts and capture success rate (captures/100 trap-nights) derived from camera trap surveys carried out for the caracal in Ranthambhore Tiger Reserve, India, from December 2006 to December 2009.

Sampling occasion	Sampling duration	Total number of camera trapping stations	Area sampled (MCP) (km^2)	Number of camera trap-nights	Number of caracal photographs	Capture success rate
S1	5 December 2006 to 30 March 2007	114	178	3336	10	0.30
S2	15 November 2007 to 21 February 2008	224	233	4480	1	0.02
S3	13 April 2008 to 19 June 2008	167	233	3340	0	0.00
S4	9 October 2008 to 30 November 2008	141	189	2820	4	0.14
S5	5 December 2008 to 19 February 2009	196	233	3920	2	0.05
S6	21 March 2009 to 3 May 2009	185	233	3700	8	0.22
S7	26 October 2009 to 20 December 2009	178	233	3560	12	0.34

western India. The detailed study area was described by Singh et al. (2013a).

We conducted seven continuous camera trapping replicate surveys to evaluate ecological attributes of caracal between December 2006 and December 2009, under an ongoing project of long-term monitoring predators in RTR (Singh et al., 2013b, 2013a). The details of camera traps used and sampling design was described in Supporting information S1, (layout of camera traps, Fig. 1S). To compute the species richness, we used the camera trap encounter rate (number of independent caracal capture divided by sampling efforts). To study the habitat selection of caracal, single season occupancy was estimated using a likelihood-based method (MacKenzie et al., 2002, 2005). The habitat variable (i.e. terrain ruggedness) was calculated using the extension Topographical Position Index (TPI; Jenness, 2006) in the ArcView v 3.2 GIS software package (ESRI, Redlands, California) from elevation data at 30 m resolution derived from the ASTER Global Digital Elevation Model (http://www.jspacesystems.or.jp/ersdac/GDEM/E/). Forest characteristics (i.e., forest, scrub, open area) were extracted from a land use/land cover map at 30 m resolution available from RTR (Singh, 2011). Human habitation data were derived at 1:50,000 scale maps produced by the Survey of India (SOI) then converted into distance maps in the ArcView v.3.2 GIS software package (ESRI Inc., Redlands, California). We carried out the analysis using the PRESENCE software package (http://www.proteus.co.nz; Hines, 2006). We used single season occupancy because we were primarily interested in habitat use and not in the dynamic of occupancy across years. We pooled data from 2006 to 2009, assuming that occupancy does not change over the surveys. As we conducted several replicates across the study duration, we added the survey as a covariate in the occupancy analyses. We analysed the activity pattern of caracals using the date and time printed on each photograph obtained using camera traps (Gerber et al., 2012). Photo-capture of caracal captured from all camera traps were combined and separated by each hour of the day, as the % of all caracal photos collected in each hour of the 24-h cycle. We divided the 24-h day into eight 3-h time bins: Midnight = 22:00–01:00; Late Night = 01:00–04:00; Dawn = 04:00–0730; Early Day = 07:00–10:00; Midday = 10:00–13:00; Late Day = 13:00–16:00; Dusk = 16:00–19:00; and Early Night = 19:00–22:00. The total number captured in each bins was divided by the total number of captures to determine the percentage of activity throughout the day. We also collected additional information during the study period of, direct sighting recorded by personnel of the forest department and of a rare sighting of a caracal on a kill by photographers.

During our study we recorded 37 photo-captures of caracal after a sampling efforts of 25,156 camera trap-days, (0.02–0.34 photo-captures/100 trap-nights) or 1caracal every 679.9 trap-nights. In our study area caracals were detected consistently with a very low encounter rate over the duration of the study (Table 1). Thus our data revel the low abundance of caracal in RTR. However, the use of camera trapping rates as an index of abundance, have been widely debated (Jennelle et al., 2002; Sollmann et al., 2013). But we expect that if abundance increases, the probability of encounters between camera traps and individuals would also increase (Rovero and Marshall, 2009).

Our analysis showed that caracal presence was associated with forest and terrain ruggedness (Table 2). This may be related to the suitability of the habitat for the caracal, which provides cover for hunting and shelter and distribution of prey species (Farhadinia et al., 2007; Heptner and Sludski, 1992; İlemin and Gürkan, 2010). Similarly, Avenant and Nel (1998), suggested caracals spend most of their time foraging in vegetation. Our results suggested forest cover and ruggedness are important environmental variables that had the highest influence on caracal occupancy. As suggested caracal prefers habitats of drier woodlands; with low rainfall and vegetation cover (Stuart and Stuart, 2000). Our study area is situated in the semi-arid part of Rajasthan (Krishnan and Shankarnarayan, 1964), which receives 800 mm of annual precipitation (interpolation from Hijmans et al., 2005; http://www.diva-gis.org/climate), and the vegetation or woodland corresponds to tropical dry

Table 2
Caracal habitat use within trapping sites in Ranthambhore Tiger Reserve, India, from December 2006 to December 2009. (ψ is the probability a site is used by caracal and ρ is the probability of detecting caracal in the ith survey, $\psi(.)$, $\rho(.)$ assumes detection probability of caracal are constant across sites. ΔAIC the difference in AICc values between each model with the low AICc model, ω_m is the AICc model weight.

Model	AICc	ΔAIC	ω_m	-2ℓ
ψ(forest + ruggedness), ρ(survey)	143.33	0.00	0.3012	125.33
ψ(ruggedness), ρ(survey)	144.47	1.14	0.1703	128.47
ψ(forest), ρ(survey)	144.52	1.19	0.1661	128.52
ψ(forest + scrub + ruggedness), ρ(survey)	144.69	1.36	0.1526	124.69
ψ(forest + scrub), ρ(survey)	145.62	2.29	0.0959	127.62
ψ(forest + scrub + open + ruggedness), ρ(survey)	146.51	3.18	0.0614	124.51
ψ(forest + scrub + open + ruggedness + habitation), ρ(.)	146.83	3.50	0.0523	122.83
ψ(.), ρ(.)	160.87	17.54	0.0001	156.87