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Camera-trapping snow leopards in the Tost Uul region of Mongolia

The snow leopard's reclusive behaviour, generally low population density, fragmented distribution and rugged mountain habitat make it exceptionally hard to enumerate. Since conservation success hinges upon sound understanding of population size and distribution, there is an urgent need for reliable, non-invasive status surveys under differing environmental and habitat conditions. We conducted a camera-trap survey in the South Gobi of Mongolia for comparison with data from previous camera-trap abundance-population surveys in India, China and Kyrgyzstan conducted by other researchers. We documented the presence of 4 adults and 3 cubs during the 65-day survey. Based on the standard buffering technique, we surveyed a 264 km^2 area yielding an estimated density of 1.52 adult snow leopards per 100 km^2. However, since capture-recapture models perform poorly with less than 20 individuals, snow leopard camera-trap survey results should also include simpler, more basic metrics for future comparisons between surveys or areas, namely the minimum number of individuals detected, number of recaptures and camera-trap success per 100 trap nights.

Snow leopards *Panthera uncia* are conventionally regarded as a high-elevation species occurring in the Himalaya and other major mountain ranges of Central Asia. However, their distribution also encompasses much lower elevations down to 1000 m asl, and occasionally as low as 500 m (Bannikov 1954, Heptner & Sludskii 1972). In Mongolia, snow leopards occur along the Mongolian Altai, Gobi Altai and Khangai ranges eastward to about 106° E, and also in several small isolated desert ranges to the south (Bannikov 1954, Schaller et al. 1994, McCarthy 2000).

We carried out a camera-trap survey of snow leopards in the South Gobi in the spring of 2007 to assess the efficiency of this method for detecting snow leopards in that habitat type, and to compare findings to similar studies in high-elevation areas including the Ladakh Himalaya (Jackson et al. 2006) and Tien Shan mountains of Kyrgyzstan and China (McCarthy et al. 2008).

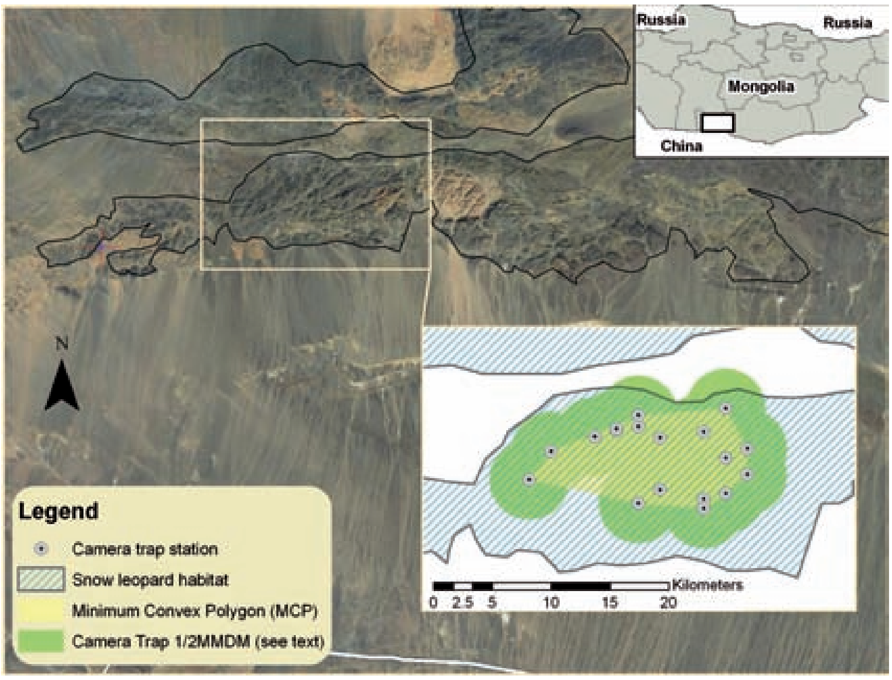

Fig. 1. Map of study area showing camera trap placement and buffered areas in relation to snow leopard habitat in Tost Uul and the immediate vicinity.

Study area

Our survey was conducted in the isolated desert massif of Tost Uul in the Gurvantes county of South Gobi province (100°35'E / 43°10'N). We selected Tost Uul because: (1) It was the site of a pioneering study of snow leopards in the 1970s (Bold & Dorjzunduy 1976); (2) It is a key location for Snow Leopard Enterprises, an innovative conservation program, and (3) the snow leopard population was sampled via the collection of scats two months earlier (Janecka et al. 2008), thus also offering an opportunity to compare genetic analysis of scat and camera-trapping for detecting and enumerating snow leopards.

Tost Uul is broken by seasonal drainages, rocky outcrops and sandy washes, with elevations ranging from 1,800 m to 2,517 m at Sharga Morit Uul (Fig. 1). The terrain is extremely rugged with narrow ridges, steep slopes and a high proportion of loose, exposed rock. Three major valleys cut north-south through the range and facilitate movement around the area, although only along rough 4-wheel drive tracks.

The climate is arid continental. Mean temperature in July, the warmest month, is 25°C, but varies from 23°C to 40°C. In January, the coldest month, daily temperatures range from -35°C to -4°C. Annual precipitation ranged from 56 to 209 mm between 1978 and 1984, with most falling in August. Winds are strongest in April and May.

The flora is dominated by low shrubs e.g. *Caragana* spp., *Artemisia* spp. with sparse feather grass *Stipa gobica*, *S. glareosa* and herbaceous plants including *Ajania* spp, *Eurotia ceratoides* and *Scorzonera capito* (Lavrenko & Sokolov 1986). The bush *Amygdalus mongolica* is prominent in most valleys and small gullies. Ibex *Capra sibirica*, the main prey of snow leopard are widespread while argali *Ovis ammon*, the area's other large ungulate are now very rare. Other mammals include gray wolf *Canis lupus*, red fox *Vulpes vulpes*, tolai hare *Lepus tolai*, Pallas's pika *Ochotona pallasii* and several small rodents (Bannikov 1954, Bold & Dorjzunduy 1976).

Animal husbandry is the primary economic activity, with local herders occupying some 14 winter or spring camps from late October through mid-May. In July, herders move to nearby desert slopes for the summer, resulting in lower densities of humans and livestock in areas used by snow leopards. The local communities are highly dependent upon a few wells and springs, which are also critical to wildlife.

Fig. 2. A typical camera trap station (Photo D. Mallon).

Methods

This survey was carried out from 5 May through 17 July 2007, following the basic methodology described by Jackson et al. (2006). Eighteen camera stations were established, each deploying an active infra-red TrailMaster TM1550 sensor unit and two cameras positioned to capture both sides of a passing snow leopard. There should be no "holes" within the trapping array for a snow leopard to escape undetected: therefore, we aimed for least one trap station per 16–30 km^2, the estimated minimum home range of an adult female snow leopard in good habitat (Jackson & Ahlborn 1989). However, since home ranges in Mongolia may be 10 times or more as large (McCarthy et al. 2005) we accepted some larger gaps within our trap coverage, which targeted the main Tost Uul massif (Fig. 1).

Camera stations were located along characteristic snow leopard movement areas following ridgelines or valley bottoms, adjacent to clusters of scrapes or active scent-rocks. Alignment of transmitter and receiver is critical when using TrailMaster sensors, and thus we constructed robust rock cairns to offer stability necessary to resist the strong winds (up to 65km/hr) which prevail at this time of year (Fig. 2). Two homemade digital camera traps were deployed to help build an image library for identification of individual snow leopards.

Trap stations were visited every 2–10 days to record the number of events, photographs, change film or batteries as required and to document snow leopard sign. No baits or lures were utilized. We elected not to relocate traps during the survey because of limited access to sites and in order to maximize the likelihood of capturing all snow leopards present within the core study area over the full survey period.

Individual snow leopards were distinguished from their unique rosette or spotting patterns using the criteria described by Jackson et al. (2006). We applied the capture-mark-recapture (CMR) technique to estimate snow leopard abundance based on daily, 3-day and 5-day sampling occasions using the software program CAPTURE (White et al. 1982, Karanth & Nichols 1998), including its selection function that ranks four primary and four mixed effects models on a scale of 1.00 (best fit) to 0.00 (poor fit) (Otis et al. 1978). Cubs and unidentified individuals were excluded from analysis. We examined population closure using the standard CAPTURE test, as well as Stanley & Burnham's (1999) statistically more robust closure test for time-specific capture-recapture data. We estimated the area sampled using the minimum convex polygon (Karanth & Nichols 1998) and individual camera station buffering methods (Silver et al. 2004).

Results

We camera trapped for 65 consecutive days (12 May to 16 July 2007) for a total of 1,114 trap nights at 18 trap stations. We tallied 207 pictures of non-target species including ibex, livestock, hare and birds, and 180 images made during camera setup and testing. We obtained 120 photographs of snow leopards during 47 capture events. The majority of pictures (107) accrued from 39 capture events (2.74 photographs per event), with the remaining 13 (10.8%) not identifiable to a particular individual. This represents a capture rate of 10.77 snow leopard photographs per 100 trap nights or 0.63 individu-

Table 1. Camera-trap results for Tost Uul based on three sampling-occasion scenarios.

Sampling occasions	Stanley-Burnham closure test			Number of captures	Model $M_{(o)}$ capture probability	Snow leopard abundance[a] ± SE
	X^2	df	P			
Daily (N=55; 55-day survey)	18.036	19	≤ 0.5200	26	0.118	4 ± 0.06; 95% CI = 4–4
3-day occasion (N=18; 54-day survey)	18.864	13	≤ 0.1274	23	0.319	4 ± 0.06; 95% CI = 4–4
5-day occasion (N=11; 55-day survey)	8.258	8	≤ 0.4087	19	0.432	4 ± 0.09; 95% CI = 4–4

[a] SE = STANDARD ERROR; CI = 95% CONFIDENCE LIMITS

Fig. 3. Female snow leopard SL-1 and three cubs photographed during their visit to a spring (Photo R. Jackson).

als (including cubs) per 100 trap nights, for an overall capture effort of 9.28 trap station nights per snow leopard photograph. We identified seven snow leopards, including a female (SL-1) and her three cubs estimated to be about 12 months of age, two adult males (SL-2 and SL-4), and one individual of unknown gender but likely an adult female (SL-3).

The capture events included 12 captures of SL-1 and/or one of her three cubs (Fig. 3), 21 captures of SL-2, four captures of SL-3, three captures of SL-4, and seven captures which could not be positively identified. Capture rates declined somewhat after 40–50 days of trapping, especially for SL-1, who may have shifted her cubs to another area since no recaptures occurred after the initial 40-day period. We also suspect that leopards SL-3 and SL-4 ranged more widely outside the core trapping area. Fifty-two percent of captures were made at four trap sites within the core study area where sign abundance suggested these to be regularly utilized travel corridors. Snow leopards were not detected at another four (22%) trap sites.

We captured snow leopards 26, 23, and 19 times under the daily, 3-day, and 5-day occasion trap scenarios, respectively (Table 1). While CAPTURE supported population closure irrespective of survey duration, the more reliable Stanley-Burnham (1999) test indicated this was only achieved during the first 55 days of survey, which results we present here. Capture probabilities ranged from 0.118 under the 1-day occasion to 0.432 under the 5-day occasion aggregated sampling regime for the Null Model, $M_{(o)}$ selected by CAPTURE as offering the best fit with a score of 1.00 (Table 1). However, the Heterogeneity Model, $M_{(h)}$ represented a close contender (1-day, 0.95; 3-day, 0.93; 5-day, 0.84). Snow leopard abundance was estimated at 4 ± S.E. 0.06 for daily and 3-day occasion surveys and 4 ± 0.09 for 5-day sampling occasions.

The half mean maximum distance moved (½MMDM) by snow leopards between photo captures was 3.38 km, resulting in sampled areas of 294 km^2 when buffering the Minimum Convex Polygon of the camera traps (MCP method) or 264 km^2 when buffering each individual camera station. Thus, the four detected adult snow leopards represented a density of 1.36 and 1.52 snow leopards per 100 km^2, respectively. The density is reduced to 0.72 and 0.75 per 100 km^2 respectively, when MMDM is used as an outer buffer width (Table 2).

Table 2. Density estimates for Tost Uul using different buffering methods.

		MCP buffer[a]		Individual camera buffer[b]	
Means of buffer	**Width (km)**	**Area (km^2)**	**Density ± SE[c]**	**Area (km^2)**	**Density ± SE**
MMDM[d]	6.765	552.5	0.72 ± 0.01	536.9	0.75 ± 0.02
½MMDM[e]	3.383	294.4	1.36 ± 0.02	264.0	1.52 ± 0.02

[a] Buffer strip around Minimum Convex Polygon (Karanth & Nichols 1998)

[b] Buffer strip around individual camera stations (Silver et al. 2004)

[c] SE = standard error

[d] Mean maximum distance moved by snow leopards between photographic captures

[e] Half MMDM for snow leopards

Discussion

We obtained 0.63 captures of individually identifiable snow leopards per 100 trap-nights, similar to capture rates in the Tien Shan of Kyrgyzstan and China (McCarthy et al. 2008), but lower than rates over two successive years in Hemis National Park, India (5.63–8.91; Jackson et al. 2006). In addition, the mean interval between photographs was 17.8 days, comparable to the inter-capture duration observed in Hemis (11.2 and 17.7 nights), but much less than in 19 camera-trap tiger surveys (mean = 99.4 days, summarized in Carbone et al. 2001).

Using standard buffering techniques, we estimated snow leopard densities at 1.36 –1.52 adults per 100 km^2, about twice those reported from the Tien Shan mountains along the Kyrgyzstan – China border (0.15, 0.87 and 0.74 individuals per 100 km^2, McCarthy et al. 2008), but well short of those from Ladakh, India over two successive winters (8.49 and 4.45 individuals per 100 km^2, Jackson et al. 2006). Bold & Dorjzunduy (1976) estimated 22 ± 5 snow leopards in Tost Uul, representing a density of 4.4 per 100 km^2, although the methods used to arrive at this figure were not explained in detail.

When generating population estimates from CMR data, it is necessary to obtain a sufficiently large sample over a large enough area for making credible estimates. Population estimates of rare and elusive carnivores are particularly problematic (Otis et al. 1978), as exemplified by our study with its narrow confidence intervals and selection of the simplest estimator (i.e., null model $M_{(o)}$), despite high capture probabilities or apparent differences in trapping success between individuals. White et al. (1982) recommended against using closed population models to estimate population size with less than 20 individuals.

Density estimates are strongly influenced by camera spacing (especially variations in camera to buffer edge distances) and the degree of concordance between home ranges and the buffered area. Thus, knowledge of how far individuals move outside the sampled area is required for determining the width needed to establish the outer buffer strip. Karanth & Nichols (1998) recommended using a buffer strip equivalent to ½MMDM for individual tigers between successive captures, a suggestion followed by subsequent researchers (e.g. Silver et al. 2004, Jackson et al. 2006) and this study. However, the validity of this approach to snow leopard has yet to be demonstrated through concurrent radio-tracking and camera-trapping studies. From a practical viewpoint, the primary constraints to camera-trap surveys targeting snow leopards are its low densities, fragmented habitat, difficult ground access imposed by the mountainous terrain, time-consuming logistics when moving cameras to sample large areas, and the limited number of cameras available for deployment, all of which tend to work against population closure unless surveys are short in duration. In light of these important limitations, as well as the high cost of undertaking repeated surveys, perhaps the most sensible option for sharing snow leopard camera-trapping results would be to also report capture rates (Karanth & Nichols 1998, Carbone et al. 2001), minimum number of individuals detected, approximate size of area surveyed, and general camera-trap configuration employed.

The establishment of a permanent research station and launching of a long-term telemetry study by Panthera, WCS and the Snow Leopard Trust at the study site should provide excellent opportunities for detailed investigations into the most optimal trapping configurations for estimating snow leopard density, at least within a highly fragmented desert habitat.

Acknowledgements

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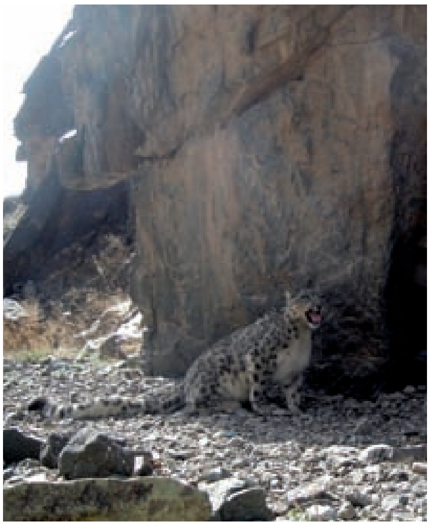

Fig. 4. Snow leopard showing flemen at a rock scent (Photo R. Jackson).

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