ISSN 1027-2992

CAT news

N° 53 | AUTUMN 2010

SPECIES SURVIVAL COMMISSION

CAT SPECIALIST GROUP

IUCN

The World Conservation Union

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Preliminary results of a long-term study of snow leopards in South Gobi, Mongolia

Snow leopards *Panthera uncia* are under threat across their range and require urgent conservation actions based on sound science. However, their remote habitat and cryptic nature make them inherently difficult to study and past attempts have provided insufficient information upon which to base effective conservation. Further, there has been no statistically-reliable and cost-effective method available to monitor snow leopard populations, focus conservation effort on key populations, or assess conservation impacts. To address these multiple information needs, Panthera, Snow Leopard Trust, and Snow Leopard Conservation Fund, launched an ambitious long-term study in Mongolia's South Gobi province in 2008. To date, 10 snow leopards have been fitted with GPS-satellite collars to provide information on basic snow leopard ecology. Using 2,443 locations we calculated MCP home ranges of 150 – 938 km^2, with substantial overlap between individuals. Exploratory movements outside typical snow leopard habitat have been observed. Trials of camera trapping, fecal genetics, and occupancy modeling, have been completed. Each method exhibits promise, and limitations, as potential monitoring tools for this elusive species.

The snow leopard is an icon of the mountain ranges of central Asia, yet as few as 3,500 remain in the wild today (McCarthy & Chapron 2002). Categorized as Endangered (IUCN) and listed on Appendix I of CITES, the cat's numbers are likely declining across much of their range. Poaching for trade in pelts and bones poses a serious threat (Theile 2003). Retaliatory killing in response to predation on livestock is pervasive. Widespread declines in native prey due to excessive hunting and competition with domestic stock round out a suite of anthropogenic threats to the species. A thorough understanding of the species' ecology, behavior and habitat requirements is needed to design effective conservation strategies.

The snow leopard's highly cryptic nature and remote inaccessible habitat make studying the cats extremely difficult. Although two detailed short-term (4-6 year) studies of snow leopards using VHF radio collars were undertaken between 1982 and 1999 in Nepal (Jackson 1996) and Mongolia (McCarthy 2000), logistical and technological constraints made their findings equivocal. Hence, essential knowledge on snow leopard habitat use, home-range size, activity patterns, and daily or seasonal movements has been deficient and sometimes conflicting, and essentially no information exists on basic population parameters such as birth and mortality rates, cub survival, or dispersal rates.

In addition to our limited understanding of their basic ecology, snow leopard population size is unknown for any area within their range. Surrogate measures of abundance, such as sign density along transects (Jackson and Hunter 1996), have proven unreliable for assessing population size and trends, and nearly impossible to compare across sites (McCarthy et al. 2008). Without a statistically-reliable way to estimate snow leopard abundance or trends, it is difficult to assess the impact of conservation programs, make decisions regarding the allocation of scarce resources, or modify conservation strategies to achieve desired outcomes. Several 'non-invasive' field methods, including fecal genetics (Waits et al. 2004, Waits et al. 2007, Janecka et al. 2008), camera trapping (Karanth & Nichols 1998, Jackson et al. 2009) and occupancy modeling using detection-non detection surveys (MacKenzie & Nichols 2004), hold promise as tools for estimating population size of rare and elusive species, including snow leopards.

To address the paucity of basic ecological information on snow leopards and to assess the efficacy of novel population monitoring tools, Panthera, the Snow Leopard Trust (SLT), and the Snow Leopard Conservation Fund (Mongolia) launched a long-term (> 15 year) study of snow leopards in 2008 in Mongolia's South Gobi province. Here we summarize progress during the first 22 months of the study (August 2008 through June 2010).

Study Area and Research Center

In summer 2008, we established the J. Tserendeleg Snow Leopard Research and Conservation Center in South Gobi Province, Mongolia (Fig. 2). Located in the Tost-Tosonbumba Mountains, 250 km west of the provincial capital of Dalanzadgad, the area harbors a relatively high density of snow leopards (McCarthy 2000), and SLT has maintained a conservation program there for nearly a decade focused on two herding communities. The

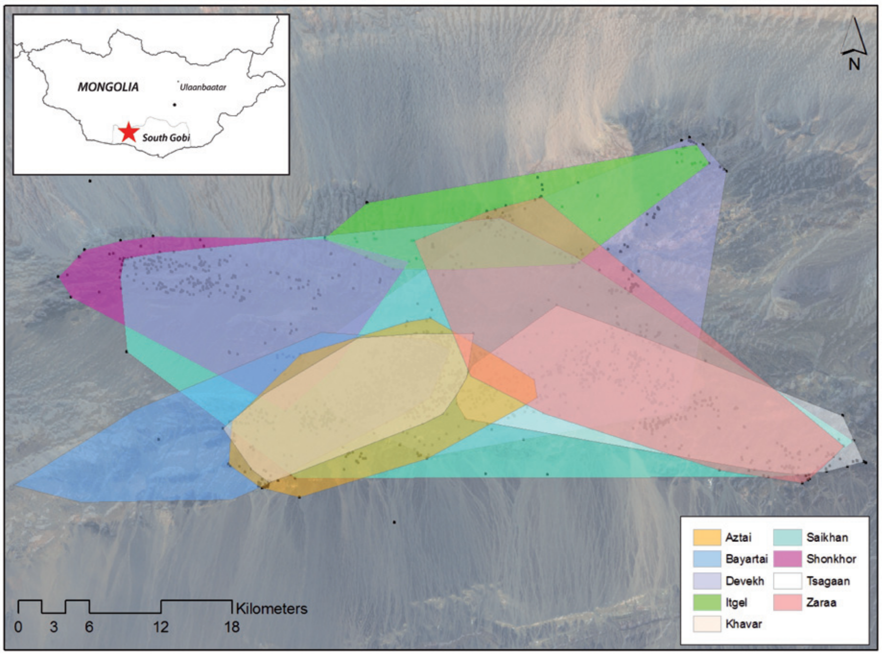

Fig. 1. Home ranges (MCP) of 9 snow leopards fitted with GPS collars in Tost-Tosonbumba study area between August 2008 and June 2010 in South Gobi, Mongolia.

Fig. 2. J. Tserendeleg Snow Leopard Research and Conservation Center in South Gobi Province, Mongolia (Photo T. McCarthy).

facility will eventually include an information center and training facility for snow leopard researchers and conservationists from around the region.

The Tost-Tosonbumba study area supports a diverse range of large mammals including Siberian ibex *Capra sibirica* and argali *Ovis ammon)* Other carnivores include grey wolf *Canis lupus*, lynx *Lynx lynx*, red fox *Vulpes vulpes* and Corsac fox *Vulpes corsac*. Approximately 230 herder families live in the study area with livestock holdings of nearly 40,000 animals, comprised of goats, sheep, camels and horses. Annual precipitation is <130 mm a year and temperatures range from -35°C to 38°C.

Ecological Study

Collaring Methods

We selected GPS collars which uplink locations via the Globalstar satellite phone system. Collars from both North Star Science and Technology (King George, VA, USA) and Vectronic Aerospace (Berlin, Germany) have been deployed. Initially, GPS acquisition was programmed for every 9 hours; this was changed to every 5 hours on collars placed after June 2009. Individual uplinks were attempted for each GPS location. In addition, all locations were permanently stored in collar memory, allowing subsequent downloading of data that failed to uplink. All collars were equipped with programmed drop-offs and VHF transmitters to facilitate retrieval.

We placed modified Aldrich-style foot snares on known snow leopard trails and at scrape sites. As many as 18 snares were set at any one time, with 12 to14 being the norm. Each snare was equipped with a trapsite transmitter (TBT-500, Telonics, Inc.) to ensure immediate notification when snares were tripped. Snow leopards caught in snares were immobilized using a combination of medetomidine and Telazol™ administered by dart injection using a blowpipe or a CO_2 powered dart gun.

Preliminary collaring results

Between August 2008 and June 2010, we collared 10 snow leopards (8 males and 2 females; Table 1). Total trap-nights expended was 2,967 for a mean of 164 per capture (range of 63-303). One male snow leopard we collared was captured by a local herder in a steel-jaw trap set for predators. The cat was, treated with antibiotics for leg wounds, collared and released. One collared male was killed by a herder 3.5 months after initial capture when the cat was trapped near a livestock corral. One female dropped her collar less than a day after capture, and one male lost his collar 2.5 months after capture. Six males and 1 female remained collared as of June 2010.

A total of 2,443 locations were uplinked by all collars, ranging from 43 to 1147 per leopard (Table 1). To date we have only calculated crude minimum convex polygon home ranges for each cat, which range from 150 km^2 to 938 km^2 (mean = 365.9, SD = 250.0). As anticipated from past studies (Jackson 1996, McCarthy et al. 2005), snow leopards in the Tost-Tosonbumba Mountains exhibit substantial home range overlap (Fig. 1). McCarthy (2000) noted use of open steppe-desert by snow leopards elsewhere in Mongolia when they transited between mountain massifs. In this study we have noted several similar excursions that appear to be exploratory in nature, with male leopards traveling up to 60 km out of the mountains before returning to what our limited data might suggest is their 'normal' home range. Three sub-adults and one prime age male have made such movements. Even omitting 'exploratory' movements, the mean home range for sub-adult males is the largest of any sex or age category at 481.3 km^2 (SD = 354.2)

At the outset of the study we used North Star collars. Initial uplink success rates for those collars was just under 50% and deteriorated over their 13 month designed life (Fig. 3). Uplink success rate is not necessarily indicative of GPS success rate, and we have yet to analyze enough stored GPS data from North Star collars to report on the latter (4 collars remain deployed). In spring 2010 we began using Vectronic collars and 3 had been deployed by June. Initial uplink success for Vectronic collars is about 70% and we have seen no deterioration in performance, although those collars have only been in use for 1.5 to 2.5 months.

Methods Development and Testing

Fecal Genetics

Scat transects were conducted in conjunction with occupancy surveys during summer 2009. We collected all large carnivore scats encountered along trails, and all carnivore scats, independent of size, associated with snow leopard scrapes. We recorded GPS coordinates, as well as characteristics of each collection site and feces (size, color, shape) to help develop collection protocols that reduce collection of non-target feces. Each sample was divided into 3 sub-samples for separate analysis. One subsample was submitted to the Global Felid Genetics Program at the American Museum of Natural History

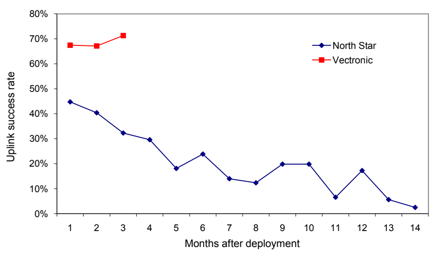

Fig. 3. Overall GPS uplink success rates using the Globalstar satellite telephone system for two different collar types deployed on snow leopards between August 2008 and June 2010.

(AMNH) for species and individual identification through microsatellite analyses at a minimum of 10 loci. A second sub-sample was sent to Working Dogs for Conservation (Bozeman, Montana, USA) to help train and test scat detection dogs in species identification. A third sub-sample went to the Laboratoire d'Ecologie Alpine for dietary analysis using DNA barcoding (Valentini et al. 2009).

Of 200 samples submitted to AMNH, 184 were successfully typed to species, 90 (48.9%) of which were snow leopard. Red fox, wolf, and Pallas's cat made up the remaining 94 samples. Individual identification of snow leopards represented in that sample is incomplete; however, preliminary results indicate that the number of individuals in the sample far exceeds any reasonable estimate of cats currently alive in the study area. This is likely indicative of lengthy persistence of feces with viable DNA in the Gobi's highly desiccating environment. If so, that would preclude generating population estimates from this method. More investigation is warranted and ongoing.

The dietary constituents of snow leopard feces were determined using DNA amplification with universal primers coupled with snow leopard specific blocking primers. The resultant PCR products were sequenced using next generation sequencing (Illumina/Solexa) and prey identified via DNA barcoding with Genebank referencing. Prey remains were identified in 66 of 88 samples. Ibex was the most frequent prey item (69.7%) followed by domestic goat (21.1%). The method could not discern between the remains of argali and domestic sheep, but *Ovis* sp. was found in 14.5% of the samples. Chukar (*Alectoris chukar*) was found in one feces (1.3%). More extensive use of this methodology for determining snow leopard diets is planned, with improved assessment of wild versus domestic sheep remains.

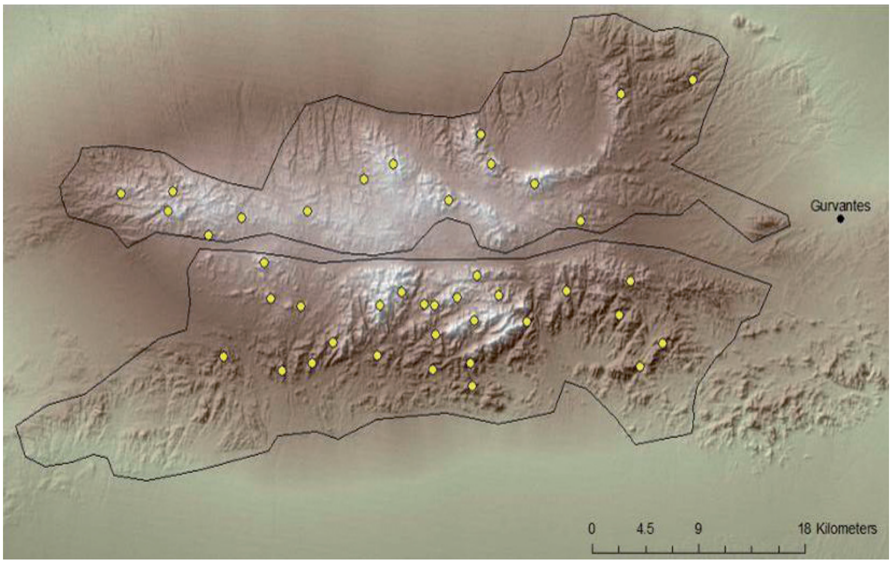

Fig. 4. Locations of 41 camera traps deployed in the Tost-Tosonbumba study area in summer 2009.

Table 1. Capture date, recollars, sex, number of GPS locations, home range size, and status of ten snow leopards collared as part of the long-term ecological study of the species in South Gobi, Mongolia, 2008-2010.

Snow leopard	Original Capture Date	Captures/ collars	Sex	GPS Locations	Home Range MCP (km^2)	Status as of 30 June 2010
Aztai	19-8-2008	5/3	Male	1147	238	Vectronic collar active Scheduled drop-off 19-4-2011
Bayartai	14-9-2008	1/1	Male	167	274	Killed by a herder 1-1-2009
Tsagaan	23-2-2009	4/3	Male	153	261	North Star collar failed immediately Scheduled drop-off 17-3-2011
Shonkhor	21-4-2009	2/1	Male	273	260	North Star collar active Scheduled drop-off 31-5-2010 (failed)
Saikhan	6-5-2009	1/1	Male	196	938	North Star collar failed after 8 months Scheduled drop-off 15-6-2010 (failed).
Suhder	11-5-2009	1/1	Female	0	NA	Lost collar 11-5-2009
Itgel	7-7-2009	0*/1	Male	43	185	Lost collar 19-9-2009
Devekh	25-2-2010	1/1	Male	112	577	North Star collar failed after 4 months Scheduled drop-off 1-3-2011
Khavar	26-4-2010	1/1	Male	216	150	Vectronic collar active Scheduled drop-off 26-4-2011
Zara	16-5-2010	1/1	Female	136	410	Vectronic collar active Scheduled drop-off 16-5-2011

* Snow leopard captured in a trap set by a herder.

Fig. 5. Subadult siblings captured by a camera trap on 10 August 2010.

Camera Trapping

In June 2009 we deployed 41 Reconyx RM45™ digital cameras across the 1,300 km^2 study area (Fig. 4). A grid was overlaid on the study area with cell size of 9km x 9km, which was smaller than the minimum snow leopard home range in our study. Between one and three cameras were placed in each grid cell, ensuring that all leopards in the study area had a chance of being photographed. Cameras were placed at recently-used scrapes in saddles located along ridgelines and at scrapes near steep walls in canyons. We deployed cameras singly, rather than in pairs, to maximize the survey area with the available cameras. The cameras remained in the field for 30 days.

Thirty-seven of the 41 cameras functioned for all or part of the survey period for a total of 1,112 trap nights. We recorded 18,253 photos including 4,345 photos of non-target wildlife, 3,932 photos of livestock, 1,528 photos of humans, and 645 photos of snow leopards (Fig. 5). A total of 15 snow leopards were identified in 34 encounters including 9 adults and 6 cubs. After excluding the cubs, mark-recapture analyses indicate 10 adult snow leopards use the 1,300 km^2 study area, with a 95% confidence interval of 9 to 16 adults.

Camera trapping will be repeated for a 60-day period in 2010 with a reduced grid size of 5 km x 5 km, which matches occupancy surveys cell size (below), allowing a more direct comparison of outputs. Additionally, 10-20 camera traps will remain in the field indefinitely in areas of high snow leopard use to identify new individuals, monitor condition of collars, and to record demographic patterns and seasonal associations between male-female, siblings and mother-cubs. To date we have captured multiple pictures of females with cubs at various stages of growth. These offspring can now be identified if they remain in the study area after becoming independent.

Occupancy Surveys

Occupancy surveys were conducted during the summers of 2008 and 2009. The goals of the surveys differed and this was reflected in the study design. In 2008 the primary objective was to estimate site occupancy (i.e., the probability that a particular site is occupied or alternately the proportion of sites occupied by the species of interest) while collecting data on factors that might influence the probability of occupancy to develop a predictive model. In contrast, in 2009 we tested a survey protocol designed to optimize the power of detection/non-detection surveys to detect a decline in occupancy over time by sampling high-quality habitats.

We surveyed 465 km at 45 sites in 2008 and 125 km at 42 sites in 2009. Sites were selected randomly in 2008, although habitat that exhibited little topographic relief was excluded because of the lack of preferred marking terrain. In 2009 we used a terrain ruggedness and slope model, along with information on snow leopard habitat preferences obtained during 2008 occupancy surveys, to identify sites with a high probability of snow leopard use within in each survey area. At each survey point, a 2-6 km transect was walked along micro-habitats most likely to be marked by snow leopards. Transects were broken into segments reflecting changes in topography which may influence the probability of detecting snow leopard sign. At each change in topography, the GPS coordinates and distance traveled were recorded to determine the segment length. Information on terrain brokenness and the presence of fecal pellets of livestock and wild prey was recorded within each segment. In addition, we recorded distance to human settlement.

In both years we recorded the presence of snow leopards scrapes along transects. In 2008 scrapes were classified as either very fresh, fresh, old, or very old. In 2009 we simplified the classification to fresh or old to reduce classification errors. Only segments with very fresh or fresh sign were classified as occupied. Detection probability and the probability of occupancy were estimated using PRESENCE 2.1 (Hines 2006).

In 2008, the mean probability of occupancy for all habitats in the study area was 0.49 ± 0.29 (mean ± S.E.). In comparison, in 2009 the mean probability of site use in the suitable habitat within the study area was 0.92 ± 0.06, verifying high probability of use by snow leopards in areas predicted as 'highly suitable' by our terrain model.

Occupancy and camera trapping survey results are promising steps toward developing rigorous, cost-effective survey methods needed to identify priority areas, and guide the development of conservation strategies. The availability of high-capacity digital cameras with long battery life, and cost-effective detection/non-detection surveys, allows application of these methods at spatial scales biologically relevant to snow leopard conservation.

Additional occupancy survey trials are planned for 2010 to further refine the protocols described here and investigate the relationship between changes in population size and changes in occupancy. If the relationship between these state variables can be clarified, the potential cost-savings of occupancy surveys over camera trapping holds promise for applications in range countries where resources are often scarce. Although cameras are a much more expensive alternative to sign surveys for documenting snow leopard presence, they have the advantage of providing unambiguous confirmation of species presence and the potential for individual identification.

Acknowledgements

We thank Wasim Shehzad for sharing data on snow leopard diet constituents, which will be part

of his doctoral thesis now being completed at Université Joseph Fourier, Grenoble, France.

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