Snow leopard population assessment in Jammu and Kashmir

INTERIM PROJECT REPORT

(Assessment Year 2016-17 & 2021-23)

Submitted to
Ministry of Environment, Forests and Climate Change
(Government of India)



Executing Agency
Department of Wildlife Protection
Govt. of Jammu and Kashmir

PROJECT PARTNERS

University of Jammu

SKUAST Kashmir

National Development Foundation

Nature Conservation Foundation

Wildlife Trust of India

EXECUTIVE SUMMARY

The majority of snow leopard surveys in the erstwhile Jammu and Kashmir were limited to Ladakh. Institute of Mountain Environment (IME), University of Jammu pioneered the snow leopard surveys with the goal to understand the spatiotemporal change in snow leopard distributions in Kishtwar high altitude National Park (KNP) in 2016. This was the first attempt of an assessment on occupancy and human – snow leopard interactions at the landscape level in the region. Post reorganization of Jammu and Kashmir, the Department of Wildlife Protection, Govt. of Jammu and Kashmir formally initiated the surveys for assessing the distribution and population estimates of snow leopard in the Lesser and Great Himalayan landscapes in J&K in the year 2021. The techniques used during the surveys aligned with the protocols prescribed by the Ministry of Environment, Forest and Climate Change under Snow Leopard Population Assessment in India (SPAI) as adopted across all Himalayan States where snow leopards occur. The project, currently in its third year, is being executed by many partners, including local research institutes and reputed scientific organizations, under the aegis of the Department of Wildlife Protection, J&K. The study employed various data collection methods, including interviews and sign-based occupancy surveys, camera trapping, and genetic sampling. The report presents the results based on occupancy and spatial capture-recapture.

The summary of the results obtained for this project:

1. This is the first systematic effort at a regional scale to estimate snow leopard population over an area of 12,700 km^2 following two step strategy prescribed under SPAI. The first step included occupancy surveys that provided a probabilistic distribution map of survey units (grids) utilized by snow leopard occurrence across two time periods (25 years apart) based on questionnaire surveys of local communities residing around Kishtwar high altitude National Park (henceforth Kishtwar National Park). Step two, involved the intensive camera trap surveys carried out in whole landscape covering Greater and Lesser Himalayas. Greater Himalayas is roughly divided in three regions, namely the northern Zojila-Thajwas-Baltal circuit, the middle Wadwan-Marwah-Dachhan (Kishtwar national Park) circuit, and south-eastern Paddar circuit. The lesser Himalayan landscapes including Kailash ridge in south and Pir Panjal range reaching far west bordering Pakistan were also surveyed for snow leopards.
2. The probability of site-use (occupancy) by snow leopard was defined as a quadratic function of elevation indicating that snow leopards were likely to use moderately higher elevations. The models suggested on upward shift of snow leopard with pronounced local abandonment near human settlements at lower elevations. This was higher than the colonization rate for the species implying a decline in its spatial distribution over a period of 25 years.
3. The sample counts based on camera trap were used to compute abundance and density of snow leopard. A grid size of 5*5 km^2 was chosen to ensure that it was less than the typical snow leopard home range to allow for recaptures. A total of 225 grids (sampling units) were delineated using randomized grid search method while optimizing the spatial coverage.

4. A total of 278 Infra-red cameras were deployed at 135 locations involving 80 grids (75 in Greater and 5 in lesser Himalayas) randomly across the entire landscape at an elevation of 1700-4780 meters. The entire survey effort totalled 20,207 active camera trap nights.
5. The snow leopard was photo captured in 25 of the 135 locations with two frames recording a female with two sub-adults and a pair, respectively. While most snow leopard sightings have occurred in Kishtwar National Park, the animal has only been captured twice outside the protected area. This includes a single detection each from Kashmir's Thajwas-Baltal Wildlife Sanctuary (PU-2) and Wadwan Valley, Kishtwar (PU-3). The animal has been detected at an altitude of 2970–4120 meters.
6. We identified nine individual snow leopards, seven adults and two sub-adults from 25 detections. Four individuals were excluded from the analysis owing to poor image quality and bad capture angle. This dataset is however inadequate to estimate the size of the snow leopard population across the entire landscape.
7. Most detections were observed in Renai (n=6) followed by Kiyar (n=17) in Kishtwar National Park. Seven of the nine individuals were re-captured at more than two occasions. PU-5 was captured on 11 occasions followed by PU-1 (four occasions) and PU-6 and PU-7 (three occasions, each). PU-2 and PU-3, the ones outside the protected area were detected once only during the entire sampling. Snow leopard PU-5 exhibited a significant level of activity and mobility, as evidenced by its repeated recapture in both the Renai and Kiyar watersheds.
8. The current sampling efforts have yielded a moderately high snow leopard density of 0.75 individuals per 100 km^2, based on SECR. With only two detections observed beyond Kishtwar National Park during the entire effort, the SECR based density was evaluated for the park only. The low sigma values indicate 'valley confined' populations and this is ascertained by high recapture rates in Renai and Kiyar watersheds. The robust density estimates for the entire landscape shall be obtained following multi session SECR commencing this season.
9. Other carnivores detected during the sampling include Himalayan brown bear, Asiatic black bear, Tibetan wolf, red fox, yellow throated marten, leopard cat, Siberian weasel, stoat while the prey-base primarily comprised of Asiatic Ibex, musk deer, Himalayan Gray langur, long tailed marmot, Kashmir flying squirrel, pikas and a few Galliformes. The abundance, density and activity pattern of associate predators and prey base has not been computed and shall be projected in the final report due next year.

Given the efforts, the first of their kind in the region, the results are incredibly encouraging and indicative of immense snow leopard research potential of the landscape. The results provide a strong baseline that will be further refined following the rigorous surveys aimed to arrive at robust snow leopard population estimates for entire Jammu and Kashmir. The department is committed to extending its efforts as a long-term monitoring initiative aimed at tracking the population of snow leopards and their wild prey species across the whole snow leopard landscape in Jammu and Kashmir.

INTRODUCTION


A Camera trap image of snow leopard in Kishtwar National Park

Snow Leopard *Panthera uncia*, the smallest member of the genus Panthera is the most elusive and sought over cat inhabiting cold and rugged mountain landscapes of Great and Trans Himalayas in north western Himalayas. Its secretive behaviour, camouflage, and adaptation to extreme environmental conditions makes it one of the most charismatic species in the world. The snow leopard is found across the high mountains of twelve countries of South and Central Asia and India has the third largest share of snow leopard distributional range. In India, the snow leopard is found in the Union Territories of Ladakh and Jammu and Kashmir, the states of Uttarakhand and Himachal Pradesh in the Western Himalayas and the states of Arunachal Pradesh and Sikkim in the Eastern Himalayas.

The erstwhile Jammu and Kashmir enjoyed being one of the richest abode of snow leopard in the Himalayas. After the reorganization of Jammu and Kashmir, while Ladakh retained the vast and well-known snow leopard habitat in the north, the Union Territory of Jammu and Kashmir (herein after Jammu and Kashmir) encompasses a potential north-eastern (Greater Himalayas) and the central arc (the Lesser Himalayas) that makes around 12,700 km^2 of the potential snow leopard landscape (Fig. 1). Nearly one-fourth of the geographic area of Jammu and Kashmir is located in the Great Himalayan region, the preferred habitat of the snow leopard, which borders Drass in the north and Zanskar in the east. Highly fragile, topographically complex and rugged, this landscape is mostly un-inhabited and disturbance free except for summers that witness the livestock migration of transhumant and local herders. The region is rich with unique animal species including the associate carnivores like Himalayan brown bear, Asiatic black bear, Tibetan wolf, red fox and the preferred prey base including Asiatic ibex, Himalayan tahr, musk deer and Himalayan marmot. The intactness and ecological integrity of the landscape is supported with the presence of two protected areas, Thajwas-Baltal Wildlife Sanctuary and Kishtwar high altitude National Park (here after Kishtwar National park), the largest protected area in J&K.


A typical snow leopard habitat in Haghsu Valley bordering Zanskar

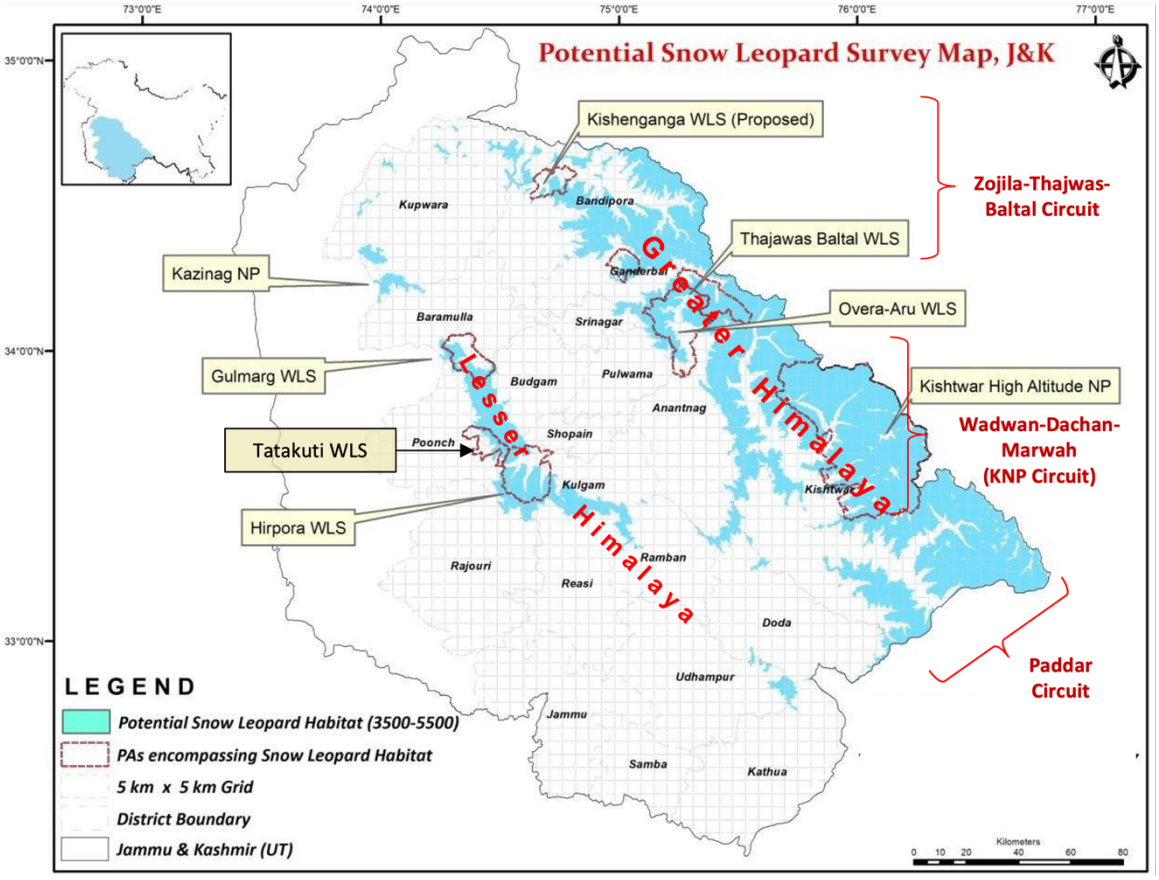


Fig- 1 Potential snow leopard habitat map overlaid with Protected area network in Jammu and Kashmir

The Lesser Himalayas (the Pir-Panjal), which separate the Kashmir Valley from Jammu, also contain a number of protected areas, the most notable of which are Kazinag National Park, Hirpora Wildlife Sanctuary, and Gulmarg Wildlife Sanctuary (Fig 1). These landscapes provide immense ecosystem services and sustains the subsistence of millions of people living downstream.

Though no reliable global snow leopard population estimates exist on date, their number seems to fluctuate between 3900 to 8745 (McCarthy et al 2016). The IUCN recently down listed the snow leopard from Endangered to Vulnerable (McCarthy et al 2017). To get the number right, there is a need to sample large contiguous heterogenous landscapes including the protected areas and multi-use landscapes. The governments of the twelve snow leopard range countries agreed to a collaborative effort called PAWS, or Population Assessment of World's Snow Leopards (The Bishkek Declaration 2017). The Indian government responded by releasing the methodological guidelines for a countrywide Snow leopard Population Assessment in India (MOEF 2019). Now with the recreation of boundaries, the Department of Wildlife Protection, Jammu and Kashmir initiated a new APO and adopted the modalities for assessing the distribution and population estimates of snow leopard in northern Greater Himalayan landscapes bordering Kargil and Zanskar and the central Lesser Himalayas bisecting Jammu from Kashmir region. For the sake of administrative convenience, the vast northern landscape is roughly divided into three regions, the northern Zojila-Thajwas-Baltal circuit, the middle Wadwan-Marwah-Dachan (Kishtwar National Park) circuit, and south-

eastern Paddar circuit in Greater Himalayas. The lesser Himalayan landscape including Kailash ridge in the east and Pir Panjal range reaching far west bordering Pakistan have been considered as a single spatial entity for sampling (Fig -1).

The J&K's conservation efforts can be gauged by the fact that the current SPAI exercise is not restricted to protected areas but spread across the entire landscape with an equal thrust to the habitats outside the protected areas. As Ladakh had been the epicentre of snow leopard research, this region of erstwhile Jammu and Kashmir received little attention and remained deprived of any such surveys in the past until 2016, when researchers from Sher-e-Kashmir University of Agricultural Sciences and Technology – Kashmir used camera traps to establish the presence of the snow leopard in the Baltal-Thajwas Wildlife Sanctuary (Ahmed and Ahmed, 2016). Recent surveys conducted by the Institute of Mountain Environment, University of Jammu provided fascinating insights into the spatial and temporal distribution of snow leopards using an occupancy framework (Ahmed, 2021; Kichloo et al., 2023).

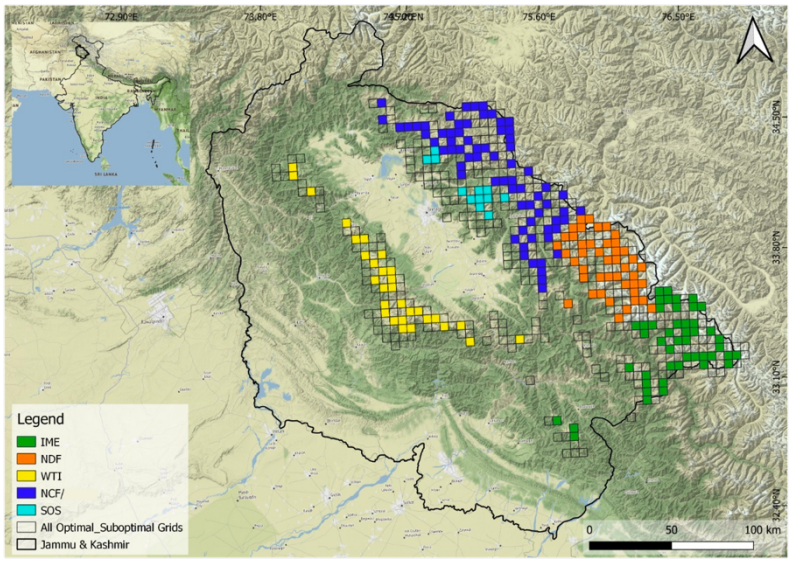


Fig-2 Map showing the grids allocated to different partners

In November 2021, the Department of Wildlife Protection, Government of Jammu and Kashmir, launched its ambitious Snow leopard population survey in J&K by involving a group of collaborators comprised of established scientific organizations and local institutes. The Ministry of Environment Forests and Climate Change (MoEFCC), Govt. of India designated Nature Conservation Foundation (NCF), Mysore as its technical partner and mentor for the snow leopard population assessment in the Union Territory. NCF in collaboration with National Center for Biological Sciences, Bangalore, and Snow Leopard Trust, organized a series of capacity building workshops on PAWS guidelines and SPAI protocols for local partners, researchers, and wildlife support staff. The partner institutes identified for SPAI J&K included Institute of Mountain Environment, Sher-e-Kashmir University of Agricultural Sciences and Technology – Kashmir, National Development Foundation, Nature Conservation Foundation, and Wildlife Trust of India. Each partner was assigned a patch of sampling grids that represented a specific region in Lesser and Great Himalayas (Fig 2).



A camera trap image of snow leopard in Kishtwar National Park


Picturesque Gandhari Valley, Paddar

The snow leopard population estimates can be obtained through the use of appropriate sample counts using camera trap (Karanth, 1995) or molecular genetics (Mondal et al., 2009). The cameras are deployed in microhabitats preferred by snow leopards, spread across the study area using a uniform grid system or a random spatial design (Alexander et al., 2015; Jack- son et al., 2006; Sharma et al., 2014). Individual snow leopards are identified from photographs using their distinctive pelage patterns, and the data are analyzed by generating individual capture histories in order to estimate population density and size (Alexander et al., 2015; Sharma et al., 2014). Recent advances in Spatially Explicit Capture-Recapture (SECR) methods have increasingly put camera traps at the forefront of population monitoring programs.

Population density is a useful parameter for many ecological purposes. SECR methodology is a widely accepted population density estimation tool to monitor populations of large carnivores and it incorporates animal movement in the statistical estimation process. Some applications require estimates of population size rather than density, and population size in a defined area may be obtained as a derived parameter from SECR models. SECR based density estimation was developed independently by Borchers and Efford (2008) and Royle and Young (2008). What separates SECR density estimation from closed capture-recapture models is the incorporation of an explicit spatial component to each individual's detection history, as well as a defined state-space over which density is estimated (Efford and Fewster, 2013; Royle et al., 2014). SECR models explicitly use the spatial information of detection location at the camera traps, accounting for the heterogeneity in captures due to animal activity center location. Decline in detection probability with the distance between a detector and a home range center can likewise be inferred from the clumping of locations at which each individual is observed. This requires that some individuals are detected at multiple locations. Due to a lack of adequate multi session data and number of recaptures in the given data set, we performed single session SECR to estimate snow leopard population densities in the current sampling effort.


Upper Hagshu Valley, Paddar bordering Zanskar range

Though most of the snow leopard surveys in the region focused on assessing distribution, habitat suitability and human-animal interactions, no rigorous field studies have been conducted on estimating abundance and density of snow leopards in the Union Territory. These estimates are pre-requisite for establishing the baseline, assessing the efficacy of conservation efforts, and formulating management plans. SPAI-JK partners initiated the scientific investigations adopting a two-step sampling strategy, one involving occupancy-based snow leopard assessment (following questionnaire approach), and second, population sampling for regional density estimation of snow leopards using camera trapping.





The entire study area sprawled in 12,700 km^2 was divided into 490, 5*5 Km grids, which corresponded to the smallest snow leopard home range (reported in Nepal) and allowed for the most effective recaptures. The grids were further reduced to 225 using a random grid search approach yet retaining the spatial representativeness of the landscape (Fig 3). The report depicts the estimates of the distribution, abundance, and density of snow leopards, but not their prey base.



METHODOLOGY

The study used a two-step sampling process recommended by the PAWS guideline (Sharma et al. 2019) to ensure robust design and adequate coverage of the Union Territory. First the macro level sampling to identify the sites where camera-trapping and ungulate surveys were to be conducted, and second the micro level sampling to deploy cameras, transect walks, genetic sampling, and questionnaire surveys at each site (grid). The potential snow leopard habitats were identified on the assumptions that the animal prefers the elevation above 3000 m to 5500 m, avoids the forested areas with canopy cover more than 50%, and stay away from permanent glaciers and steep rocky terrain based on literature and recent surveys in KHNP (Kichloo et al. 2023).

A grid size of 5*5 km^2 was chosen to ensure that it was less than the typical snow leopard home range (12-39 km^2 to 124-207 km^2) to allow for recaptures. In view of the above, 225, 5*5 km grids (sampling units) covering 12,700 km^2 of potential snow leopard habitat was delineated using randomized grid search method while optimizing the spatial coverage (Fig 3). The grids were plotted in Google Earth (Google Inc., USA), and all known landscape features were identified and marked. While the report aimed to cover the Great Himalayan landscapes, the ideal snow leopard habitats, it did not rule out the possibility of animal's presence in lesser Himalayan landscapes that were also duly scanned for the signs of snow leopards.

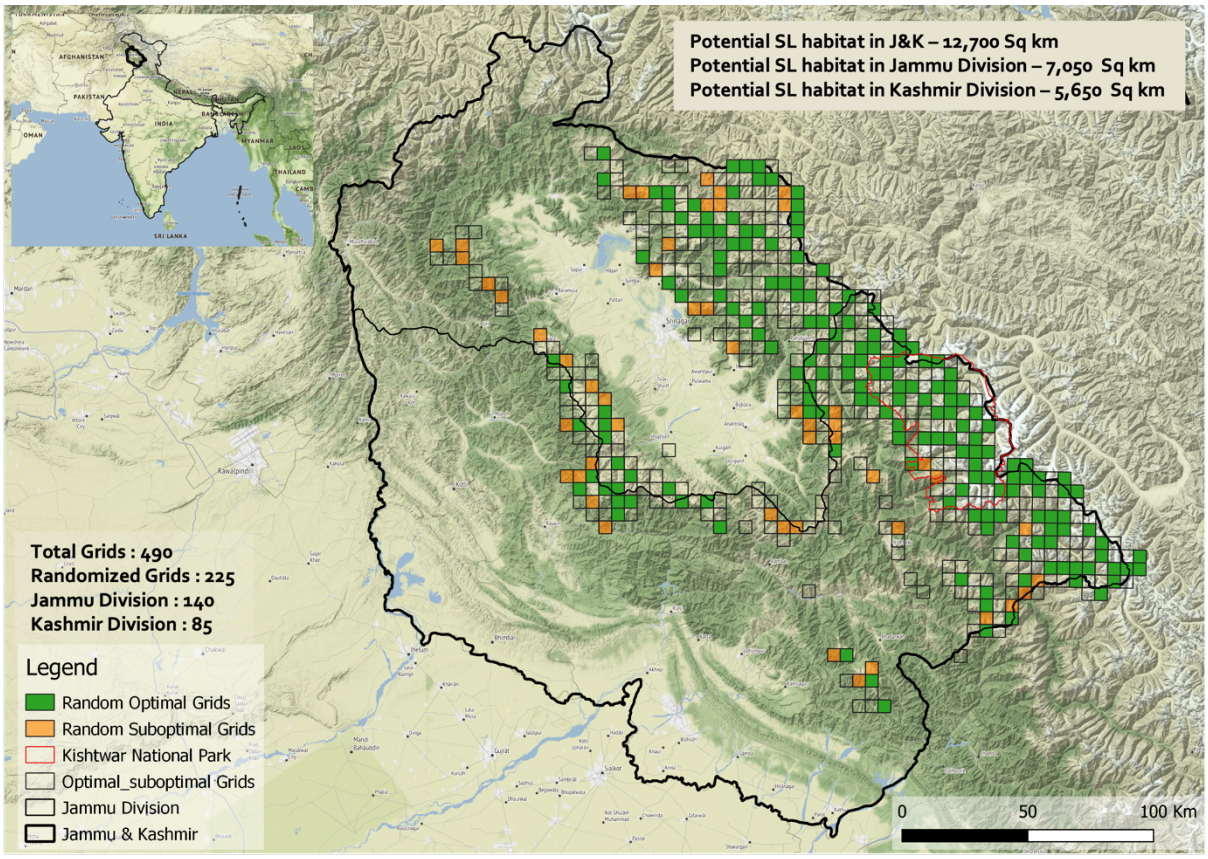


Fig - 3 Potential snow leopard habitat map of Jammu Kashmir overlaid with optimal and sub-optimal grids based on randomized grid search approach

1. Species site use (Occupancy)

Questionnaire based surveys were conducted with the locals who spent considerable time in the study area, the Kishtwar National Park (Fig. 4) and analyzed reports of detection and non-detection by interviewees using a multi-season occupancy framework (MacKenzie et al., 2006). Four broad target groups were identified, a) tribal shepherds (Bakerwals), b) forest and wildlife officials, c) gatherers, and d) others, that included forest resource gatherers or dwellers belonging to different professions. The information about grid-cells where interviewees reported snow leopard was arranged in a detection/non-detection (1/0) format. Occupancy estimates for the three species were considered as the probability of sites being used by each species in the respective time periods (1990s and 2016-17) by relaxing the assumption of closure of sites (MacKenzie and Nichols 2004; Taubmann et al. 2016; Mackenzie et al. 2018).

Data analysis :

Probability of local extinction (ε) was estimated as the probability of a site being used by the species in the past but not in the current period whereas the probability of colonization (γ) was considered the probability of a site being used in the current time period and not in the past (MacKenzie et al. 2018). Covariates that could influence the probability of a site being used by a species, its local extinction and colonization were incorporated in the models using logistic insertion. Six spatial layers *viz.,* elevation, slope, aspect, percentage area under glaciers, normalized differential vegetation index (NDVI), and least cost path distance from the nearest settlements were developed using Geographical Information System (GIS). Data on glaciers and waterbodies was downloaded from Geofabrik (https://www.geofabrik.de/data/shapefiles. html). The spatial datasets were averaged for each of the 25 km^2 sampling unit to be used as site covariates. The probabilities of site-use (ψ), detection (p), local extinction (ε), and colonization (γ) were modelled for the two time periods using package rPresence v 2.0 (Proteus, Dunedin, New Zealand) in the R programming interface (version 4.0.3, https://www.r- project.org/) using RStudio (RStudio Team 2022). The study developed candidate set of 24 single species multi-season models (MacKenzie et al. 2003) for snow leopard. Model outputs were ranked based on Akaike weights (Anderson & Burnham 2002) with top models representing minimum Akaike Information Criteria (AIC) values. Highly correlated covariates were not used in combination when defining a particular model. The analysis was performed in QGIS, version 3.14 (QGIS Development Team, 2023).

2. Micro sampling (Camera trapping)

The sites for the IR camera deployment were selected for the micro-habitats that are preferred by snow leopards but spread across the study area in a uniform grid system or distributed randomly in space (Alexander 2015; Jackson, 2006; O'Connell, 2010; Sharma et al., 2014). Camera-trapping was performed in 80, 5*5 km^2 grids spread across entire snow leopard habitat in the entire J&K. The Infrared cameras (Reconyx, Cuddeback make) were installed for 45-60 days, during which, cameras were checked once for battery condition and for replacement of memory cards. The IR cameras were placed between 30 and 50 cm above the ground (Jenks et al., 2011; Tobler et al., 2008) along paths, trails, overhanging rocks, cliffs, ridgeline saddles etc, based on prevalence of snow leopard signs such as hair, scat, scrape or urine spray marks and suitable microhabitats to maximize detection within each cell. The trap locations were spaced at least 800 - 1000 meters apart.

Image classification

Image classification was done in two phases – image identification phase followed by the review phase that involved two teams each from IME and NCF. Rosette patterns from the face, limbs, rump, shoulder, upper parts of the tail and cheeks of the snow leopard were used to identify different individuals. All the identified individuals were reviewed by team-2 at respective institutes and in case of insufficient evidence towards identification, the individual was discarded for further analysis. Following the individual identification for each site, image comparisons across sites were made to check if any of the individuals were detected at more than one site. All snow leopard images were tagged using the digiKam image management software (https://www.digikam.org/) and tags were read- out using the CamtrapR (Niedballa et al., 2016) package.



SECR based density estimates

A maximum-likelihood based single-session SECR model was used to estimate population densities of snow leopards (Efford and Fewster 2013). SECR models explicitly use the spatial information of detection location at the camera traps, accounting for the heterogeneity in captures due to animal activity centre location. Heterogeneity may arise because the probability of capture in a specific camera trap depends on its location relative to the animal's activity centre (Efford et al., 2009). A buffer size of 14 km was used around the traps to model the state-space. A habitat mask which excluded non-habitable areas above 5200 meters ASL was incorporated into the state-space. A half-normal detection function was used to model detection probability and trap response was assumed to be absent. The model was implemented using R Package ‘secr’ (Efford 2016) in R (version 3.2.3) (R Core Team 2023). Abundance was obtained using a buffer of 4-km which best represented the sampled region.

RESULTS

1. Site use (Occupancy)

In total, 102 interviews were conducted within and outside Kishtwar National Park (Fig 4). Average sampling area coverage reported by each respondent was 24 grids or 600 km^2 (range: 9–46 or 225–1150 km2; SD=10.7 or 268 km^2), and average active period in the area of knowledge was 30.5 years (range: 8–60 years; SD=13.5 years). Interviewees reported the presence of snow leopard in 38 (naïve occupancy = 0.34) sampling units. The study used 24 single species multi-season occupancy models for snow leopard.

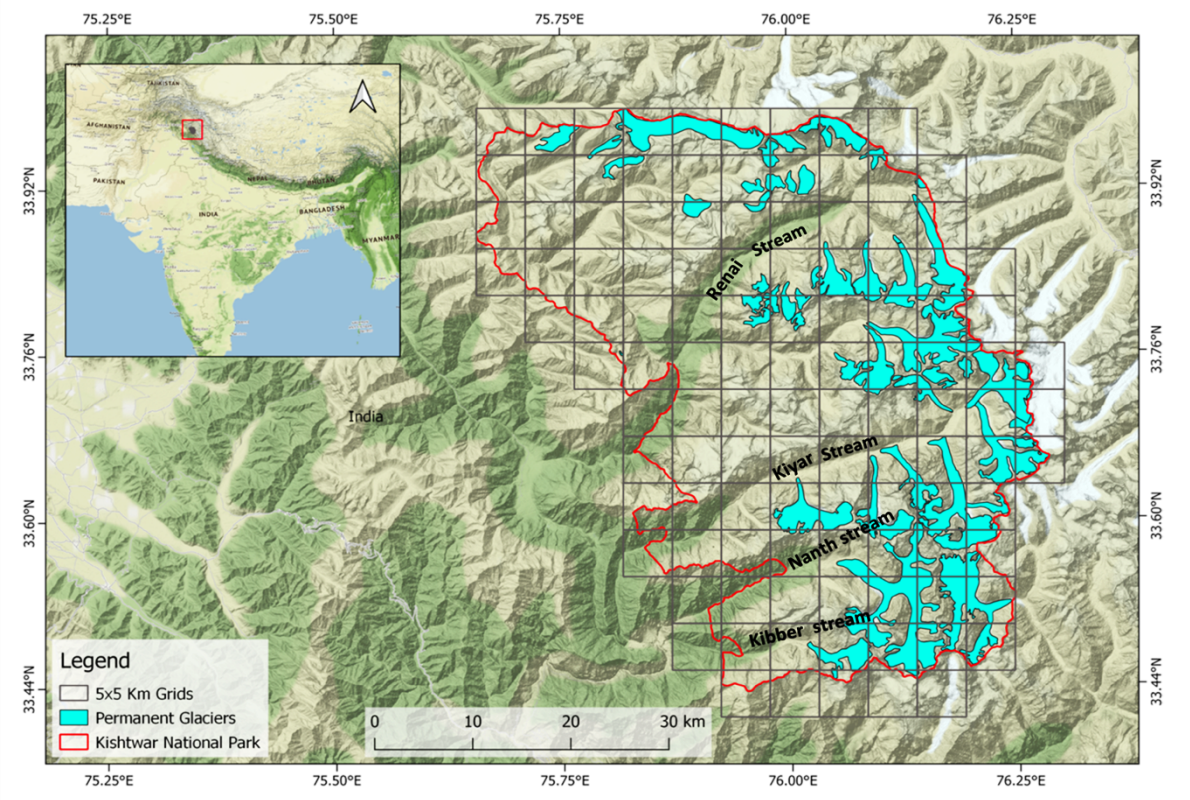


Fig - 4 Kishtwar high altitude National Park (KNP) and the sampling grids. A total of 73 (64.6%) grids were represented in 102 interviews conducted for this study (Kichloo et al, 2023).

The models were ranked for each species on the basis of their respective AIC weights in decreasing order (Supplementary Information, S2). Here the study present the top 10 models for each species (Table - 1).

Table 1 : Top ten models from the candidate model of 24 models for snow leopard

S. No	Model	ΔAIC	AIC weight	N par	Likelihood
1	psi(Elev + I(Elev^2)), p(Season + Occupation), gamma(), epsilon(Stlm)	0	0.493	11	1017.78
2	psi(Elev + I(Elev^2)), p(Season + Occupation), gamma(), epsilon(Stlm + Glacier)	1.18	0.2731	12	1016.96
3	psi(Elev + I(Elev^2)), p(Season + Occupation), gamma(), epsilon(Glacier)	3.65	0.0796	11	1021.43
4	psi(Elev + I(Elev^2)), p(Season + Occupation), gamma(), epsilon(Slope)	4.27	0.0583	11	1022.05
5	psi(Elev + I(Elev^2)), p(Season + Occupation), gamma(), epsilon()	4.93	0.0418	10	1024.71
6	psi(Elev + I(Elev^2)), p(Season + Occupation), gamma(), epsilon(Elev)	6	0.0245	11	1023.78
7	psi(Elev + I(Elev^2)), p(Season), gamma(), epsilon()	7.56	0.0113	7	1033.34
8	psi(Elev + I(Elev^2)), p(Season + Age), gamma(), epsilon()	7.88	0.0096	8	1031.66
9	psi(Elev + I(Elev^2)), p(Occupation), gamma(), epsilon()	8.73	0.0063	9	1030.51
10	psi(Slope), p(Season + Occupation), gamma(), epsilon(Glacier)	13.28	6.00E-04	10	1033.06

Detection probability

The top models indicated that the detection probability varied between two seasons by a factor of−0.53 (SE=0.24) on the logit scale for snow leopard. NFTP gatherers were more efficient at detecting and reporting snow leopard ($\beta_{SLp:gatherers}$=0.77, SE=0.38) followed by shepherds ($\beta_{SLp:shepherd}$=0.74, SE=0.37). Age and the period respondents remained active in the area of knowledge did not seem to affect the detection probability of the species (Table - 2).

Table – 2 Untransformed estimates of coefficient (β) from the top models of snow leopard

Covariate	**Snow leopard** $\beta \pm SE$
Occupancy (Ψ)	
Elevation	-0.83 ± 0.34
(Elevation)^2	-0.65 ± 0.24
Settlements	-
NDVI	-
Detection Probability (ρ)	
Season	-0.53 ± 0.24
NTFP gatheres	0.77 ± 0.38
Others	-0.09 ± 0.57
Shepherds	0.74 ± 0.37
Abandonment (ε)	
Elevation	-
Settlements	-1.21 ± 0.60
Local Colonization (γ)	
Elevation	-

Species site-use, expansion, and contraction

The top model defined probability of site-use by snow leopards as a quadratic function of elevation ($\beta_{SLelevation}$=−0.83, SE=0.34; $\beta_{SLelevation^2}$=−0.65, SE=0.24) indicating that snow leopards were likely to use moderately higher elevations as opposed to high and low elevations (Fig 5). Probability of local abandonment was higher than the colonization rate for the species indicating an overall decline in its spatial distribution over the years. Further, the probability of snow leopard having faced local abandonment was greater closer to the settlements ($\varepsilon_{SLsettlements}$=−1.21, SE=0.60), than at higher altitudes.

Overall, while snow leopard showed an upward shift away from settlements with marked local abandonment at lower elevations (Fig 6). Sampling units with a major portion of their area under permanent glaciers were also less likely to have undergone local extinction of snow leopards ($\varepsilon_{SLglaciers}$ = − 0.42, SE = 0.51).

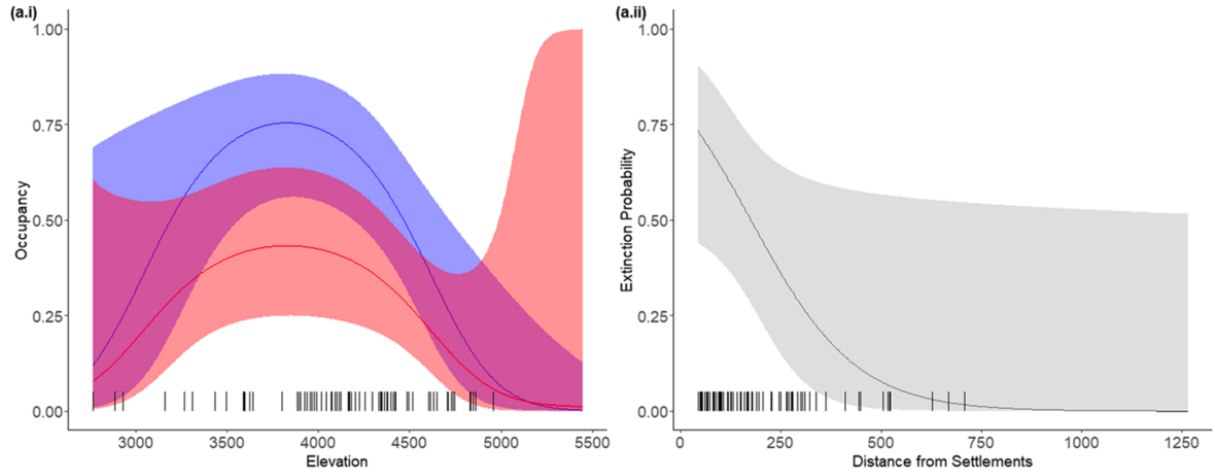


Fig. 5 Relationship between the probability of site-use (occupancy) in the past (blue) and present (red) time periods, and local extinction probability as a function of covariates included in the top model for (a) snow leopard [(i) occupancy~elevation; (ii) abandonment ~Distance from settlements] (Kichloo et al., 2023)

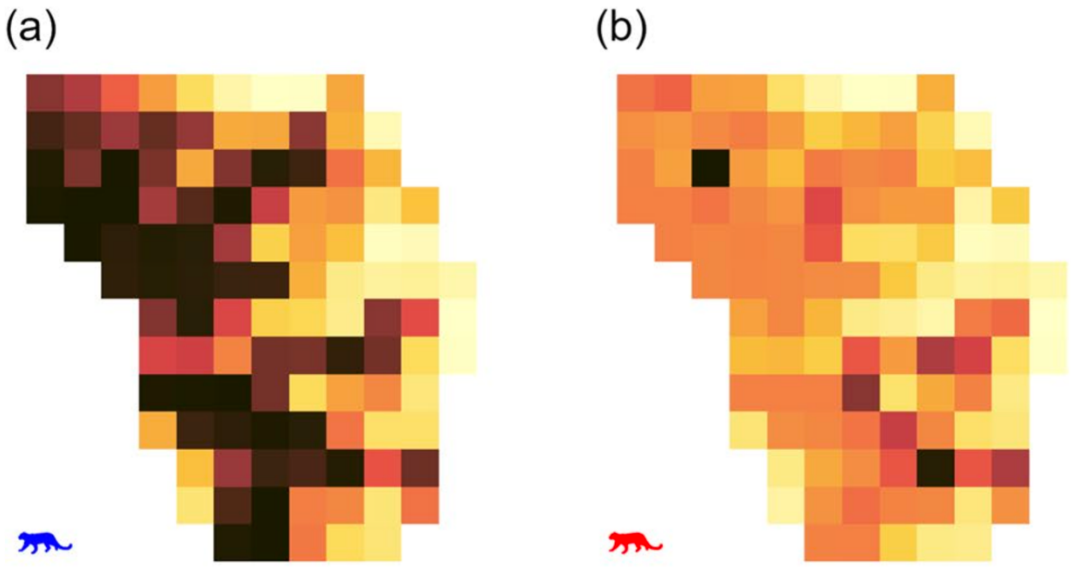


Fig. 6 Probability of sites being used by snow leopard (a, b) in the past (1990s), and current (2016– 2017) time periods respectively. Each past and current distribution of the species is estimated using the top model as selected by minimum AIC (Kichloo et al., 2023)

2. Camera trap based snow leopard abundance and density:

Snow leopards were detected in 25 of the 135 sites surveyed in 80 grids involving 278 cameras (Fig 7). Nine individual snow leopards, seven adults and two sub-adults have been identified.

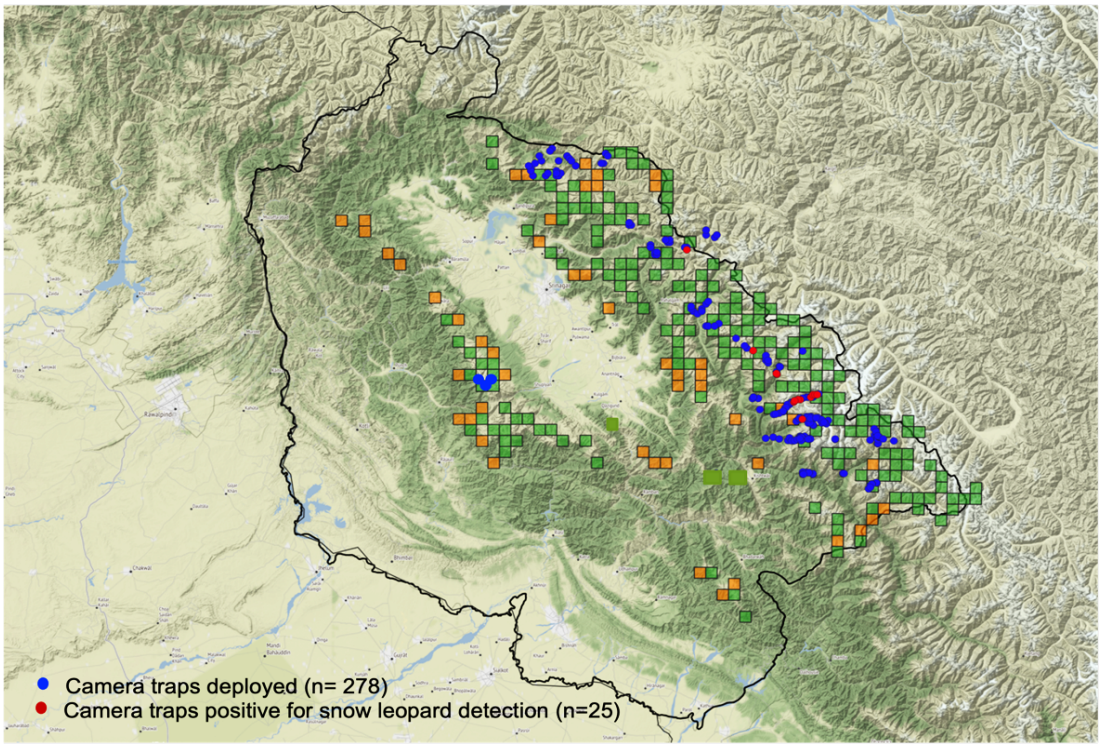


Fig 7. Map showing total camera traps deployed and camera traps positive for snow leopards. The grids in green are the optimal and those in orange are sub-optimal

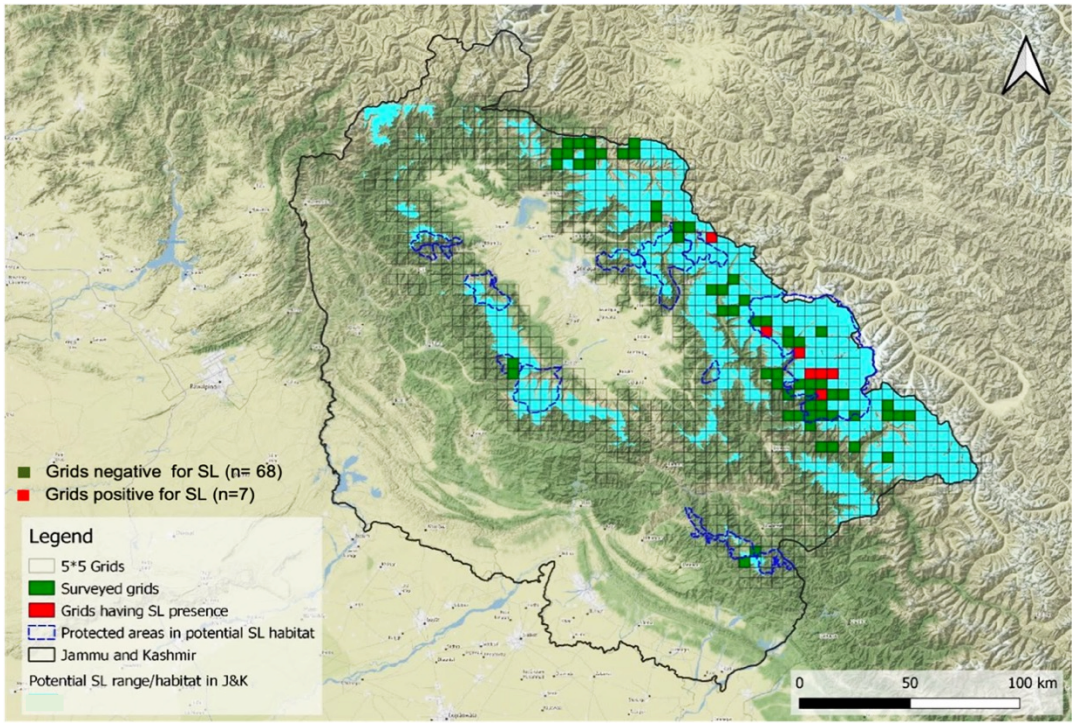


Fig 8 Map showing grids positive (red dots) and negative (blue dots) for snow leopard presence.

Estimated snow leopard population size (SECR based) in the current sampling effort is likely to be 13 individuals. Four individuals were excluded from the analysis owing to poor image quality and bad capture angle. This dataset is however inadequate to estimate the size of the snow leopard population across the entire landscape. Of the 75 grids camera trapped in the Greater Himalyas, seven were found postitve for snow leopard (Fig 8).

Image classification

The image classification yielded 9 individuals, seven adults and two sub-adults across 135 locations. The snow leopards have been named as PU (*Panthera uncia*) followed by arabic numeral, say PU-1, PU-2 and so on. One detection each comes from the Thajwas-Baltal Wildlife Sanctuary and Wadwan landscape, while the rest are confined to the Renai (n=6) and Kiyar watersheds (n=17) of Kishtwar National Park. Two of the images showed a female with two sub-adults and, a mating pair in Renai watershed. Seven of the nine individuals were re-captured at more than two occasions with PU-5 captured 11 times followed by PU-1 (four occasions) and PU-6 and PU-7 (three occasions, each). PU-2 and PU-3 were detected once only during the entire sampling (Table-3). Snow leopard PU-5 exhibited a significant level of activity and mobility, as evidenced by its repeated recapture in both the Renai and Kiyar watersheds. The animal has been detected at an altitude of 2970–4120 meters, with a few detections along the forest edges. Most of the detections are during the months of May and October.

Table 3 : Site wise details about camera trapping effort, date of detection and snow leopard id

S.No.	Sampling site	Region / PA	Date	ID
1.	Kainpathri 3	Thajwas-Baltal WLS	09/05/23	PU 3
2.	Dandoli pad	Wadwan, Kishtwar	19/05/23	PU 4
3.	Jayal top(Renai)	Kishtwar National Park	03/07/23	PU 1
4.	Jayal top(Renai)		03/11/22	PU 1
5.	Jayal top(Renai)		02/12/22	PU 7 and PU 8
6.	Jayal top(Renai)		19/02/23	PU 7, PU 8, PU 9
7.	Jayal top(Renai)		30/11/22	PU 5
8.	Jayal top(Renai)		12/05/22	PU 5
9.	Kiyar nallah		30/11/22	PU 1
10.	Kiyar nallah		21/10/22	PU 5
11.	Kiyar nallah		08/04/23	PU 5
12.	Kiyar nallah		10/04/23	PU 5
13.	Kiyar nallah		11/10/22	PU 7
14.	Dodtang		07/04/23	PU 1
15.	Drash		29/05/23	PU 4
16.	Sarbal top		11/05/23	PU 5
17.	Geem		27/05/23	PU 5
18.	Geem		15/06/23	PU 5
19.	Geem		25/05/23	PU 5
20.	Padhi cliff		28/05/23	PU 5
21.	Sarbal top		11/05/23	PU 5
22.	Sarbal top		23/05/23	PU 6
23.	Geem		13/05/23	PU 6
24.	Sarbal top		13/05/23	PU 6
25.	Sarbal top		13/05/23	PU 6

The first Snow leopard to be detected, PU-5 was photo captured on May 12, 2022 in Jayal Top, Renai, while PU-2 was photographed in Thajwas Baltal Wildlife Sanctuary on October 01, 2022. A classic frame of three individuals, a female with two sub-adults (PU-7, 8 & 9) captured on February 19, 2023 in the Renai watershed established an active breeding population within the park (Table-3).

SECR based density estimates

Table 4 shows the SECR results. The estimated density was 0.75 individuals per 100 sq.km. (0.22-2.56). This resulted in an estimated abundance of 5 individual, with minimum 4 and up to 13 individuals present. In SECR models 'detectability' is modelled as a (typically halfnormal) function of distance, so the parameters g0 and sigma that together define that function replace 'p' (detection probability) in non-spatial models. 'Sigma' on its own can be interpreted as an index of home range size, but not directly as 'average distance moved': in some idealized conditions it may equal the sigma of a circular bivariate normal home range model. A sigma of 3383 m (1709 m – 6696 m) with a g0 of 0.013 seems to suggest that snow leopards here move lesser compared to snow leopards in more trans-Himalaya habitats like (who have estimated sigma of over 4,500m). This could indicate a population that is restricted to certain regions within a valley in and around Kishtwar National Park.

Table 4 SECR based estimate of Snow Leopards from Kishtwar National Park

Parameter	Estimate	SE	LCI	UCI
Density (per 100 sq.km.)	0.75	0.52	0.22	2.56
g0	0.013	0.007	0.004	0.038
Sigma (m)	3383	1215	1709	6696
Abundance (4km buffer)	5	1.46	4	13

SE = Standard Error, LCI = Lower Confidence Interval, UCI = Upper Confidence Interval.













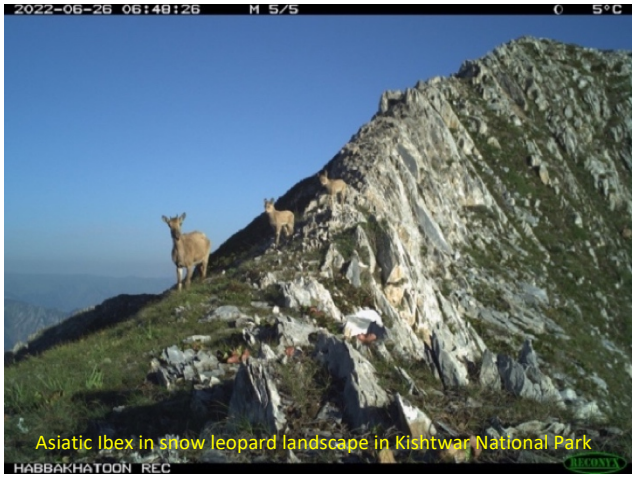




Images PU-1 to 9 : Snow Leopard individuals identified in the current sampling effort

Non targeted mammal (carnivores and herbivores) species

While we did not attempt for computing the abundance and density of sympatric predators and prey species, we tend to highlight their co-occurrence based on photo captures. The carnivores detected during the sampling include brown bear, Asiatic black bear, Tibetan wolf, red fox, leopard cat, yellow throated marten, stone marten, Siberian weasel, stoat while the prey-base primarily comprised on Asiatic Ibex, musk deer, Himalayan Gray langur, long tailed marmot, pikas and a few Galliformes. The sympatric red fox was the most detected animal photo captured on 95 occasions followed by stone marten (77 occasions) brown bear (33 occasions) and Tibetan wolf (6 occasions). Among the prey species, Asiatic Ibex and Musk deer dominated the sampling area with 15 detections each (Table-5). The abundance, density and activity pattern of associate predators and prey base shall be projected in the final report due next year.



Asiatic Ibex in snow leopard landscape in Kishtwar National Park

Table-5 Occurrence data on mammals (predators and prey base) based on the number Camera trap detections.

S.No.	Family	Species	Binomial name	Number of Detections	IUCN status
1	Cercopithecidae	Rhesus Macaque	*Macaca mulatta*	2	LC
2	Cercopithecidae	Himalayan Grey Langur	*Semnopithecus ajax*	1	EN
3	Moschidae	Himalayan Musk Deer	*Moschus leucogaster*	15	EN
4	Bovidae	Asiatic Ibex	*Capra sibirica*	15	NT
5	Felidae	Snow Leopard	*Panthera uncia uncia*	25	VU
6	Felidae	Leopard Cat	*Prionailurus bengalensis*	1	LC
7	Canidae	Tibetan Wolf	*Canis lupus chanco*	6	EN
8	Canidae	Red Fox	*Vulpes vulpes*	95	LC
9	Ursidae	Asiatic Black Bear	*Ursus thibetanus*	4	VU
10	Ursidae	Himalayan Brown Bear	*Ursus arctos isabellinus*	33	CE
11	Mustelidae	Stone Marten	*Martes foina*	77	LC
13	Mustelidae	Yellow-throated Marten	*Martes flavigula*	5	LC
14	Mustelidae	Mountain Weasel	*Mustela altaica*	5	NT
15	Mustelidae	Least Weasel	*Mustela nivalis*	5	LC
16	Ochotonidae	Royle's Pika	*Ochotona roylei*	48	LC
17	Sciuridae	Himalayan Marmot	*Marmota himalayana*	3	LC
18	Sciuridae	Long-tailed Marmot	*Marmota caudata*	29	LC
19	Sciuridae	Kashmir Flying Squirrel	*Eoglaucomys fimbriatus*	8	LC





Himalayan brown bear and red fox in snow leopard landscape of Kishtwar National Park





The prey base, Asiatic Ibex and Kashmir Musk deer in Kishtwar National Park





Long tailed Marmot and Himalayan snowcock in snow leopard landscape

Way forward

The results from this study provide a snapshot of snow leopard abundance and density estimates in the Greater Himalayan landscape mostly targeting Kishtwar National park and adjoining landscapes based on primary evidence. Though limited to site use (occupancy) and camera trapping, the study provides a significant baseline information to set up a long term monitoring project to track the population of snow leopard and its wild prey species. The department is committed to extending its efforts as a long-term monitoring initiative aimed at tracking the population of snow leopards and their wild prey species across the whole snow leopard landscape in Jammu and Kashmir.



Acknowledgements :

Project Execution :
Dr. Kumar, M.K (IFS), Regional Wildlife Warden, Jammu
Sh. Rashid Naqash, Regional Wildlife Warden, Kashmir

Project Mentor :
Dr. Yashveer Bhatnagar, Nature Conservation foundation and Country Representative, IUCN

Project partners :
Dr. Khursheed Ahmed and team, SKUAST- Kashmir
Dr. Neeraj Sharma and team, IME, University of Jammu
Dr. Pankaj Chandan and team, National Development Foundation
Dr. Munib Khanyari and team, Nature Conservation foundation
Dr. Tariq Ahmed and team, IME and WLW, JK
Dr. Tanushree Srivastava, Wildlife Trust of India