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Estimating Snow Leopard Population in Lapchi Valley, Gaurishankar Conservation Area, Nepal

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Abstract

Accurate estimations of species abundance are crucial for effectively conserving endangered species. Estimating the population of snow leopards, a cryptic species living in remote and harsh habitats, based on camera trap photos is not easy but can still be useful for baseline estimations. In this study, we used camera traps to estimate the number of snow leopards in Lapchi Valley in Gaurishankar Conservation Area (GCA), Nepal. The study area spanned roughly 280 square kilometers, and for 25 months, we used 26 camera traps (CTs) strategically placed in 16 locations based on potential snow leopard activity. CTs captured a total of 39 snow leopard events. Seven peer observers independently and

jointly identified six adults and two sub-adults using fur coloration, spot patterns and unique differences including one individual with an eye abnormality. Two individuals were accompanied by cubs, one of which was later observed with abdominal injuries. We observed seasonal variations in snow leopard activity, with higher occurrences in cold season and absence from May to October. The study area's high snow leopard density and seasonal concentration highlight the importance of Lapchi Valley as a crucial habitat for conservation. In addition, Lapchi Valley connects directly to the Tibetan plateau, so there is a potential for transboundary movement. This research contributes valuable insights for snow leopard conservation strategies, considering the species' elusive nature and the challenges in accurate population estimation.

Introduction

The snow leopard (*Panthera uncia*), known as "Ghost of the mountains" is a flagship apex predator distributed across 12 different countries of the Central and South Asian mountains including Nepal (Ale et al. 2016, Ghoshal 2017). It is categorized as Vulnerable on the IUCN Red List (McCarthy et al. 2017) and is a protected species under Nepal's National Parks and Wildlife Conservation Act 1973. In Nepal, snow leopards range across the northern frontier, described/recorded from all mountainous protected areas of Nepal: Annapurna Conservation Area (Oli et al. 1993, Hanson 2022), Api Nampa Conservation Area (Khanal et al. 2020), Kangchenjunga Conservation (Karmacharya et al. 2011, Thapa et al. 2013), Manaslu Conservation Area (Shrestha et al. 2018, Chetri et al. 2019), Makalu Barun National Park, Dhorpatan Hunting Reserve (DNPWC 2017), Langtang National Park (Chalise & Kyes. 2003), Sagarmatha National Park (Ale et al. 2007, Lovari et al. 2009) but the snow leopard at Sagarmatha National park is assumed as only dispersing individuals presently (Lovari & Mishra 2024), Shey Phoksundo National Park Area (Jackson 1996, Thapa 2006, Devkota et al. 2013) and Gaurishankar Conservation Area (Koju et al. 2021, Pandey et al. 2021, Koju et al. 2023, Koju et al. 2024) as well as outside the protected areas of Nepal (Ale & Karky 2002, Hanson et al. 2019, Hanson 2022).

Snow leopard conservation is a priority in Nepal, and accurate estimations of species abundance are crucial for the effective management and conservation of endangered species (Johansson et al. 2020). When genetic analyses are not available, camera trapping is the most widely used data collection method for estimating abundance of snow leopards (Choo et al. 2020). Individual identification of snow leopards from camera trap images for population and abundance estimation is not an easy task, however, and the accuracy of this method is limited by human observer errors from misclassifying individuals (Alexander et al. 2020, Johansson et al. 2020, Bohnett et al. 2023). Three tools are primarily used to estimate the population from individual identification of snow leopard:

1. Using experts and non-experts to identify individuals based on visual observation
2. Using capture recapture modelling and
3. AI based visual matcher software (Wegge et al. 2012, Alexander et al. 2020, Johansson et al. 2020, Suryawanshi et al. 2021, Blount et al. 2022, Bohnett et al. 2023).

According to an estimation based on sign surveys, approximately 301 – 400 snow leopards reside throughout the distributional range within Nepal (DNPWC 2017). Recently, a total of 90 individuals from Shey – Phoksundo National Park (SPNP 2023) and 34 individuals from Annapurna – Manaslu complex have been estimated using spatial capture-recapture method (Chetri et al. 2019). However, studies based on strong scientific methodologies that estimate the abundance of snow leopards are still scarce in most areas of Nepal. Although photographic evidence of snow leopard presence in Lapchi Valley has only recently been confirmed at GCA (Koju et al. 2021), GCA is potentially very important for snow leopard conservation because it lies between Langtang and Sagarmatha National Parks in Nepal and adjacent to the Qomolongma Protected Area in China. To better understand the importance of GCA, it is essential to explore the number of snow leopard individuals that use it. The study aimed to estimate the number of snow leopards and their seasonal movement based on photos and videos, recorded from 2018 to 2023 using camera traps at Lapchi Valley of Gaurishankar Conservation Area.

Methods

Study area

Lapchi Valley, Gaurishankar Conservation Area's (GCA) lies between 86°10'32.53" and 86°29'9.45"E and 28°20'13.19" and 28°21'54.55"N. It is a renowned Tibetan Buddhist pilgrimage site situated at the base of the LapchiKhang mountain range. The "ChöraGephel Ling," the main monastery in Lapchi, is surrounded by caves, used as meditation sites by the renowned 11th century poet and saint Jetsun Milarepa. As a result, it is a very important site for Tibetan Buddhism. It is confined to the east, west, and north by China (Koju et al. 2020). It ranges from 968 to 7,181 meters above sea level and features various habitats, from sub-tropical to nival (Figure 1). The valley has 16 major vegetation types and is home to a wide range

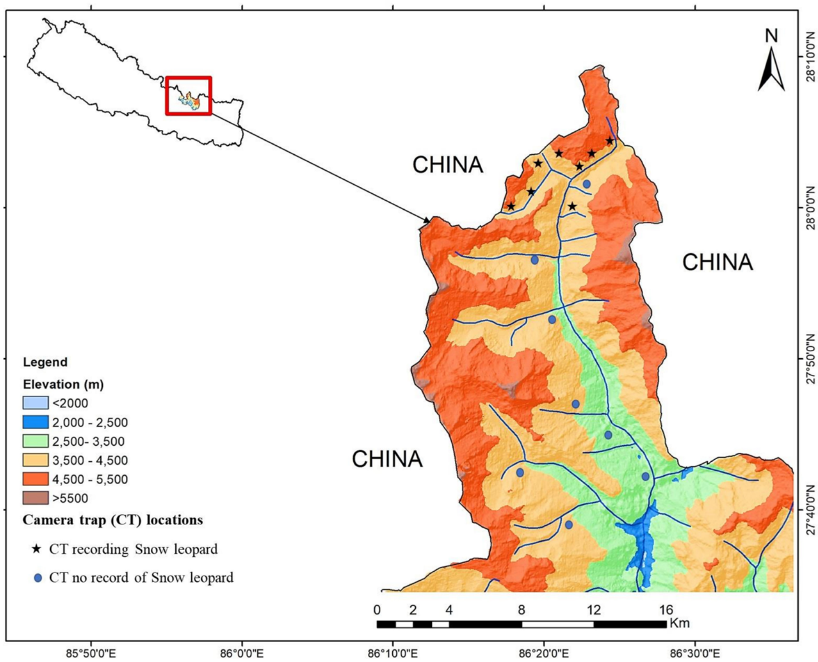

Figure 1: *Map showing Camera trap locations and where snow leopards were recorded in the study area*

of flora and fauna, including 235 bird species, 77 mammal species, 16 fish species, 22 reptilian species, and 10 amphibian species. The GCA is important for snow leopards and other wildlife as it connects habitats from the Tibetan Plateau to the north, Langtang National Park to the west, and Sagarmatha National Park to the east (Awasthi & Singh 2015, Koju et al. 2021, Pandey et al. 2021, Chetri et al. 2022). Livestock rearing is the major source of income for people of Lapchi, and they follow nomadic pastoral practices of seasonal movements of their livestock. Lumnang is their winter retreat area and take livestock to the high valleys in Lapchi and the Tibetan region during the warm period.

Methodology

Camera trapping

In this study, we installed 26 Bushnell Trophy Camera Traps (CTs) (Model #119537C), set in hybrid mode to take both photographs and videos simultaneously for 25 months in two phases: 1) from 22 October 2018 to 16 May 2019, and 2) from 19 October 2021 to 15 March 2023. Due to the challenges of conducting field research in remote mountainous regions, we deployed 26 camera traps at 16 locations close to potential scats and scrapes of leopards and its prey species, 30-40 cm above the ground depending on the slope of the land (Li et al. 2018, Wangdi et al. 2019). We selected these locations ensuring a fair representation of different habitats in the study area. All the camera locations were placed maintaining a minimum of 2 km distance from each other except for four camera traps, which were placed on either side of the river between the forest habitat and the alpine area of Lapchi Valley. The camera traps were set to function over 24 hours with the one-second trigger time between the events and were able to record images at night using infrared LEDs. The CTs were visited at interval of three months during the study period to undertake data recovery and replacing the batteries in order to maintain data integrity and camera functioning. Unfortunately, eight camera traps were lost in different locations which were replaced in the same location during consecutive visits.

Data management and analysis

Images of the same species taken at least 30 minutes apart were considered independent occurrences to analyze the data from the camera traps. Successive photos of distinct individuals, whether of the same or different species, as well as non-consecutive images of the same species at a particular place, were supposed independent events (Carbone et al. 2001). Images that were blank or could not be recognized were removed from the study. The study period was divided into cold and warm months, as delineated by Koju et al. (2023) and Koju et al. (2024). The warm season, defined as the period when yaks and horses graze in the highland pastures of Lapchi Valley, spans from April 16 to November 15. Conversely, the cold period, characterized by the migration of yaks and horses to lower elevation pastures, extends from November 16 to April 15. For the seasonal and monthly events analysis of snow leopards, data from a complete year (March 2022 to February 2023, N=35) were utilized, following the methodology outlined by Koju et al. (2024). The seasonal and monthly events were statistically analyzed using Karl Pearson's Chi-Square Tests.

Identification using observers and peer observation

Identification of individual snow leopards was carried out in two steps: independent and joint identification. For independent identification, we invited seven peer observers with good experience on camera trapping of snow leopards and dedicated to snow leopard conservation, as well as associated with NGOs or universities. All peer observers received the photos and videos of the snow leopards, with a request to identify the individuals following PAWS guidelines. Four experts, jointly revised the analysis and the concurrent conclusion was used as the result following Bayandonoi et al. (2021) and Bohnett et al. (2023). Distinctive spot patterns on the flanks, legs, back, and tail of each snow leopard were used to distinguish individual snow leopards. The utilization of burst photography and video footage maximized the capture of snow leopards from diverse perspectives and body angles. Instances involving single-flank encounters, unclear images, distant subjects, limited body parts in the images, or situations where spot patterns could not be conclusively identified and compared with other instances were categorized as 'Unidentifiable'. Such encounters were excluded from the final analysis (Bayandonoi et al. 2021).

Results

Population estimation

Throughout the study period, our camera traps captured a total of 39 snow leopard events across eight distinct locations (Figure 1) within an area of approximately 60 km^2. The lowest elevation for a snow leopard record was 3535 m asl and the highest level was 4628 m asl (at highest elevation, where CT was installed in this study). The experts' evaluation confirmed the presence of a minimum of 6 individuals (Figure 5, Table 1), including one with an abnormality in its left eye (SL1 [Figure 2]). SL1 was spotted in two locations, CAM1 (winter) and CAM 56 (summer). Two snow leopards, SL4 and SL5, were accompanied by at least one cub each in November and December (Figure 3 [A, B]). Moreover, a juvenile with abdominal injuries (Figure 4) was spotted on March 13, 2023 at CAM 55. The cause and effect of injuries was not known.

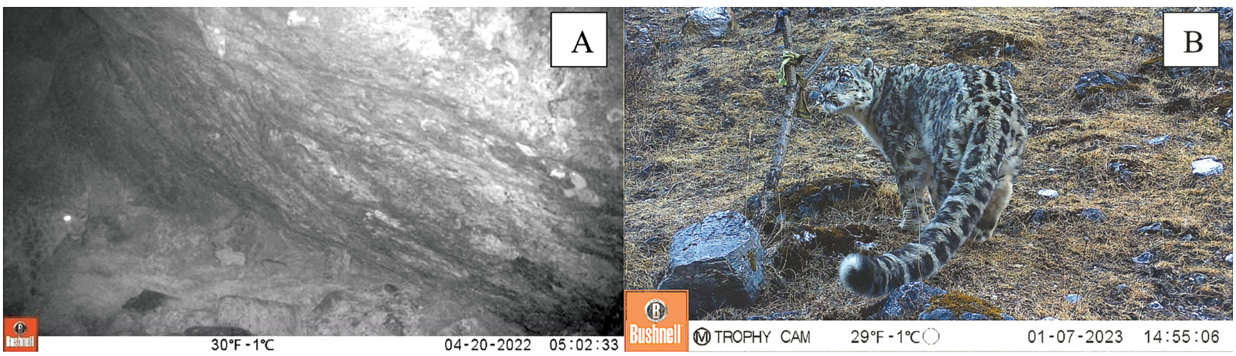

Figure 2: *A snow leopard with injury in left eye at Lapchi Vally: recorded on April 20, 2022 (A) at CAM 56 and on Jan 7, 2023 at CAM1 (B)*

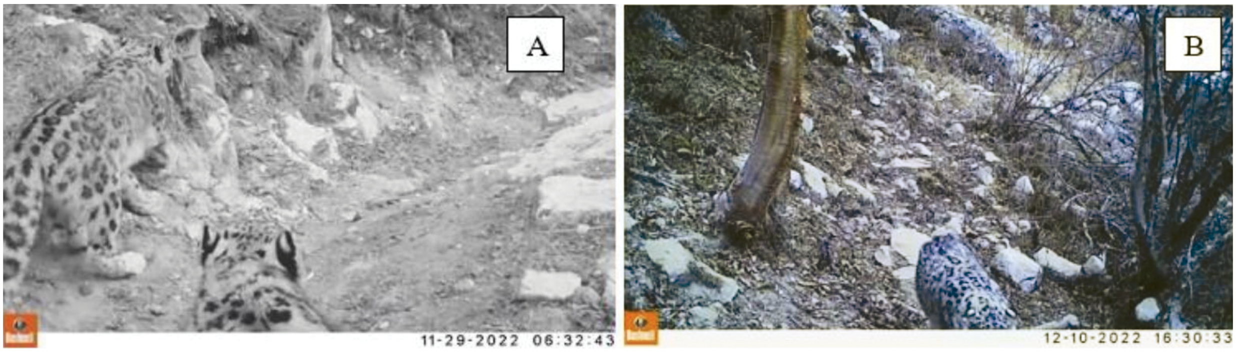

Figure 3: *A pair of female snow leopard with respective cubs: Recorded on November 29, 2022 at CAM 6 (A) and December 10, 2022 at CAM 55 (B)*

Figure 4: *A snow leopard (cub) with deep cut in abdomen as external injuries, recorded on March 13, 2023 at CAM 55.*

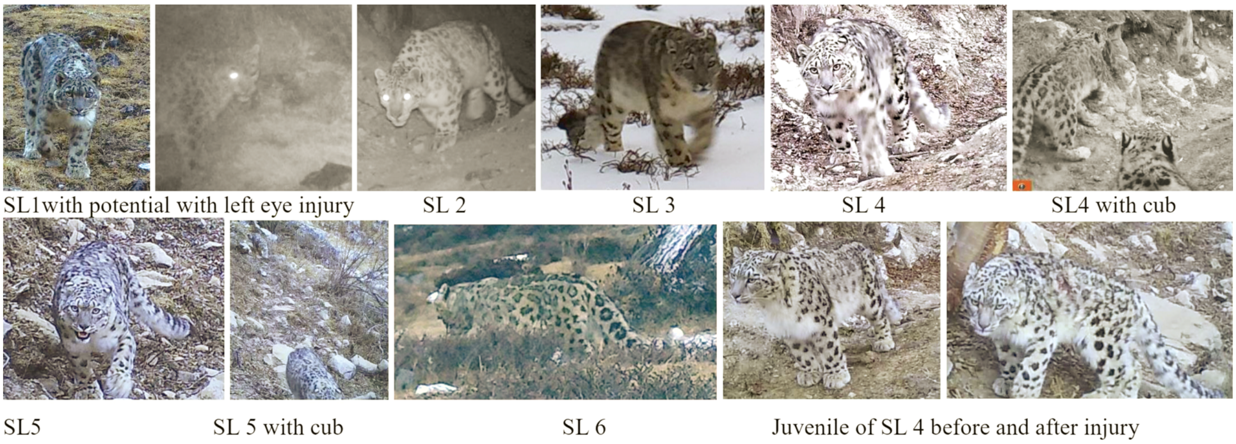

Figure 5: *The visual peer observation from experts confirmed possibility of 6-8 snow leopard individuals*

Table 1: *Snow leopards recorded in cameras and individual identification by peer and group identification*

CAM name	GPS coordinate Latitude	Longitude	Detection number cold	warm	Total	Snow leopard identification (frequency and recorded date) SL 1	SL 2	SL 3	SL 4	SL 5	SL 6	unknown
CAM1	28.10060	86.13891	3	0	3	1 1/7/2023		1 1/22/2023				1 1/21/2023
CAM3	28.10754	86.14855	11	1	12			4 3/25/2022 11/10/2022 11/30/2022 1/22/2023	1 2/8/2023			6 11/11/2018 4/3/2019 11/28/2021 12/1/2022 12/28/2021 2/25/2022 12/10/2022
CAM5	28.12950	86.19231	5	0	5		1 1/20/2023			1 1/20/2023	1 1/22/2023	2 1/14/2023, 2/11/2023
CAM6	28.11988	86.17811	8	1	9		6 11/29/2022 12/18/2022 1/4/2023 2/8/2023 2/12/2023 3/1/2023			1 4/21/2022	1 2/5/2023	1 2/17/2023
CAM9	28.11666	86.17382	2	1	3				1 12/18/2022		1	2 4/21/2022, 12/18/2022
CAM10	28.09368	86.1673	1	0	1							1 1/5/2023
CAM55	28.12359	86.15702	2	0	2				1 12/10/2022		1 13/13/2023	
CAM56	28.12798	86.15861	2	2	4	1 4/20/2022		1 12/9/2022				2 4/20/2022, 12/18/2022
Total number of records			34	5	39	2	6	7	1	2	3	11

Temporal records of snow leopard

From March 2022 to February 2023, a total of 35 snow leopard detections were recorded. The majority of these records occurred in the cold months (88.51%, n=31), with the highest frequency in January (10 events across six camera traps), followed by December (eight events across five camera traps), and February (seven events across three camera traps) (Figure 6). In warm season, only four detections were recorded in April. There were fewer records in November and March, and no records were recorded from May to October (Figure 6). A chi-square test indicated significant seasonal (p = 0.0005, χ^2 = 20.83, df = 1) and monthly (p = 0.0001, χ^2 = 50.64, df = 11) variations in snow leopard visits to Lapchi Valley.

Discussion

Our study showed the importance of Lapchi Valley, GCA for snow leopards with at least six adults and two sub-adult individuals consistently identified by expert observers. This support the reliability of manual identification based on camera trap images. While manual identification of individual identification of snow leopards, using the unique fur pattern such as rosettes, remains the most widely used and trusted approach (Jackson et al. 2006, Sharma et al. 2014, Alexander et al. 2016). It is not without challenges, particularly the potential for inaccuracies. To mitigate this, identification by multiple expert observers provides a more robust method, as it reduces individual observer bias and enhances the accuracy of the result.

With a study area of nearly 280 square kilometers being used by at least six snow leopards (2.14 per 100 square kilometers), yielding a population density comparable to estimates from other regions in Nepal. For instance, in Api Nampa Conservation Area Snow leopard density was estimated 3-4.5 individuals per 100 km^2 (Khanal et al. 2020), 34 individuals in 4393 square kilometers in north-central Nepal (Chetri et al. 2019), 1.5

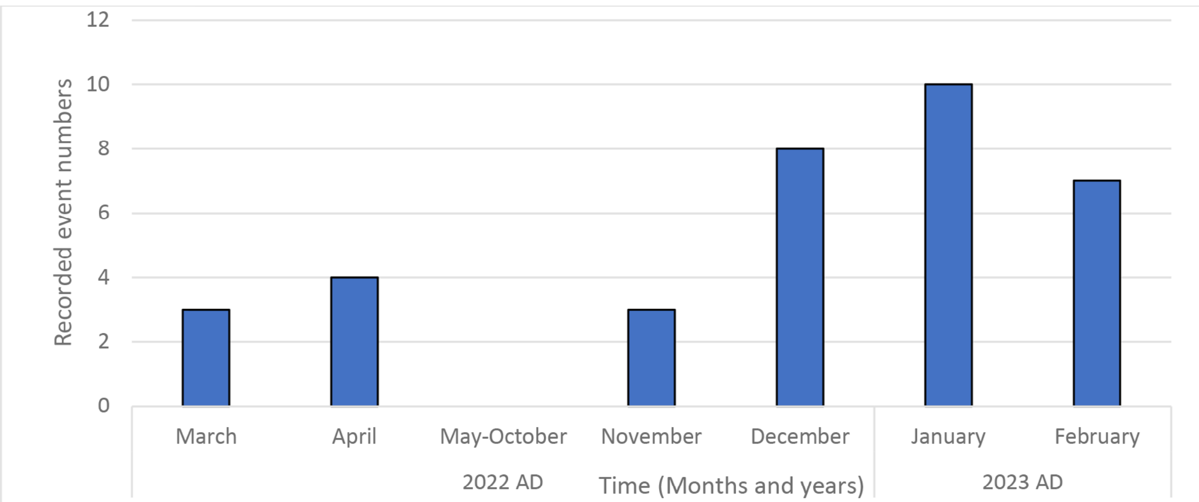

Figure 6: *Annual (March 2022-February 2023) record of snow leopards recorded in camera traps during study period*

per 100 km^2 in Manaslu Conservation Area (Shrestha 2021, Neupane 2024), and 2.21/100 km^2 in Shey Phoksundo National Park (DNPWC & DoFSC 2024). Chetri et al. (2019) has mentioned, however, that higher snow leopard densities can be biased from small sampling areas, and Jackson & Ahlborn (1989) have reported home range overlapping in snow leopards and that certain areas can be used by more than one snow leopard. Lapchi valley is not only a direct transit route to Qomolangma National Nature Reserve in the Tibetan plateau but also between Langtang and Sagarmatha national parks in Nepal, so the valley might be an important link among these habitats. In the future, it is necessary for large scale systematic monitoring of snow leopards to clarify snow leopard ranging and density not only in GCA, but also in collaboration with similar monitoring of snow leopard habitat in adjacent protected areas.

Local studies have reported that livestock comprises the majority of the snow leopard diet during summer in Nepal (Shrestha et al. 2018, Koju et al. 2023), and a recent study from Shey Phoksundo National Park has shown that livestock density may limit the abundance of snow leopards (Khanal et al. 2020). Snow leopards have been assumed to follow the winter and summer migratory movements of their primary prey species from high to low elevations and low to high elevations respectively (Snow Leopard Network 2014). The lower number of snow leopard images during the warm period (May to October) coincides with the movement of livestock to higher pastures and might support the seasonal movement of snow leopard out of Lapchi valley, but this too needs confirmation from a more extensive camera trap survey. For example, our highest camera trap was located at 4628 m asl, and perhaps in the future we need to sample more at this altitude and higher. Furthermore, the period from May to October was aligned with the seasonal migration of villagers' livestock to upper alpine pastures. During this time, many villagers relocate their livestock to grazing areas near or across the China border (Koju 2023), where the installation of camera traps is not feasible. This migration pattern likely contributes to the absence of snow leopard records during these months. It is suggested that while the Lapchi Valley provides some summer grazing grounds, they may not be sufficient to support all the livestock. This insufficiency prompts the need for cross-border grazing, which may also be a traditional practice and area for grazing.

The snow leopard's frequent presence, concentrated cold months activity (Koju et al. 2024), and their absence during May to October in Lapchi Valley, suggests the seasonal preferences for cold season as in Sagarmatha National Park (Lovari et al. 2013), and in Mongolia (Johansson et al. 2022). But the importance of the narrow Lapchi valley is that a minimum of six individuals using the habitat. The area around the Lapchi Monastery was used by all snow leopards that visited Lapchi Valley. Consequently, conserving the habitat in Lapchi Valley becomes vital for snow leopard conservation, as these animals may utilize territories extending across China's political boundary and Nepal. Additionally, this research findings suggest the need of a vigorous survey over large landscape and trans-boundary research initiatives for snow leopard conservation.

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