

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Short Communication

Population monitoring of snow leopards using camera trapping in Naryn State Nature Reserve, Kyrgyzstan, between 2016 and 2019

Julie Rode^{a,1}, Claire Lambert^{a,2}, Lucile Marescot^{a,b,3}, Bastien Chaix^a, Julie Beesau^a, Suzanne Bastian^{c,4}, Joldoshbek Kyrbashev^d, Anne-Lise Cabanat^{a,*,5}^a Objectif Sciences International NGO, OSI-Panthera Program, Geneva, Switzerland^b CIRAD, UMR CBGP, INRAE, Institut Agro, IRD, University of Montpellier, Montpellier, France^c INRAE, Oniris, BIOEPAR, 44300 Nantes, France^d Naryn State Nature Reserve, Kyrgyzstan

ARTICLE INFO

Keywords:

Snow leopard
Camera trapping
Citizen science
Kyrgyzstan

ABSTRACT

Four field seasons of snow leopard (*Panthera uncia*) camera trapping inside Naryn State Nature Reserve, Kyrgyzstan, performed thanks to citizen science expeditions, allowed detecting a minimal population of five adults, caught every year with an equilibrated sex ratio (1.5:1) and reproduction: five cubs or subadults have been identified from three litters of two different females. Crossings were observed one to three times a year, in front of most camera traps, and several times a month in front of one of them. Overlap of adults' minimal territories was observed in front of several camera traps, regardless of their sex. Significant snow leopard presence was detected in the buffer area and at Ulan area which is situated at the reserve border. To avoid poaching on this apex predator and its preys, extending the more stringent protection measures of the core zone to both the Southern buffer area and land adjacent to Ulan is recommended.

1. Introduction

Snow leopards are listed as Vulnerable (C1) by the IUCN (McCarthy et al., 2017) and their world population is estimated at 2710 to 3386 mature individuals fragmented over twelve countries in Central Asia (McCarthy et al., 2017). In Kyrgyzstan, the total population was estimated at around 350–400 individuals (National Academy of Sciences of Kyrgyzstan: unpublished data; McCarthy and Mallon, 2016). The Naryn State Nature Reserve located in Kyrgyzstan is known for the protection of several ungulates and predators, including snow leopards in the high altitude ranges. A preliminary census giving five snow leopards per 200 km² was performed in Naryn State Reserve (as mentioned in McCarthy and Mallon, 2016). McCarthy and Mallon (2016) recommended a precise estimation and a long-term monitoring of this population, which led to this study. In addition, the Snow Leopard Survival Strategy written by members of the Snow Leopard Network emphasizes the importance of providing accurate demographic trends (McCarthy and Chapron, 2003).

* Corresponding author.

E-mail address: direction@osi-panthera.org (A.-L. Cabanat).¹ ORCID: 0000-0001-6510-9953² ORCID: 0000-0001-6520-1362³ ORCID: 0000-0001-7625-5446⁴ ORCID: 0000-0003-4903-9742⁵ ORCID: 0000-0002-7735-2392<https://doi.org/10.1016/j.gecco.2021.e01850>

Received 27 April 2021; Received in revised form 26 September 2021; Accepted 27 September 2021

Available online 28 September 2021

2351-9894/© 2021 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license

<http://creativecommons.org/licenses/by-nc-nd/4.0/>.

As they are very elusive felids living in rocky and cliffy places (McCarthy and Mallon, 2016) and as their range is covering very steep and not easily accessible ground, one of the best non-invasive methods to monitor their population is through camera trapping. This method is indeed widely used for recording and studying felids in general (Duckworth et al., 2014; Sliwa et al., 2018) and snow leopards in particular (Alexander et al., 2016; Jackson et al., 2006; Sharma et al., 2014; Simms et al., 2011). Thanks to citizen science expeditions organized from 2016 to 2019, once to four times every summer setting up cameras that were left in place and retrieved after several months, we were able to collect observations over several years on the snow leopard population in this region. This project is still ongoing.

The goal of this short communication is to report preliminary results of population size, sex, distribution and reproduction inside Naryn State Nature Reserve. The detection and identification of individuals was based on a camera trap system deployed on a sample area of 61 km², that was expanded to 260 km² from 2017.

2. Material and methods

2.1. Study area

The study area (Fig. 1) is located inside the eastern part of Naryn State Nature Reserve created in 1983. The altitude inside the reserve varies between 2200 and 4500 m for a total area of 1056 km² (Farrington, 2005). Most of the study area is located in the core zone of the reserve while a small area, including K k- z n valley, is in the buffer zone. The North-Eastern part is bounded by the Naryn and Ulan rivers, while the ridges of the Naryn-Too mountain range occupy the Southern limit. To the West, the study area is bounded by the Chong-Taldy valley. Habitats are composed of spruce forests up to 3000 m on the Northern slopes, while the rest of the landscape is occupied by mountain pastures, rocky areas and glaciers (Farrington, 2005). No human activities are authorized except accredited scientific activities. Extensive pastoralism is allowed only in the buffer zone.

2.2. Camera trap on-field devices

Camera traps were set up and controlled during Objectif Sciences International NGO citizen science expeditions, under the supervision of scientists and reserve rangers. We used Bushnell Essential (E2 and E3) camera traps with infrared sensor and low glow LED flash equipped with SD cards of at least 16 gigabits and lithium batteries.

The camera traps were installed in permanent stations, within about five kilometers from one another (Sharma et al., 2014), in favorable places where we found snow leopard signs of presence, on narrow passes, along cliffs, facing large rocks, etc. (Jackson et al., 2006). Each camera trap was fixed to a rock with a strap at around fifty centimeters to one meter from the ground and at a minimum of two meters from the expected snow leopard crossing. When possible, the orientation was chosen with a horizontal angle of about 45  to the estimated snow leopard crossing location.

They were set on camera mode, with bursts of three pictures, a 0.3 s trigger between each picture and one second between each burst, and without time lapse or field scan.

They registered fauna on the spot, all year long, except if unintentional triggers saturated the SD card and exhausted batteries or if the camera was damaged by fauna. The camera traps were checked at least once every summer, sometimes more often.



Fig. 1. Map of the study area in and around Naryn State Nature Reserve; Numbers on the map are referring to localities insert in the right bottom corner.

The study area was of 61 km² in 2016 (3 camera traps), and was expanded to 260 km² in 2017 (10 camera traps). The estimation of the covered surface was limited at the exterior by ridge lines. We only counted the area of the watershed that is inside the camera trap dispositive. Camera trap locations and dates are available in [Table S1](#) in [supplementary materials](#).

2.3. Manual individual identification

A total of 1984 usable pictures were retrieved over the period of 4 years. As software identification is not efficient enough yet to properly differentiate individual snow leopards ([Miguel et al., 2019](#)), we performed a manual identification based on the unique patterns of their fur rosettes ([Alexander et al., 2016](#); [Jackson et al., 2006](#); [Macdonald and Loveridge, 2010](#); [McCarthy et al., 2008](#); [Sharma et al., 2014](#)). Three distinct readers made an independent examination of retrieved snow leopard pictures following the identification principles stated for bobcats ([Heilbrun et al., 2003](#)) and already used for snow leopards ([Jackson et al., 2006](#)).

The results of each reader's analysis were put in common to obtain final identifications. In case of disagreement on an individual identification, the picture was discarded. Data concerning each snow leopard, namely time, location of observation (camera trap number, position, GPS coordinates), sex and if accompanied, are compiled into a database. This allowed for a growing number of pictures of each individual over the years which in turn made possible a posteriori identification. Sex determination was made only when we could observe the presence or absence of genitals on pictures ([Alexander et al., 2015](#)) or in case of a mother with cubs, as they stay together during breeding ([Fox and Chundawat, 2016](#); [Novikov et al., 1962](#)).

We consider one "crossing" or "event" when a snow leopard, a couple or a mother and its litter, is pictured by a camera trap. We consider that two different events have occurred, when more than 15 min have passed between two pictures of a same individual or group.

R software ([R Core Team, 2017](#)) was used for extracting data from the database and performing statistics, visual representations and mapping using packages of the *tidyverse* suite ([Wickham, 2016](#)) and other ([Wickham et al., 2019](#)).

3. Results

Each year we captured snow leopards on all but one camera trap, namely Chong-Taldy. Among the 172 snow leopard crossings observed, we were able to precisely identify individuals on 156 crossings (91%). Identification wasn't possible when only fur appeared on the picture or when individuals were covered by snow. [Table 1](#) shows which snow leopards were captured each year. In 2019, a minimal number of individuals of five adults and three subadults were observed. All captured adults had been recaptured during previous years. Among them we identified three females and two males. [Fig. 2](#) displays the minimal number of adults, cubs (less than one year) and subadults (more than one year still with their mother) that have been captured between 2016 and 2019.

Two of the three identified females have been captured with cubs during the four years of study. The individual named Aika was observed in 2016 with a 1–1.5 years old subadult Meerim and from 2017 to 2019 with another litter of three cubs. The individual Ilgiz was observed with a subadult in May 2018.

Three individuals traveled extensively through the reserve, Aika (female, detected by five camera traps), Ayana (female, by six camera traps) and Nagima (male, by eight camera traps). Others were seen on a smaller portion of the study area. One individual, Ilgiz (female), was detected every year, only at Ulan Dūngürömö/Kara-Tör. Ilgiz's cub was also detected elsewhere and was likely following its mother. The frequency of crossings was very unbalanced across the different locations ([Table 2](#)).

Nagima, Aika and Ayana were crossing one to three times a year, at regular intervals, in front of each camera traps except in Umöt where crossings were registered every month, sometimes three times a month with an interval of around 10–20 days. All three of them were observed alone or with cubs in Aika's case.

4. Summary

This survey gives an insight into the snow leopard population census and dynamics by pluriennial left in place camera-traps inside Naryn State Reserve, which had never been extensively surveyed. Between 2016 and 2019, we observed five individually identified adults in our sample area of around 260 km². They were recaptured every year. Among the five adults, we identified three females and two males i.e. a sex ratio of (1.5:1) and witnessed reproduction events. More detailed analyses are needed to estimate the long-term stability of this population, along with an increase of the study area which was decided after 2019.

Pictures from camera traps in different locations showed several individuals, supporting the idea that adult snow leopards have overlapping territories, regardless of their sex ([Ahlborn and Jackson, 1988](#); [McCarthy et al., 2005](#)). Snow leopards are rarely observed

Table 1

Capture and recapture of each identified individual along the years of the study with sex if determined.

	Individual Sex	Aika Female	Ayana Female	Fatima /	Ilgiz Female	Malie Male	Merim /	Naguima Male	3 cubs Aika /	1 subadult Ilgiz /
Capture/Recapture	2016	x		x	x	x	x	x		
	2017		x		x	x		x	x	
	2018	x	x		x	x		x	x	x
	2019	x	x		x	x		x	x	

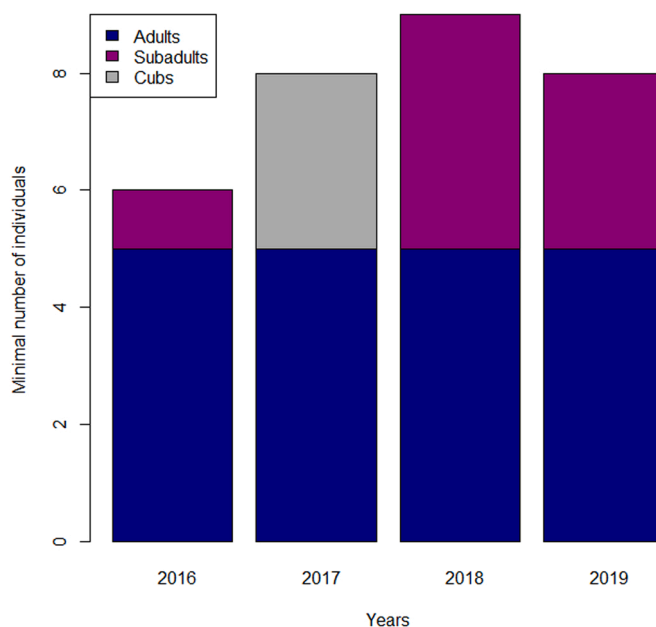


Fig. 2. Minimal number of captured snow leopards along the years of the study divided between adults (blue), subadults (purple) and cubs (gray). Aika was taken into account in 2017 even if not pictured as it was present before and after in our camera traps and pictured by Kaiberen Wildlife Research and Conservation Project of the Shinshu University and Naryn State Nature Reserve camera traps [unpublished data]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2

Number of crossings and unique individuals captured by each camera trap location.

Camera trap location	Number of snow leopard's crossings	Number of identified individuals
Kok-ozon – Ailuteur	5	4
Umeut	4	3
Akuluk 2	9	4
Umeut – ridgeline	95	5
Ulan Dungeureumeu/Kara-tor	21	5
Kok-ozon pass	6	2
Kashka suu glacier	3	2
Ak bai	6	2
Kashka suu West	23	4

with other adults, except when mating and mothers with cubs during the breeding period (Ahlborn and Jackson, 1988; Johansson et al., 2020; McCarthy et al., 2005). This is supported by the observations in this study.

Some individuals crossed in front of the same camera trap several times a year suggesting that they regularly visit the same places and use travel routes for hunting, controlling and going through their territories (McCarthy and Mallon, 2016). Some places are however more frequently used, like Umöt and Kashka-Suu West.

The Southwest of the study area extends into the buffer zone and shows four crossings by four individuals (Table 2), meaning that we also have snow leopards in the Southern buffer area. Ulan, situated at the edge of the reserve, also shows crossings from four individuals. This place is adjacent to a hunting concession. The Naryn State Nature Reserve was initially created to protect the spruce forest habitat and Tian Shan wapitis (*Cervus canadensis songaricus*) (Farrington, 2005). Snow leopard protection came after; hence borders are not adapted to protection goals for this species. Shepherds leading their flocks inside the buffer area as well as the hunting of ungulates at the borders of the reserve are depleting snow leopards' preys. It also provides more opportunities for poaching both snow leopards and their preys. To increase the species and its prey's protection we strongly weight in for the core zone extension to include at least the Southern buffer area and a large portion of the land adjacent to Ulan.

Finally, camera trapping combined with citizen science seems to be relevant to perform a long-term non-invasive monitoring at low cost. This kind of study relies on volunteers who can also participate in the collection of other valuable data: scat sampling, ungulate counting, etc. It is not dependent on external funding and thus can be sustainable. Furthermore, it contributes developing responsible tourism and environmental education in snow leopard range countries, which participates to conservation efforts.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments

We would like to acknowledge Naryn State Nature Reserve director Mirtemir Turdaliev, vice-director Joldoshbek Kyrbashev and rangers for supporting us during our studies in the reserve, Maksatbek Anarbaev from the Kaiberen Wildlife Research and Conservation Project of the Shinshu University and Naryn State Nature Reserve for sharing some of their camera trap data from 2016 to 2019, our local partners, all the OSI-Panthera expedition volunteers from Objectif Sciences International NGO and staff members of Objectif Sciences International NGO. We would also like to acknowledge Frédéric Salgues from Piège Photographique for providing us the camera traps at reduced prices, Rosina Karavia for spell checking and Koustubh Sharma for his helpful insights.

Funding

This research was completely funded by donations provided by OSI-Panthera participants to join field expeditions.

Code availability

The code used is available on GitHub: <https://github.com/ObjectifSciencesInternational/OSI-Panthera/tree/main/CameraTrapNaryn>.

Author's contributions

J.R., B.C., A.-L. C. designed the study. J.R., C.L., B.C., J.B., J.K. and A.-L. C. participated in the field camera trapping. J.R., C.L., B.C. replaced in 2019 by J.B. performed the manual identification of individuals. J.R, C.L., L.M. and A.-L. C. analyzed the data. J.R. and A.-L. C. wrote the manuscript. All authors revised the manuscript and approved the final version.

Ethics approval

An authorization to set camera traps was given by the head of Naryn State Nature Reserve and an authorization to mention some camera trap results from the Kaiberen Wildlife Research and Conservation Project of the Shinshu University and Naryn State Nature Reserve was given by Maksatbek Anarbaev. This study was none-invasive as field works relies on setting and retrieving camera traps.

Consent to participate

In the OSI participation conditions (<http://www.vacances-scientifiques.com/Conditions-de-Participation.html>), it is stated that data gathered by participants during these expeditions will be used for scientific purposes.

Consent for publication

All the authors consent to the publication of this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.gecco.2021.e01850](https://doi.org/10.1016/j.gecco.2021.e01850).

References

- Ahlborn, G.G., Jackson, R.M. 1988. Marking in free-ranging snow leopards in west Nepal: a preliminary assessment. In: Proceedings of the Fifth International Snow Leopard Symposium, pp. 25–49.
- Alexander, J.S., Gopalaswamy, A.M., Shi, K., Riordan, P., 2015. Face value: towards robust estimates of snow leopard densities. *PLoS One* 10 (8), 0134815. <https://doi.org/10.1371/journal.pone.0134815>.
- Alexander, J.S., Zhang, C., Shi, K., Riordan, P., 2016. A granular view of a snow leopard population using camera traps in Central China. *Biol. Conserv.* 197, 27–31. <https://doi.org/10.1016/j.biocon.2016.02.023>.

- Duckworth, J.W., Lynam, A., Breitenmoser-Würsten, C., 2014. Non-Panthera cat species in South-east Asia: present knowledge and recommendations, *Cat News*, Special Issue 8, pp. 62–67.
- Farrington, J.D. 2005. A Report on Protected Areas, Biodiversity, and Conservation in the Kyrgyzstan Tian Shan with Brief Notes on the Kyrgyzstan Pamir-Alai and the Tian Shan Mountains of Kazakhstan, Uzbekistan, and China, U.S. Fulbright Program, Environmental Studies Section, Bishkek, 270.
- Fox, J.L., Chundawat, R.S., 2016. Chapter 2 – what is a snow leopard? Behavior and ecology. In: McCarthy, Thomas, Mallon, D. (Eds.), *Snow Leopards*. Academic Press, pp. 13–21. <https://doi.org/10.1016/B978-0-12-802213-9.00002-X>.
- Heilbrun, R.D., Silvy, N.J., Tewes, M.E., Peterson, M.J., 2003. Using automatically triggered cameras to individually identify bobcats. *Wildl. Soc. Bull.* 31 (3), 748–755.
- Jackson, R.M., Roe, J.D., Wangchuk, R., Hunter, D.O., 2006. Estimating snow leopard population abundance using photography and capture–recapture techniques. *Wildl. Soc. Bull.* 34 (3), 772–781. [https://doi.org/10.2193/0091-7648\(2006\)34\[772:ESLPAUJ2.0.CO;2](https://doi.org/10.2193/0091-7648(2006)34[772:ESLPAUJ2.0.CO;2).
- Johansson, Ö., Samelius, G., Wikberg, E., Chapron, G., Mishra, C., Low, M., 2020. Identification errors in camera-trap studies result in systematic population overestimation. *Sci. Rep.* 10 (1), 6393. <https://doi.org/10.1038/s41598-020-63367-z>.
- Macdonald, D.W., Loveridge, A.J., 2010. *Biology and Conservation of Wild Felids*. Oxford University Press.
- McCarthy, T.M., Chapron, G. 2003. *Snow Leopard Survival Strategy*, International Snow Leopard Trust and Snow Leopard Network.
- McCarthy, K.P., Fuller, T.K., Ming, M., McCarthy, T.M., Waits, L., Jumabaev, K., 2008. Assessing Estimators of snow leopard abundance. *J. Wildl. Manag.* 72 (8), 1826–1833. <https://doi.org/10.2193/2008-040>.
- McCarthy, Thomas M., Fuller, T.K., Munkhtsog, B., 2005. Movements and activities of snow leopards in Southwestern Mongolia. *Biol. Conserv.* 124 (4), 527–537. <https://doi.org/10.1016/j.biocon.2005.03.003>.
- McCarthy, T., Mallon, D., Jackson, R., Zahler, P., McCarthy, K., 2017. *Panthera uncia*. The IUCN Red List of Threatened Species 2017: e.T22732A50664030. [Data set], International Union for Conservation of Nature. <https://doi.org/10.2305/IUCN.UK.2017-2.RLTS.T22732A50664030.en>.
- McCarthy, Thomas M., Mallon, D., 2016. *Biodiversity of the World: Snow Leopards*. Academic Press.
- Miguel, A.C., Bayrakçismith, R., Ferre, E., Bales-Heisterkamp, C., Beard, J., Dioso, M., Grob, D., Hartley, R., Nguyen, T., Weller, N., 2019. Identifying individual snow leopards from camera trap images. In: Mao, K., Jiang, X. (Eds.), *Tenth International Conference on Signal Processing Systems*. SPIE, p. 36. <https://doi.org/10.1117/12.2521856>.
- Novikov, G.A., Biron, A., Cole, Z.S., 1962. Carnivorous mammals of the fauna of the U.S.S.R., Israel program for scientific translations.
- R Core Team, 2017. R: a language and environment for statistical computing. (<https://www.R-project.org/>).
- Sharma, K., Bayrakçismith, R., Tumursukh, L., Johansson, O., Sevger, P., McCarthy, T., Mishra, C., 2014. Vigorous dynamics underlie a stable population of the Endangered Snow Leopard *Panthera uncia* in Tost Mountains, South Gobi, Mongolia. *PLoS One* 9 (7), 101319. <https://doi.org/10.1371/journal.pone.0101319>.
- Simms, A., Moheb, Z., Salahudin, Ali, H., Ali, I., Wood, T., 2011. Saving threatened species in Afghanistan: snow leopards in the Wakhan Corridor. *Int. J. Environ. Stud.* 68 (3), 299–312. <https://doi.org/10.1080/00207233.2011.577147>.
- Sliwa, A., Wilson, B., Lawrenz, A., Lamberski, N., Herrick, J., Küsters, M., 2018. Camera trap use in the study of black-footed cats (*Felis nigripes*). *Afr. J. Ecol.* 56 (4), 895–897. <https://doi.org/10.1111/aje.12564>.
- Wickham, H., 2016. *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag, New York. (<https://ggplot2.tidyverse.org>).
- Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L.D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T.L., Miller, E., Bache, S.M., Müller, K., Ooms, J., Robinson, D., Seidel, D.P., Spinu, V., Yutani, H., 2019. Welcome to the tidyverse. *J. Open Source Softw.* 4 (43), 1686. <https://doi.org/10.21105/joss.01686>.