Photographic evidence suggests habitat overlap and co-occurrence of tigers and snow leopards in Jigme Dorji National Park, Bhutan

Pema Dendup and Choki Lham

Abstract The Endangered tiger *Panthera tigris* and Vulnerable snow leopard *Panthera uncia* are umbrella species and conservation priorities. Jigme Dorji National Park is an important protected area for the conservation of both species because it serves as a source site for tigers to adjacent areas and has the largest snow leopard population in Bhutan. Habitat overlap of tigers and snow leopards in Bhutan has been previously reported based on evidence of tigers (pugmarks, livestock killed and camera-trap images) in known snow leopard habitat above 4,000 m altitude. Here we report the first photographic evidence of both tigers and snow leopards at the same locations, confirming habitat overlap and co-occurrence of the two species. The data are derived from the countrywide tiger survey carried out during October 2021–January 2022. Fifty-six pairs of camera traps were installed in a 5 × 5 km grid at an altitude range of 1,200–4,300 m. After a survey effort of 1,528 trap-nights, 478 tiger images and 31 snow leopard images were captured at 12 and three camera stations, respectively. At all three camera stations that captured snow leopard images, tigers were also captured. These findings indicate the habitat overlap and co-occurrence of tigers and snow leopards in Jigme Dorji National Park. Further research is required to inform conservation practice in the National Park focusing on these apex predators.

Keywords Bhutan, co-occurrence, habitat overlap, Jigme Dorji National Park, *Panthera tigris*, *Panthera uncia*, snow leopard, tiger

The tiger *Panthera tigris* is categorized as Endangered on the IUCN Red List (Goodrich et al., 2022) and the snow leopard *Panthera uncia* as Vulnerable (McCarthy et al., 2017). Poaching, prey depletion, habitat loss and fragmentation, human–wildlife conflict and climate change are threatening both species (Seidensticker, 2010; Mir, 2020; Rashid et al., 2021). The global tiger population is estimated to be 2,608–3,905 (Nowel & Jackson, 1996; Seidensticker et al., 1999; Goodrich et al., 2022) and that of the snow leopard is estimated to be 2,710–3,386 (McCarthy et al., 2017). Both species are umbrella species and play crucial roles in the functioning of the ecosystems they inhabit (Sunquist et al., 1999; Ripple et al., 2014).

Habitat overlap of tigers and snow leopards in Bhutan has been previously reported based on evidence of tigers (pugmarks, livestock killed and camera-trap images) in known snow leopard habitat above 4,000 m altitude (Thinley et al., 2015; Dendup et al., 2021a). However, there has been no evidence of the two species sharing the same area, despite the burgeoning use of camera-trap surveys.

The 4,374 km² Jigme Dorji National Park is the second-largest protected area in Bhutan (Fig. 1). The Park contains elevations ranging from 1,200 to > 7,000 m, and experiences four distinct seasons. The Park has five distinct vegetation types: subtropical, warm temperate, cool temperate, subarctic/cold temperate forest and rhododendron scrub (Dendup et al., 2021b). More than 5,000 people live in the Park, and they are permitted to harvest natural resources. However, to control indiscriminate resource collection the Park is delineated into four conservation management zones (Table 1), and people can only collect resources from the multiple-use zone (Dendup et al., 2021a).

The National Park has been identified as an important source site for tigers (Tempa et al., 2019; Dendup et al., 2023). During the countrywide tiger survey conducted in 2014–2015, six individual tigers were identified in the National Park (Department of Forests and Park Services, 2015), and the 2021–2022 tiger survey also identified six individuals (Dendup, 2022; Dendup et al., 2023). The 2014–2016 countrywide snow leopard survey identified 31 individuals in the National Park, the highest number in a protected area in the country, followed by Wangchuck Centennial National Park with 17 individuals (Thinley et al., 2016). Here we report the habitat overlap and co-occurrence of tigers and snow leopards from a countrywide camera-trap survey that focused on tigers.

During October 2021–January 2022, camera traps (HyperFire 2, Reconyx, Holmen, USA) were installed in a grid of 56 5 × 5 km cells at altitudes of 1,200–4,300 m. Within each grid cell one camera-trap station comprising two camera traps was placed on human or animal trails along ridges or valley bottoms or at water holes, to maximize the probability of capturing tigers and their prey.

Pema Dendup (Corresponding author, orcid.org/0000-0003-2734-2716, pemadndp@gmail.com) and Choki Lham (orcid.org/0000-0002-8979-0883) Jigme Dorji National Park, Gasa, Bhutan

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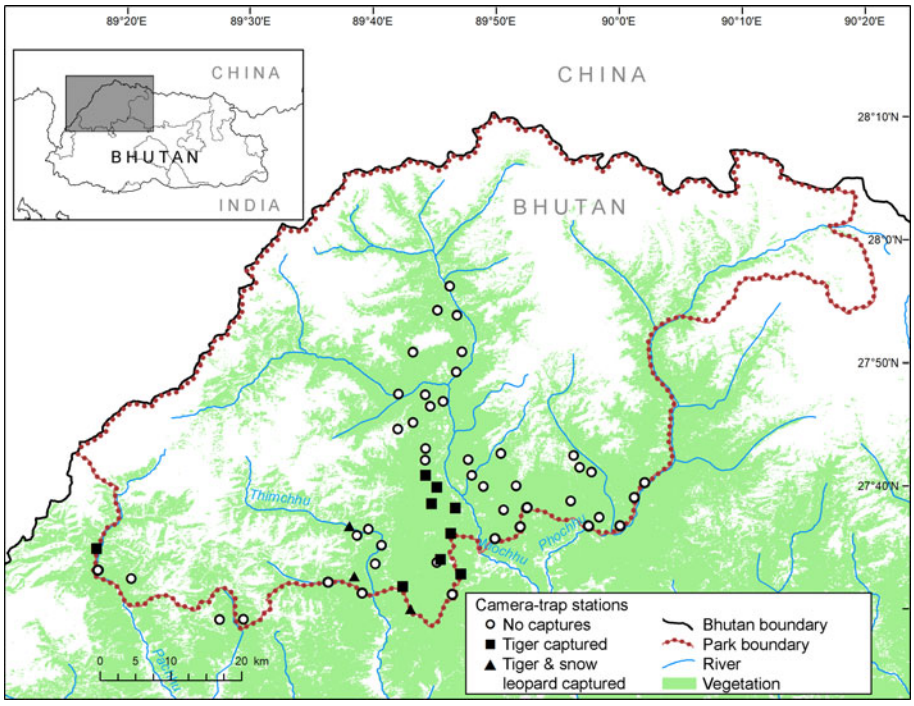

FIG. 1 Jigme Dorji National Park, Bhutan, indicating locations of the 56 camera-trap locations including those where only tigers *Panthera tigris* were photographed and those where both tigers and snow leopards *Panthera uncia* were photographed.

TABLE 1 The conservation management zones of Jigme Dorji National Park, Bhutan (Fig. 1).

Zone	Area (km^2)	Area (%)
Core	1,229	28
Transition	1,781	41
Multiple-use	853	19
Buffer	511	12

The two camera traps were separated by at least 2 m, to avoid image distortion from each camera's flash. Cameras were mounted to a tree or a wooden pole 30–45 cm above the ground and 2.0–2.5 m away from trails, to enable images to capture tigers and other animals in full frame.

A total of 478 and 31 independent images of tigers and snow leopards, respectively, were captured over a total of 1,528 trap-nights (independent images of the same species are those captured > 30 minutes apart). Based on the unique stripe patterns of tigers and the unique spots and rosettes of snow leopards, six tiger individuals were identified in 21.4% (12 out of 56) of the camera-trap stations and two snow leopard individuals were identified in 5.4% (3 out of 56) of the camera-trap stations. All three stations that captured snow leopards also captured tigers, but with temporal differences in the capture events (Plate 1, Table 2). These three camera-trap stations were at 3,615–4,010 m altitude, in mixed conifer forest and alpine meadow, one in the core zone and two in the multiple-use zone.

During 1990–2010, forest cover in Bhutan increased by 1,147 km², a mean annual increase of 59 km², and there has also been an overall reduction in grassland, shrubland and barren areas. These changes have been attributed to the establishment of plantations, and changing climatic conditions (Gilani et al., 2014). The upward movement of forests as a result of climate change could have increased the habitat for tigers and reduced snow leopard habitat, as has been reported previously for the common leopard *Panthera pardus* (Lovari et al., 2013). The habitat in which the tigers and snow leopards co-occur should be conserved both for their welfare and for that of other species, as the conservation of umbrella species is beneficial to other species within the same ecosystem (Alexander et al., 2016).

Photographic evidence of these two apex predators at the same camera traps in three separate locations is testimony of the effectiveness of conservation measures that have been implemented in the National Park. However, two of the three locations are in the multiple-use zone and therefore management is required to prevent habitat degradation in this zone or to explore the feasibility of incorporating the area into the transition zone, where traditional, sustainable use of natural resources is permitted only for a certain period (Jigme Dorji National Park, 2021). Our findings corroborate previous reports of the occurrence of tigers in presumed snow leopard habitat in Bhutan, and confirm habitat overlap and co-occurrence of the two species. These insights will be of value to researchers planning further work on these species.

Plate 1 Images of tigers *Panthera tigris* and snow leopards *Panthera uncia* captured at the same camera-trap locations in Jigme Dorji National Park, Bhutan (Fig. 1), at (a) 4,010 m; (b) 3,885 m; and (c) 3,615 m altitude (Table 2).

Table 2 Temporal differences in the occurrence of snow leopards *Panthera uncia* and tigers *Panthera tigris* photographed at three camera traps in Jigme Dorji National Park. For location IDs, see Plate 1.

Location ID	Species	Date	Time
(a)	Snow leopard	11 Dec. 2021	4.51.32
	Tiger	07 Nov. 2021	19.59.21
(b)	Snow leopard	29 Nov. 2021	4.40.17
	Tiger	04 Dec. 2021	8.35.10
(c)	Snow leopard	05 Dec. 2021	22.39.59
	Tiger	07 Dec. 2021	21.34.54

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Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards.

References

Alexander, J.S., Cusack, J.J., Chen, P., Shi, K. & Riordan, P. (2016) Conservation of snow leopards: spill-over benefits for other carnivores? *Oryx*, 50, 239–243.

Dendup, P. (2022) *Ecology of Tigers in Jigme Dorji National Park. A result of camera trap survey: beyond numbers*. Jigme Dorji National Park, Department of Forests and Park Services, Gasa, Bhutan.

Dendup, P., Dorji, R., Jamtsho, Y., Wangchuk, W., Tshering, B. & Dorji, R. (2021a) *Conservation Management Plan of Jigme Dorji National Park for the period July 2021–June 2031 (Biodiversity Conservation in Pursuit of Gross National Happiness)*. Department of Forests and Park Services, Ministry of Agriculture and Forests, Gasa, Bhutan.

Dendup, P., Lham, C., Wangchuk, W. & Jamtsho, Y. (2023) Tiger abundance and ecology in Jigme Dorji National Park, Bhutan. *Global Ecology and Conservation*, 42, e02378.

Dendup, P., Wangdi, L., Jamtsho, Y., Kuenzang, P., Gyeltshen, D., Tashi, T. et al. (2021b) Bird diversity and conservation threats in Jigme Dorji National Park, Bhutan. *Global Ecology and Conservation*, 30, e01771.

Department of Forests and Park Services (2015) *Counting the Tigers in Bhutan: Report on the National Tiger Survey of Bhutan*

2014–2015. Department of Forests and Park Services, Ministry of Agriculture and Forests, Thimphu, Bhutan.

Gilani, H., Shrestha, H.L., Murthy, M.S.R., Phuntsho, P., Pradhan, S., Bajracharya, B. et al. (2014) Decadal land cover change dynamics in Bhutan. *Journal of Environmental Management*, 148, 91–100.

Goodrich, J., Wibisono, H., Miquelle, D., Lynam, A.J., Sanderson, E., Chapman, S. et al. (2022) *Panthera tigris*. In *The IUCN Red List of Threatened Species* 2022. dx.doi.org/10.2305/IUCN.UK.2022-1.RLTS.T15955A214862019.en.

Jigme Dorji National Park (2021) *Management zones of Jigme Dorji National Park*. Department of Forests and Park Services, Ministry of Agriculture and Forests. Damji, Gasa, Bhutan.

Lovari, S., Minder, I., Ferretti, F., Mucci, N., Randi, E. & Pellizzi, B. (2013) Common and snow leopards share prey, but not habitats: competition avoidance by large predators? *Journal of Zoology*, 291, 127–135.

McCarthy, T., Mallon, D., Jackson, R., Zahler, P. & McCarthy, K. (2017) *Panthera uncia*. In *The IUCN Red List of Threatened Species* 2017. dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T22732A50664030.en.

Mir, S. (2020) Killer of over 100 ibex arrested in Gilgit-Baltistan. *The Express Tribune*, 4 June 2020. tribune.com.pk/story/2235465/killer-100ibex-arrested-gilgit-baltistan [accessed 27 August 2022].

Nowell, K. & Jackson, P. (1996) *Wild Cats. Status Survey and Conservation Action Plan*. IUCN/Species Survival Commission Cat Specialist Group, Gland, Switzerland, and Cambridge, UK. portals.iucn.org/library/node/6998 [accessed May 2023].

Rashid, W., Shi, J., Dong, S. & Sultan, H. (2021) Issues and opportunities associated with trophy hunting and tourism in Khunjerab National Park, northern Pakistan. *Animals*, 10, 597.

Ripple, W.J., Estes, J.A., Beschta, R.L., Wilmers, C.C., Ritchie, E.G. & Hebblewhite, M. (2014) Status and ecological effects of the world's largest carnivores. *Science*, 343, 6167.

Seidensticker, J. (2010) Saving wild tigers: a case study in biodiversity loss and challenges to be met for recovery beyond 2010. *Integrative Zoology*, 5, 285–299.

Seidensticker J., Christie S. & Jackson, P. (1999) Preface. In *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes* (eds J. Seidensticker, S. Christie & P. Jackson), pp. xv–xvii. Cambridge University Press, Cambridge, UK.

Sunquist, M.E., Karanth, K.U. & Sunquist, F. (1999) Ecology, behaviour and resilience of the tiger and its conservation needs. In *Riding the Tiger: Tiger Conservation in Human- Dominated Landscapes* (eds J. Seidensticker, S. Christie & P. Jackson), pp. 5–18. Cambridge University Press, Cambridge, UK.

Tempa, T., Hebblewhite, M., Goldberg, J.F., Norbu, N., Wangchuk, T.R., Xiao, W. et al. (2019) The spatial distribution and population density of tigers in mountainous terrain of Bhutan. *Biological Conservation*, 238, 108192.

Thinley, P., Lham, D., Wangchuk, S. & Wangchuk, N. (2016) *National Snow Leopard Survey of Bhutan 2014–2016 (Phase I): Sign and Prey Base Survey*. Department of Forests and Park Services, Ministry of Agriculture and Forests, Thimphu, Bhutan. wwfasia.awsassets.panda.org/downloads/sl_phase_1_for_web_upload_compressed.pdf [accessed May 2023].

Thinley, P., Lhendup, T. & Dorji, R. (2015) *Conservation Management Plan of Jigme Dorji National Park for the Period January 2015–December 2019: Protecting the Legacy of the Visionary Monarch's for the Happiness of the Citizens*. Department of Forests and Park Services, Thimphu, Bhutan.