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Tigers in the Himalayan foothills: Possible linkage between two tiger population clusters in Terai Arc Landscape, Nepal

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Abstract

Conserving tigers (*Panthera tigris*) in highly fragmented landscapes is a daunting task. Terai Arc Landscape (TAL) at the base of the Himalayas aims to connect the remaining Tiger habitats in southern Nepal and northwestern India. Tiger population clusters in central (Chitwan-Parsa) and western (Bardia-Banke) Nepal are distinct with limited connectivity in recent past. We present the photographic evidence of Bengal tiger (*P. tigris tigris*) from forest patch between these population clusters for the first time. The photographs were obtained during camera trap survey across Chure region of Nepal in 2018. Two adult tigers–a female and a male—were photographed ~40 km apart. This record indicates the possibility that tiger habitat extends outside the protected areas in Nepal and natural linkages between Chitwan-Parsa and Bardia-Banke tiger population clusters through forest corridors along the Chure region. Conservation efforts should also focus on the forests outside protected areas especially the critical biological corridors to conserve tigers in TAL via a meta-population approach.

Key words: Camera traps, Chure region, habitat connectivity, meta-population, Terai Arc landscape, tigers

Introduction

The tiger (*Panthera tigris* Linnaeus), is one of the most admired and globally threatened wildlife species (Endangered in IUCN redlist; Goodrich et al., 2015). It typifies the global challenges that large mammals are facing, with increasing human exploitation of natural areas (Karanth and Chellam, 2009). Once widespread across large parts of Asia and eastern Europe, tigers are now confined to <7% of the historic range, persisting in small and isolated populations across 13 Asian countries (Dinerstein et al., 2007). Remaining tiger habitats are highly fragmented, with little chance of connectivity between different sub-populations (Joshi et al., 2016). Global decline in tiger populations and loss of habitats have received a broader attention in recent decades. In a global tiger summit held in 2010 (GTI, 2011), the 13 tiger range countries formulated an ambitious plan for doubling the wild tiger population by the year 2022. As a result of these conservation efforts, the population has increased in some countries (e.g., India, Nepal, Bhutan, Thailand) but is still decreasing in Malaysia and Indonesia and possibly extirpated from Cambodia and Vietnam (Goodrich et al., 2015). Nepal has nearly achieved its target (250 tigers by 2022), with the national population estimated at 235 adults based on the survey in 2018 (DNPWC and DFSC, 2018).

Landscape-based conservation has been identified as a strategy for the recovery of tiger population and enhancing the connectivity (Dinerstein et al., 2007; Wikramanayake et al., 2011). Terai Arc Landscape (TAL) covering an area of 51,000 km^2 in North-western India and South-western Nepal is one of the priority tiger conservation landscapes holding nearly 20% of the global tiger population (Goodrich et al., 2015; DNPWC and DFSC, 2018; Jhala et al., 2019). In Nepal, most of the tigers are confined within the Protected Areas and its adjoining forests of the TAL, located at the South-western part of Nepal which includes the Terai (floodplain of Ganga River) and Chure (Himalayan foothills) region. Tigers in Nepal are distributed in three distinct clusters or source populations i.e., Chitwan-Parsa, Banke-Bardia and Shuklaphanta (Walston et al., 2010; DNPWC and DFSC, 2018; Thapa et al., 2019). The TAL envisions to enhance the ecological connectivity between these population clusters in the protected areas through the forest corridors (Wikramanayake et al., 2004; MFSC, 2015). The evidence of tiger occurrence within the identified forest corridors (Laljhadi, Khata, Karnali, Barandabhar, and Basanta) indicates the healthy ecological functioning of the TAL (Wegge et al., 2016). However, Gurung et al. (2006) and National Tiger Surveys of Nepal (2009; 2013; 2018) repeatedly failed to detect tiger signs in large parts of the forests between Chitwan-Parsa and Banke-Bardia, two population clusters in TAL (Karki et al., 2009; Dhakal et al., 2014; DNPWC and DFSC, 2018). These two populations are known to be distinct with very low genetic mixing (Thapa et al., 2019). In this paper, we present photographic evidence of tigers in the forest patches between the Chitwan and Banke National Parks obtained during a biodiversity assessment carried out in the Chure region of Nepal, indicating the possible natural connectivity of these two tiger population clusters.

Study Area

The study was conducted in the Chure region between Chitwan and Banke National Parks (ca. 3,000 km^2) in South-western Nepal. Forests of the Chitwan and Banke National Parks in Nepal are connected by some large forest patches, two bottleneck sites (Lamahi and Dovan), and a biological corridor (Kamdi) (Wikramanayake et al., 1998; Thapa et al., 2018; Kandel et al., 2020). The Chure region extends East-West throughout Nepal parallel to the Himalayan Mountains and characterized by distinct geographical and biophysical characteristics with an elevational range from ~100 to 2,000 m (Pokhrel, 2015). At present, a large part (>70%) of the Chure region is covered with forests, however, deforestation rate (0.18% per annum) is relatively high compared to other regions of Nepal (FRA/DFRS, 2014). The region experiences a monsoon-dominated sub-tropical climate characterized by hot sub-humid summers, intense monsoon rains, and cold dry winters (FAO, 2019). Because of topographic complexity and climatic variability, significant ecological diversity is found within a small area (MFSC, 2014). Various endangered and flagship species including tigers, leopards (*P. pardus* Linnaeus), dholes (*Cuon alpinus* Pallas), Asian elephants (*Elephas maximus* Linnaeus), greater one-horned rhinos (*Rhinoceros unicornis* Linnaeus), gaurs (*Bos gaurus* Smith), and pangolins (*Manis pentadactyla* Linnaeus and *M. crassicaudata* É. Geoffroy) have been recorded from this region (Subedi et al., 2020). This region, considered vulnerable to natural disasters (i.e., landslides, erosion and flood), is also facing anthropogenic interventions such as encroachment for settlement, forest clearance for cultivation, illegal logging, grazing, roads and other infrastructure development, which have further aggravated the vulnerability of this fragile landscape (RCCP, 2020).

There is natural connectivity of forests between Chitwan and Banke National Parks in Nepal through some large forest patches, two narrow bottlenecks (Lamahi and Dovan), and a biological corridor (Kamdi) (Wikramanayake et al., 1998; Thapa et al., 2018; Kandel et al., 2020). Connectivity is weakest at the Dovan bottleneck, which lies in Rupandehi and Palpa districts near Butwal city, the capital of Province No. 5. A North-South highway between Butwal and Palpa bisects the bottleneck. The Lamahi bottleneck in the west (connecting to Banke) is another critical area where forest restoration in recent decades has enhanced the connectivity of wildlife corridor. Forest connectivity also exists in the western TAL through India (Sohelwa Wildlife Sanctuary) and the Kamdi forest corridor (Kandel et al., 2020).

Material and Methods

The study was part of a project to assess faunal diversity in the Chure region. The survey was conducted between August and October 2018. Sixty-three systematic grid cells of 10 X 10 km^2 were overlaid across the survey area. Each grid was further sub-divided into 16 sub-grids (total 1,008) of 2.5 X 2.5 km^2. Of the 1,008 sub-grids, 362 were excluded from survey as they lack wildlife habitat (cultivated land, settlements or built-up areas). The remaining 682 grids were surveyed for wildlife signs (for occupancy analysis) using 2 km walking transects within each grid. For the survey, we mobilized eight teams of 4–6 members each. Camera traps were set in 283 grid cells with high probability of wildlife detection based on the sign surveys. The survey grids, locations where tiger/leopard were recorded, and camera locations are shown in Fig. 1 (prepared in ArcGIS 10.4 (ESRI, 2016)).

A single camera trap was set within each selected grid. Its location was based on wildlife signs such as tracks, droppings, territorial marks, feeding signs along the forest roads, animal trails, hill passes, river banks etc. Digital motion sensor 'Cuddeback' camera traps (Cuddeback IR) with infrared flash for night were set at height 40–60 cm above the ground to capture mammalian species available in the area (Bowkett et al., 2008; Wang and Macdonald, 2009).

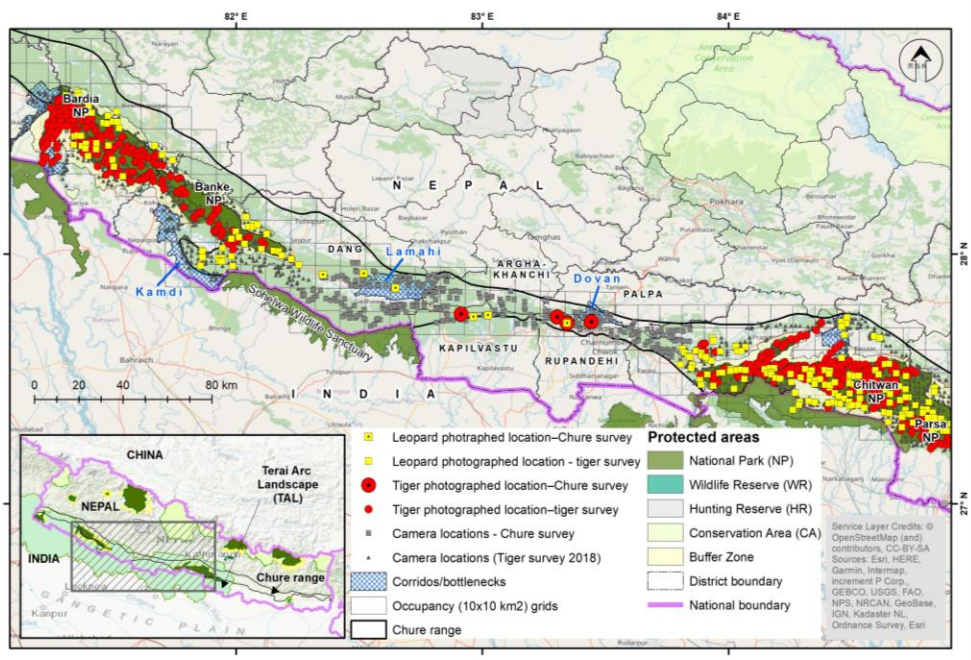

Figure 1: Study area showing camera trap locations and locations where Tigers and Leopards were photographed during the National Tiger Survey and this study, 2018 (base layer source: Open Street Maps, and WCPA).

The camera traps were programmed to record both photos (three pictures per trigger) and videos (10–15 sec at nighttime only). The cameras were operational 24 hours for 10 days in each location to record the presence/absence of wildlife species. The cameras were checked twice per week to ensure that the camera was functioning and had sufficient memory to record wildlife. After 10 days, the camera traps were removed, and pictures were downloaded systematically in folders. Wildlife species in the photographs were separated into folders by species. We estimated standard detection rate as abundance index for each species based on the independent detection in camera traps. Images of a species from a location taken within one hour were considered as an independent detection for the species. Standardized capture rate (number of detections per 100 camera trap nights) for each block (East, Central, West and Far-West) was calculated using the following formula.

$$\text{Detection Rate} = \frac{\text{No. of independent detection of X}}{\text{Total camera trap survey effort (or trap days)}} \times 100$$

Results

Camera traps were installed at 283 locations resulting in a survey effort of 2,850 camera trap days. A total of 32 mammalian species were photographed in camera traps. Two individual tigers (a male and a female) were photographed at four locations (Table 1). The female was photographed at three locations in Rupandehi and Palpa districts 15 km west of the Dovan bottleneck, whereas the male was photographed at a single location in Kapilvastu district. Tigers were photographed at elevations ranging from 444 to 542 m. We also recorded leopards at six different locations between Dovan and Banke National Parks (Fig. 1). Leopard cats (*Prionailurus bengalensis*, Kerr), jungle cats (*Felis chaus*, Schreber), crab-eating mongooses (*Herpestes urva*, Hodgson) and striped hyenas (*Hyaena hyaena*, Linnaeus) were also recorded at the camera trap stations. Prey species such as barking deer (*Muntiacus vaginalis*, Boddaert), wild boar (*Sus scrofa*, Linnaeus), Rhesus monkey (*Macaca mulatta*, Zimmermann) and Indian crested porcupine (*Hystrix indica*, Kerr) were also photographed at the same locations where tigers were recorded (Table 2).

Discussion

Our record of tigers in forest patches of Kapilvastu, Palpa and Rupandehi districts – nearly midway between two tiger population clusters (i.e., Chitwan-Parsa and Banke-Bardia) in TAL, is the first conclusive evidence of tiger dispersal in this area since the systematic survey started a decade ago. Two tiger individuals – a male and a female – were photographed ~40 km apart in the inter-connected forest patches. Tigers can be identified individually based on the stripe pattern in their body coat (Karanth and Nicholas, 1998; Lamichhane et al., 2017). We compared the tigers we recorded with our tiger photo library from Chitwan, Parsa, Banke and Bardia (DNPWC and DFSC, 2018) but failed to match them with any previously recorded individual. Thus, we could not confirm the origin of the tigers we recorded. However, nine months before our record, a female tiger was reported attacking humans at forest fringe ~25 km east in Tilottama Municipality (Pers. Comm. Dip Prasad Chaudhary, NTNC-BCC, 2020). The female we recorded could be the same individual, as these locations are connected by forest and no tiger-human conflict incidents have been reported subsequently in Tilottama area.

Table 1: Details of the Tiger photographed locations in Chure region of Kapilvastu, Palpa and Rupandehi districts during a camera trapping survey in 2018.

Parameters	Female Tiger recorded locations			Male Tiger recorded location
Grid ID	1093	1132	1136	1078
District	Rupandehi	Rupandehi	Palpa	Kapilvastu
Elevation	542	444	520	521
Date	2018-10-30	2018-10-29	2018-10-14	2018-11-01
Time	05:35	07:47	17:50	11:02
Number of detection (photo frames)	1 (5)	1 (5)	1 (1)	1 (3)
Prey species photographed	Barking deer, Wild boar, Rhesus Monkey	Barking deer, wild boar, Indian Crested Porcupine, Rhesus Monkey	Barking deer, Wild boar	Barking deer
Other carnivores photographed	Leopard cat, Large Indian civet	Common Leopard; Leopard Cat, Crab-eating mongoose	Leopard cat; Jungle cat	
Habitat type	Mixed forest	Mixed forest	Mixed forest	Riverine forest
Major plan species	Sal (*Sorea robusta*), Saanjh (*Terminalia tomentosa*), Bot dhairo (*Lagerstroemia parviflora*), Bhalayo (*Semecarpus anacardium*)	Sal, Saanjh, Bot dhairo, Bhalayo	Sal, Amala (*Phyllanthus emblica*), Botdhairo	Sal
Human disturbance (No. of detections)	8	12	74	2
Livestock presence	No	No	Yes	No

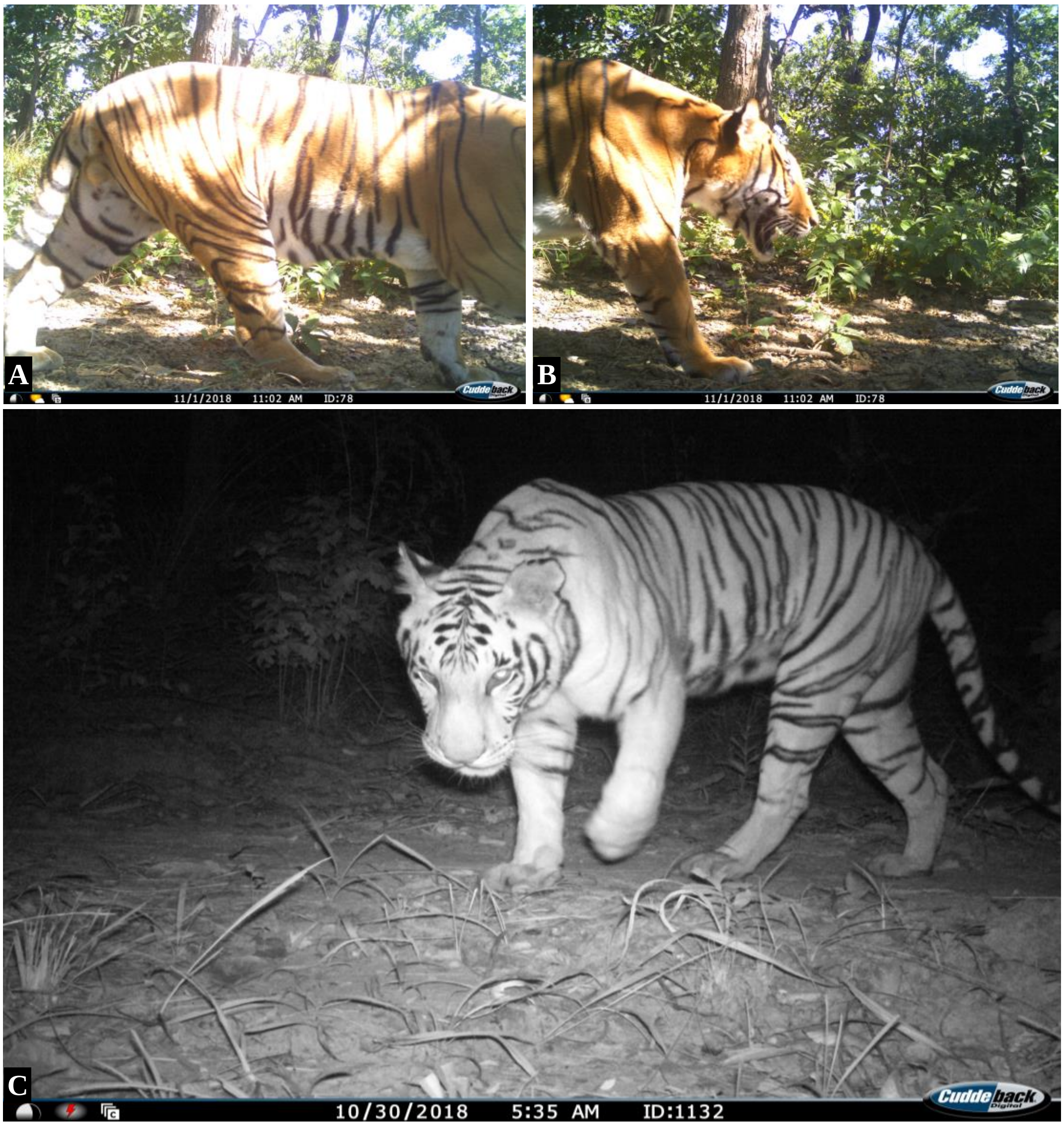

Figure 2: Bengal Tiger (a male (a, and b) and a female (c)) photographed in camera trap during this study. The male tiger was photographed in Kapilvastu and the female was detected in Rupandehi and Palpa.

Based on the available information and camera-trap locations, we assume that the female tiger we recorded dispersed from Chitwan's western part through the contiguous forest patches in Churia hills. Our female tiger record (October 2018) was located ~45 km and ~110 km from the nearest locations in Chitwan and Banke, respectively, documented during the national survey (January 2018). Similarly, we could not trace the origin of the male tiger but it was photographed closer to Banke (~70 km) than to Chitwan (~95 km). It is not unusual for tigers to cover such distances if they are not inhibited while dispersing (Joshi et al., 2013). Tigers are known to disperse long distances especially when leaving their natal territory (Smith, 1993). A study in Chitwan showed dispersing female tigers travelled up to 43.2 km (average 9.7 km, n=4) and males up to 71 km (average 33 km, n=10) from their natal territory (Smith, 1993). Although both male and female tigers were recorded in our study, it is unclear whether they encountered each other or succeeded in breeding.

Smith (1993) reported that none of the dispersing tigers went outside of the Chitwan National Park during his study in 1970s and 1980s. Tiger density and abundance (< 30 adults) was lower during that period. But recently, tiger density has either remained stable or increasing in the national parks (DNPWC and DFSC, 2018; Lamichhane et al., 2019). This might be responsible for the dispersal of tigers outside the parks, as competition for territory among tigers is intense inside the core areas of the park (Lamichhane et al., 2019). Moreover, large parts of the forests outside the protected areas are handed over to local communities as community forests. Enhanced protection and forest restoration in these community-managed forests is also providing additional habitat for wildlife and facilitating their safe dispersal.

These records indicate that the theoretical concept of TAL formulated in the late 1990s (Wikramanayake et al., 1998; Wikramanayake et al., 2004) is now being realized. The concept of TAL was based on a tiger dispersal model envisioning that tiger population clusters in protected areas could be connected by restoring natural habitats and biological corridors. The TAL program implementation in Nepal was started in 2001 (MFSC, 2015). The aerial distance between the tiger population cluster of Chitwan-Parsa and Banke-Bardia is ~170 km. Despite the gradual increase of tiger population in all three distinct tiger population clusters within TAL of Nepal, dispersal between these clusters had not previously been documented. Our record of male and female tigers nearly midway between these two population clusters indicate the possibility of functional linkage between them. A study on gene flow of tigers in Nepal Terai also indicated the exchange of few individuals between these population clusters (Thapa et al., 2019). It is possible for a tiger to move across these two clusters but scarcity of prey and risk of poaching and poisoning threatens their survival outside of the protected areas. Most of the fertile Terai plains are converted into agriculture and settlements, which probably limits the tiger dispersal. However, a large part of the Chure hills is forested, allowing the movement of tigers and other wildlife. Chitwan-Parsa cluster (including the contiguous Valmiki Tiger Reserve in India) is the easternmost population cluster of the TAL. Its connectivity with Banke-Bardia population in the center of the TAL has a greater significance for overall meta-population management of tigers in TAL.

Conclusion

Our record of tigers between two major tiger population clusters of TAL Nepal indicates the possibility they are naturally linked. As a result of conservation efforts to double the wild tiger population in Nepal, tiger density inside the protected areas is increasing, increasing the competition among tigers recruited into the population. Thus, their dispersal into the forests outside protected areas is expected. There is a need to understand the behavior and impacts of dispersing tigers, especially in the corridors and forests outside the protected areas. Tiger conservation efforts should also focus on the forests outside protected areas, especially the corridors and bottlenecks.

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Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

References

Bowkett, A. E., Rovero, F. and Marshall, A. R. (2008). The use of camera-trap data to model habitat use by antelope species in the Udzungwa Mountain forests, Tanzania. *African Journal of Ecology*, 46 (4): 479–487.

DNPWC and DFSC. (2018). *Status of tigers and prey in Nepal*. Department of National Parks and Wildlife Conservation and Department of Forests and Soil Conservation. Ministry of Forests and Environment, Kathmandu, Nepal.

Dhakal, M., Karki, M., Jnawali, S. R., Subedi, N., Pradhan, N. M. B., Malla, S., Lamichhane, B. R., Pokheral, C. P., Thapa. G. J., Oglethorpe. J., Subba, S. A., Bajracharya, P. R. and Yadav, H. (2014). *Status of tigers and prey in Nepal*. Department of National Park and Wildlife Conservation, Kathmandu. 74 pp.

Dinerstein, E., Loucks, C., Wikramanayake, E., Ginsberg, J., Sanderson, E., Seidensticker, J. and Leimgruber, P. (2007). The fate of wild tigers. *BioScience*, 57 (6): 508–514. https://doi.org/10.1641/B570608

FRA/DFRS. (2014). *Churia Forests of Nepal*. Kathmandu: Forest Resources Assessment/Department of Forest Research and Survey. 236 pp.

Goodrich, J., Lynam, A., Miquelle, D., Wibisono, H., Kawanishi, K., Pattanavibool, A. and Karanth, U. (2015). *Panthera tigris*. *The IUCN Red List of Threatened Species* 2015: eT!5955A50659951. Accessed on November 04, 2019 from http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T15955A50659951.en

GTI (2011). *Global Tiger Recovery Program*. Global Tiger Initiative Secretariat, The World Bank, Washington DC, USA.

Gurung, B., Smith, J. L. D. and Shrestha, M. (2006). Using a ''Bagh Heralu''network to map the metapopulation structure of tigers in Nepal, *In*: McNeely, J. A., McCarthy, T. M., Smith, A., Olsvig-Whittaker, L. and Wikramanayake, E. D. (Eds.), *Conservation biology in Asia*. Society for Conservation Biology Asia Section and Resources Himalaya, Kathmandu. pp. 214–231.

Jhala, Y. V., Qureshi, Q. and Nayak, A. K. (2019). *Status of Tigers, Co-Predators and Prey in India 2018: Summary Report*. National Tiger Conservation Authority, New Delhi and Wildlife Institute of India, Dehradun. 650 pp.

Joshi, A. R., Dinerstein, E., Wikramanayake, E., Anderson, M. L., Olson, D., Jones, B. S. and Davis, C. L. (2016). Tracking changes and preventing loss in critical tiger habitat. *Science advances*, 2 (4): e1501675. https://doi.org/10.1126/sciadv.1501675

Joshi, A., Vaidyanathan, S., Mondol, S., Edgaonkar, A. and Ramakrishnan, U. (2013). Connectivity of tiger (*Panthera tigris*) populations in the human-influenced forest mosaic of central India. *PloS One*, 8 (11): e77980.

https://doi.org/10.1371/journal.pone.0077980

Kandel, S. R., Lamichhane, B. R. and Subedi, N. (2020). Leopard (*Panthera pardus*) density and diet in a forest corridor of Terai: implications for conservation and conflict management. *Wildlife Research*, 47: 460–467. https://doi.org/10.1071/WR19126

Karanth, K. U. and Chellam, R. (2009). Carnivore conservation at the crossroads. *Oryx*, 43 (1): 1–2. https://doi.org/10.1017/S003060530843106X

Karanth, K. U. and Nichols, J. D. (1998). Estimation of tiger densities in India using photographic captures and recaptures. *Ecology*, 79 (8): 2852–2862. https://doi.org/10.1890/0012-9658(1998)079[2852:EOTDII]2.0.CO;2

Karki, J. B., Jnawali, S. R., Shrestha, R., Pandey, M. B., Gurung, G. and Thapa Karki, M. (2009). *Tigers and their prey base abundance in Terai Arc landscape, Nepal*. Kathmandu: Department of National Parks and Wildlife Conservation, and Department of Forests.

Lamichhane, B. R., Persoon, G. A., Leirs, H., Musters, C. J. M., Subedi, N., Gairhe, K. P., Pokheral, C. P., Poudel, S., Mishra, R., Dhakal, M., Smith, J. L. D. and de longh, H. H. (2017). Are conflict-causing tigers different? Another perspective for understanding human-tiger conflict in Chitwan National Park, Nepal. *Global Ecology and Conservation*, 11: 177–187. https://doi.org/10.1016/j.gecco.2017.06.003

Lamichhane, B. R., Leirs, H., Persoon, G. A., Subedi, N., Dhakal, M., Oli, B. N., Reynaert, S., Sluydts, V., Pokheral, C. P., Poudyal, L. P., Malla, S. and de Iongh, H. H. (2019). Factors associated with co-occurrence of large carnivores in a human-dominated landscape. *Biodiversity and Conservation*, 28 (6): 1473–1491. https://doi.org/10.1007/s10531-019-01737-4

MFSC. (2014). *Nepal National Biodiversity Strategy and Action Plan 2014–2020*. Ministry of Forest and Soil Conservation (MFSC), Kathmandu, Nepal. 232 pp.

MFSC. (2015). *Strategy and Action Plan 2015–2025, Terai Arc Landscape, Nepal*. Ministry of Forests and Soil Conservation, Singha Durbar, Kathmandu, Nepal.

Subedi, N., Bhattarai, S., Pandey, M., Gurung, A., Lamichhane, S., Thapa, S. K., Regmi, R., Parsai, A., Regmi, P. and Lamichhane, B. R. (2020). *Summary Report on Faunal Diversity in Chure Region of Nepal*. President Chure-Terai Madhesh Conservation Development Board and National Trust for Nature Conservation, Kathmandu, Nepal. 78 pp.

Pokhrel, K. (2015). Conservation of Chure Forest in Nepal: Issues, Challenges and Options. *Economic Journal of Nepal*, 35 (4): 262–278.

Smith, J. L. D., McDougal, C., Ahearn, S. C., Joshi, A. and Conforti, K. (1999). Metapopulation structure of tigers in Nepal, *In*: Seidensticker, J., Christie, S. and Jackson, P. (Eds.), *Riding the tiger: Tiger conservation in human-dominated landscapes*. Cambridge University Press, Cambridge, United Kingdom. pp 176–189.

Thapa, K., Gnyawali, T. P., Chaudhary, L., Chaudhary, B. D., Chaudhary, M., Thapa, G. J. and Joshi, D. (2018). Linkages among forest, water, and wildlife: a case study from Kalapani community forest in Lamahi bottleneck area in Terai Arc Landscape. *International Journal of the Commons*, 12 (2): 1–20. https://doi.org/10.18352/ijc.777

Thapa, K., Manandhar, S., Bista, M., Shakya, J., Sah, G., Dhakal, M. and Kelly, M. J. (2018). Assessment of genetic diversity, population structure, and gene flow of tigers (*Panthera tigris tigris*) across Nepal's Terai Arc Landscape. *PloS One*, 13 (3): e0193495. https://doi.org/10.1371/journal.pone.0193495

Walston, J., Robinson, J. G., Bennett, E. L., Breitenmoser, U., da Fonseca, G. A., Goodrich, J. and Leader-Williams, N. (2010). Bringing the tiger back from the brink—the six percent solution. *PLoS Biology*, 8 (9): e1000485. https://doi.org/10.1371/journal.pbio.1000485

Wang, S. W. and Macdonald, D. W. (2009). The use of camera traps for estimating tiger and leopard populations in the high-altitude mountains of Bhutan. *Biological Conservation*, 142 (3): 606–613.

Wikramanayake, E., Dinerstein, E., Seidensticker, J., Lumpkin, S., Pandav, B., Shrestha, M. and Sunarto, S. (2011). A landscape-based conservation strategy to double the wild tiger population. *Conservation Letters*, 4 (3): 219–227. https://doi.org/10.1111/j.1755-263X.2010.00162.x

Wikramanayake, E. D., Dinerstein, E., Robinson, J. G., Karanth, U., Rabinowitz, A., Olson, D. and Bolze, D. (1998). An ecology-based method for defining priorities for large mammal conservation: the tiger as case study. *Conservation Biology*, 12 (4): 865–878. https://doi.org/10.1111/j.1523-1739.1998.96428.x

Wikramanayake, E., McKnight, M., Dinerstein, E., Joshi, A. R., Gurung, B. and Smith, D. (2004). Designing a conservation landscape for tigers in human-dominated environments. *ConservationBiology*, 18 (3): 839–844. https://doi.org/10.1111/j.1523-1739.2004.00145.x