Asian Journal of Conservation Biology, December 2025. Vol. 14 No. 2, pp. 175-182 AJCB: FP0274/86538
ISSN 2278-7666 ©TCRP Foundation 2025 https://doi.org/10.53562/ajcb.86538

Use of bioclimatic region-specific single nucleotide polymorphism reveals cryptic long-distance dispersal of a female tiger from Terai Arc Landscape in northern to western India

Randeep Singh, [1, 2*] **Sujeet Kumar Singh**[1,2]**, Reeta Sharma**[1]**, Parag Nigam**[1]**, Bilal Habib**[1]**, and Surendra Prakash Goyal**[1*]

[1]*Wildlife Institute of India, Post Box 18, Dehradun 248 001, Uttrakhand, India*
[2]*Amity Institute of Forestry and Wildlife Sciences, Amity University, Sector – 125, Noida, 201303, Uttar Pradesh, India*

(Received: December 1, 2024; Revised: April 10, 2025; Accepted: August 24, 2025)

ABSTRACT

Tigers are showing male-biased dispersal and females philopatric. Keoladeo National Park (KNP), India, globally a bird sanctuary, and there has been no history of tiger presence. In 1999, villagers and the forest department sighted a female tiger in the grassland of KNP and was believed that female might have been from nearby tiger populations (c. < 200 km), i.e. Sariska or Ranthambhore in western India. Different approaches such as use of multi locus genotyping and isotope have been used in ancestry determination to either bioclimatic region or population. Because of microevolution, empirical studies have demonstrated presence of fixed SNP in mtDNA gene specific to different bioclimatic regions and has been used to determine ancestry. We compared mtDNA data with existing data on different mtDNA genes for tiger populations across India and revealed the presence of fixed specific SNPs which could distinguish the tigers of India into four broad bioclimatic regions. Therefore, that dispersed tigress had fixed specific SNPs (haplotype) in mtDNA genome which resembles specific to the Terai Arc Landscape (TAL) in the phylogenetic tree. This landscape is about 200 to 350 km from the KNP. Hence, our finding suggests and support occurrence of long-distance dispersal among female tigers.

Keywords: Tigress, dispersal, habitat fragmentation, TAL

INTRODUCTION

Dispersal in carnivores is the movement of individuals from the natal area to establish an independent home range, which helps in the spatial structuring of the population and acts as a population-regulating mechanism (Lidicker, 1975). Additionally, long-distance dispersal is central to ecological processes (Levin et al. 2003; Nathan, 2003), including gene flow (Trakhtenbrot et al. 2005), colonization of new areas, range shift, and helps to maintain functional connectivity between populations (Noss et al. 1996; Weaver et al.,1996; Clobert et al. 2012). Moreover, the long-term population persistence may depend on how successfully individuals traverse through a highly interspersed mosaic of forested areas, agriculture fields, and human settlements to reach another habitat (Watts et al. 2015). Literature with significant conservation and management implications must include information on such long dispersal characteristics.

Among felids, the tiger (*Panthera tigris tigris*), an endangered iconic predator, regulates ecosystem ecological processes (Goodrich et al. 2015). They are habitat specialists but can move longer distances in fractured or fragmented landscapes (Wikramanayake et al. 2010; Sarkar et al. 2016, 2021; Hussain et al. 2022). Hence it is essential to have information about the dispersal pattern and movement path in the landscapes, which helps the conservation and management agencies to act timely to make conservation strategies for the smooth passage of the animals (Wickramanayake et al. 1998). Across the tiger distribution range, the complement methods of non-invasive genetic techniques, radio/GPS telemetry and camera traps have been used to study the dispersal pattern of tigers (Smith 1993, Reddy et al. 2012, Gour et al. 2013, Singh et al. 2013, Wang et al. 2015, Joshi et al. 2016; Sarkar et al. 2016, 2021; Hussain et al. 2022).

Long-term research work using radiotelemetry in Royal Chitwan National Park, Nepal, documented that dispersal in tigers is male-biased and tigers start dispersing at 19-28 months and disperse over large distances (Smith, 1993). Dispersion among males is generally considered a response to mate competition, resource competition or both (Sunquist 1981; Smith et al. 1987). Records of tiger dispersal events have significantly increased in recent years due to broader monitoring and improved technology. While the sporadic events of long-distance dispersal of tigers have been recorded using camera traps in India (Patil et al. 2011; Singh et al., 2013; Shah et al. 2015; Chatterjee et al. 2017) and Russia (for the Amur tiger, *Panthera tigris altaica*; (Wang et al. 2015). However, with the increase in tiger population over the years (Jhala et al. 2014; Qureshi et al. 2023), incidents of long-distance dispersal movement have been recorded frequently, i.e. (i.) tiger dispersed 300 km from Madhya Pradesh and photo-trapped in Gujarat (ii) male tiger was physically captured near Satpura Tiger Reserve, Madhya Pradesh which revealed that the tiger had travelled a distance of 510 km from Chandrapur Super Thermal Power Station, Maharashtra based on comparing tiger stripes database of Wildlife Institute of India (WII) and Maharashtra Forest Department. (Table 1). The recent camera trap-based photo-graphic records and opportunistic sighting evidence suggested that tigers can occasionally move approximately 375 km through human-dominating, fragmented landscapes (Vasudev et al. 2017). Hussain et al. (2022) monitored the dispersal pattern of a sub-adult male tiger using GPS telemetry in

*Corresponding Author's E-mail: goyalsp@wii.gov.in

Central India, and they reported individuals covering a straight-line distance of 315 km over 225 days and a cumulative distance of c. 3000 km. A recent study connected using non-invasive genetics in the central landscape of India has also suggested that male tigers tend to disperse long distances and can disperse as far as 650-700 km (Joshi et al. 2016). Because of such long movement and dispersal, tigers have recently been reported in many areas where they were never observed.

Unlike males, female tigers are considered philopatric and establish their territory, usually in the natal area. Familiarity with spatial and temporal variation in resources within the natal area may benefit parental care (Seidensticker et al. 1999; Tilson & Nyhus, 2010). Therefore, dispersal among female tigers was thought to be rare and rarely documented (Smith, 1993). Contrary to this belief, Sarakar et al. (2021) reported the dispersal of a re-introduced female around 375 km away from its release site in the Central landscape of India.

Considering the empirical studies, understanding the ranging behaviour and dispersal of a species in a metapopulation framework, which occupies different bioclimatic zones, is critical for ensuring long-term conservation goals. However, radio and GPS telemetry have been widely deployed but limited due to the high cost of monitoring many individuals at the landscape level. With the advances in molecular tools, emphasis has been on establishing population/region-specific characteristics using different genetic markers, and significance has been demonstrated to tackle poaching hotspots more effectively and curb illegal wildlife trade at source (Mishra et al. 2012; Wasser et al. 2015). Considering significance not only for wildlife forensics, but such reference database is also very powerful in understanding cryptic long-ranging behaviour using noninvasively collected samples of elusive species. Kumar et al. (2016) could trace the seized elephant tail to its geographic origin using reference DNA sequences. Similarly, Gaubert et al. (2016) and Zhang et al. (2020) could also match the pangolin scales to phylogeographical regions of origin. Recently, Zhao et al. (2019) elucidated the value of harmonized reference DAN sequences of African elephants in provenance tracing.

Context of the present study:

Keoladeo National Park (KNP), Rajasthan, India, is a globally known bird sanctuary, and there has been no history of tiger presence. In 1999, villagers and the forest department reported a sighting of a female tiger in the grassland of Keoladeo National Park (KNP), Rajasthan, India. It was believed that this female might have been from a nearby tiger population, either from Sariska Tiger Reserve (STR) or Ranthambhore Tiger Reserve (RTR) in the western region of India. Similarly, in August 2010, a male tiger was also reported in KNP. Based on matching stripe patterns to those in the Wildlife Institute of India photo database, it was confirmed that the animal has dispersed from RTR (Singh et al. 2013). The aerial distance between KNP in STR and RTR is approximately 95 km and 148 km, respectively. However, the origin of the female tigress seen in KNP in 1999 could not be resolved. Therefore, we used harmonized mtDNA database across the tiger population in India (Sharma et al. 2008, 2011; Singh et al. 2015; Puneet et al. 2018) to document the geographic origin of the female who moved to KNP in 1999.

STUDY AREA

Keoladeo National Park (KNP) is a World Heritage Site situated on the extreme western edge of the Gangetic basin at the confluence point of Gambhir and Banganga rivers in the eastern part of Rajasthan with an extensive natural drainage network (Fig. 1). The total area of the KNP is 29 km^2. It has a unique mosaic of habitats, including wetlands, woodlands, scrub forests, and grasslands, supporting an incredible diversity of plant and animal species. Forests are dominated mainly by kadam *Mitragyna parvifolia*, jamun *Syzygium cuminii* and babul *Acacia nilotica. KNP has good domestic and wild prey populations.*

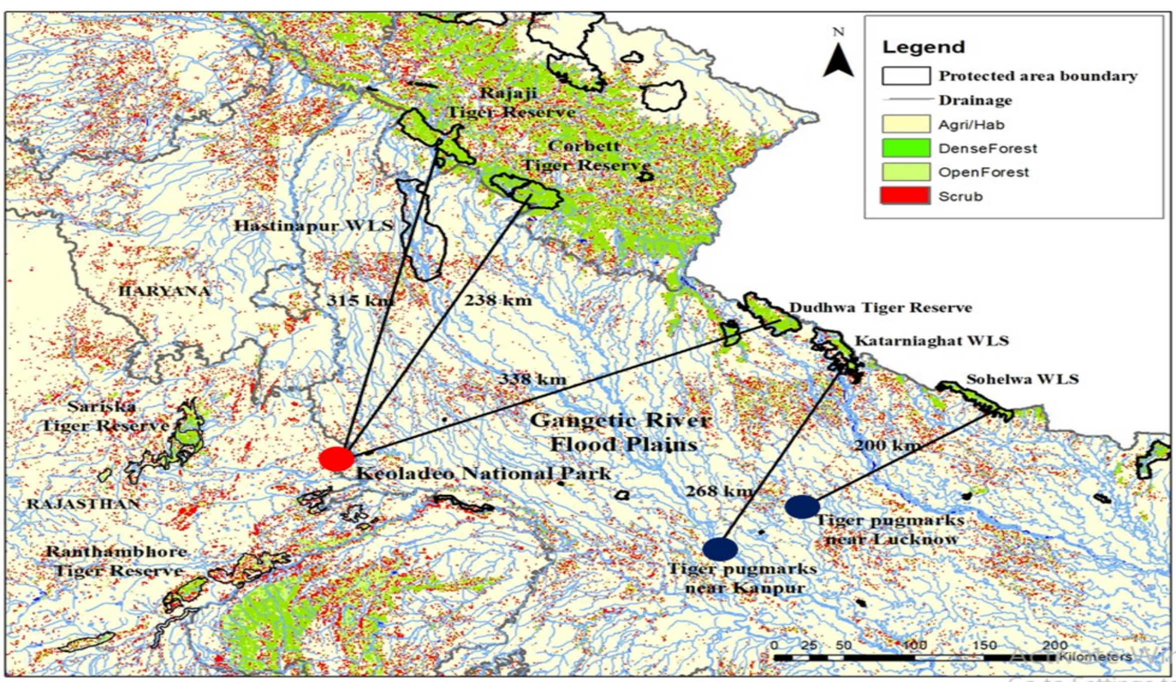
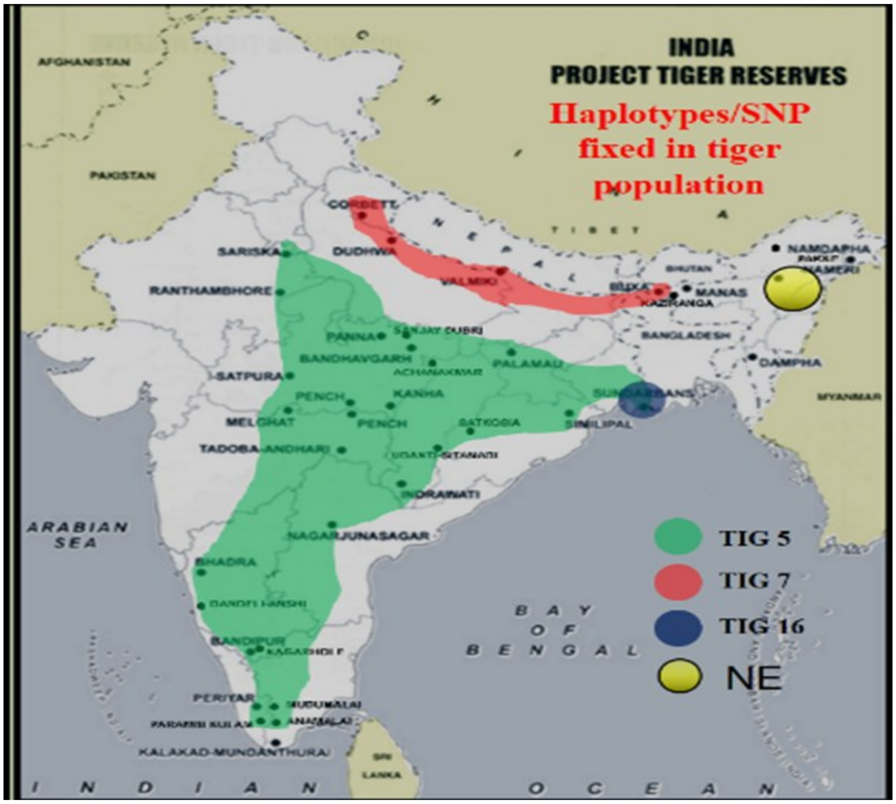
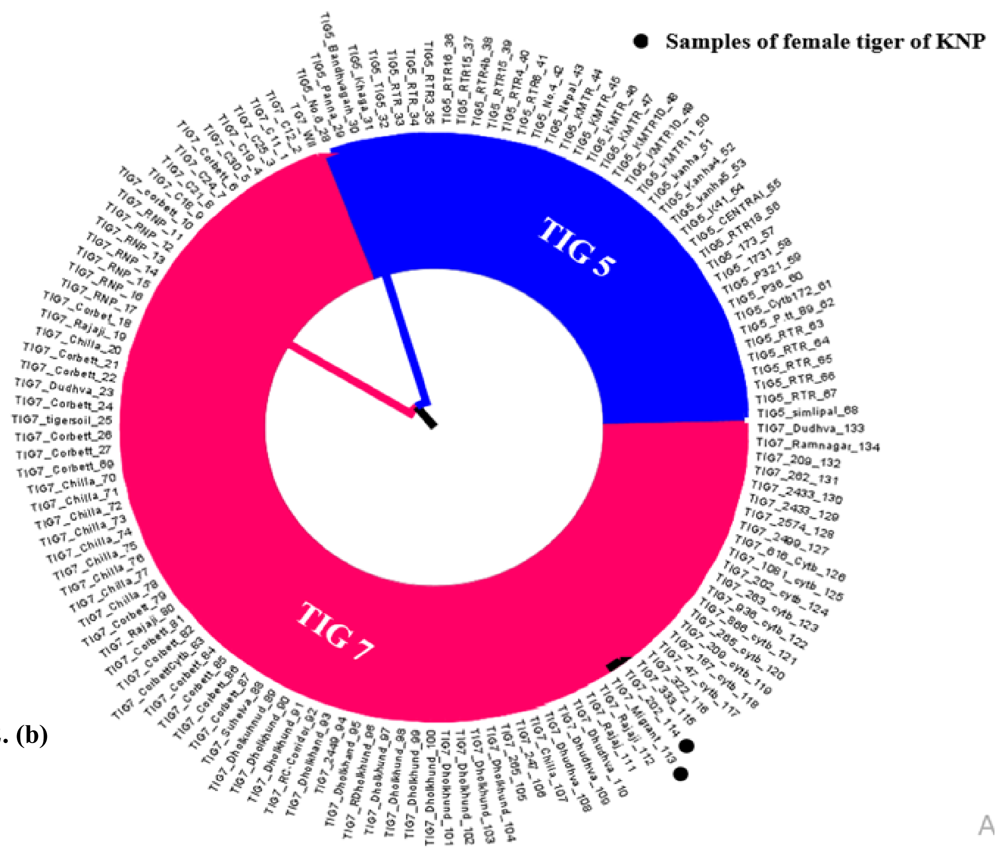


Figure 1. Observed and recorded dispersal of tigers (as per Table 1) from Terai Arc Landscape



2. (a)



2. (b)

Figure 2. (a). Compiled distribution of observed reginal specific haplotypes in tiger across India (Sharma et al. 2008, 2011; Singh et al., 2015; Puneet et al., 2018) and **(b)** alignment of DNA sequence of tiger of KNP in relation

MATERIALS AND MDTHODS

DNA extraction, PCR amplification and Sequencing

We collected scat samples of the female tiger in the year 2000. The Forest Department in Rajasthan, India, collected tissue samples after its death and sent them to the Wildlife Institute of India (WII). DNA was extracted from the dispersed tigress scat samples using QIAamp DNA Stool Mini Kit (Qiagen). We used DNeasy Blood and Tissue Kit (QIAGEN GmbH) to extract DNA from the tissue sample. Negative controls (reagents only) were also included during DNA extraction to monitor contamination. To re-confirm the origin (species) of the scat, we targeted the 172 bp region of the mitochondrial Cytb gene and amplified faecal/tissue DNA using felid-specific primers by Sharma et al. (2008). All the amplification reactions were performed on ABI FAST thermocycler (Applied Biosystems) in total volume 10µl, containing 1µl of the DNA extracted from scat sample, 1X of the PCR buffer, 2.5 Mm of the Mgcl2, 200 µm of each dNTP, 1X of BSA, 0.5U of Taq DAN polymerase (Applied Biosystems) and 0.2 µm of each primer. The thermal profile for the mtDNA amplification was initial denaturation at 94^{o}C for 10 min. Followed by the 40 cycles of denaturation at 94^{o}C for 35s, annealing at 55^{o}C for 45s and extension at 72^{o}C for the 45s, with one cycle of the final extension for 15min at 72^{o}C. The amplified PCR product was subjected to ABI 3130 Genetic Analyzer after Exo-SAP treatment for sequencing. The DNA sequences' quality was determined using Sequence Analysis software (Applied Biosystems) and edited by Sequencher 4.7 (www.genecode.com).

Phylogenetic analysis

We examined the phylogenetic relationship of the dispersed tigress and compared the tigress sequence with all other Cyt b mitochondrial sequences of tigers (Sharma et al., 2008, 2011; Singh et al., 2015; Puneet et al., 2018) and retrieved them from the GenBank. All the sequences were aligned using CLUSTAL-W implemented in BioEdit (Hall et al. 1999) sequence alignment software. The phylogenetic tree of the Cytb gene was generated based on Neighbor-joining (NJ) methods as implemented in Mega v 5.0. (Tamura et al. 2007).

RESULTS AND DISCUSSION

Empirical studies have indicated that known-origin geographical reference DNA sequences are extremely valuable for provenance tracing (Zhang et al. 2015; Kumar et al. 2016; Gaubert et al. 2016; Zhao et al. 2019). Like these studies, harmonised data on different mtDNA genes indicated the presence of population-specific SNPs, which could distinguish the tiger population of India into four geographic regions viz. Terai Arc Landscape (TAL) in northern India, Ranthambhore-Peninsular, Northeast India and Sundarbans (Fig. 2a) (Sharma et al., 2008, 2011; Singh et al. 2015; Pandey et al. 2018). Multiple sequence alignment method showed that dispersed tigress had mtDNA haplotype specific to the Terai Arc Landscape (TAL) in the phylogenetic tree (Fig. 2b). Therefore, it could be that the female tiger which moved to KNP belonged to the TAL tiger population in Northern India. She could have dispersed from one of TAL's Protected Areas (PAs), i.e., Rajaji Tiger Reserve, Corbett Tiger Reserve, Dudhwa Tiger Reserve. The aerial distance of these PA to KNP is between 238 and 338 km (Fig. 1).

Table 1. Reported tiger dispersal distances.

S.No.	Species	Sex	Distance, km	Method used	Area	Reference
1	Amur tiger (Panthera tigris altaica)	Male tiger	270	Camera trap	NA	Wang et al. 2015
2	Bengal tiger (Panthera tigris tigris)	Male	280	Camera trap	Bandipur to Shikaripur, India	Patil et al. 2011
3	Bengal tiger (Panthera tigris tigris)	Male	197	Camera trap	Bhadra Tiger Reserve to Dandeli Tiger Reserve, India	Patil et al. 2011
4	Bengal tiger (Panthera tigris tigris)	sub-adult Male	71	Radiotelemetry	Royal Chitwan National Park, Nepal, India	Smith1993
5	Bengal tiger (Panthera tigris tigris)	Male	148	Camera trap	Ranthambhore TR to Kuno Palpur National Park, India	Singh et al. 2013
6	Bengal tiger (Panthera tigris tigris)	Male	220	Camera trap	Ranthambhore TR to Datia MP.	Shah et al. 2015

7	Bengal tiger *(Panthera tigris tigris)*	Male	510	Physically capture	Chandrapur Super Thermal Power Station, Maharashtra's to Satpura power station, Madhya Pradesh	https://www.timesnownews.com/mirror-now/civic-issues/article/maharashtra-madhya-pradesh-chandrapur-power-plant-durgapur-sarni-satpura-reserve-tiger-maneater-maneating/329896
8	Bengal tiger *(Panthera tigris tigris)*	Male	300	Camera trap	Madhya Pradesh to Gujarat, India	https://timesofindia.indiatimes.com/city/bhopal/tiger-spotted-in-gujarat-walked-all-the-way-from-ratapani-in-mp/articleshow/67985472.cms
9	Bengal tiger *(Panthera tigris tigris)*	Male	139	Genetics	Ranthambhore TR to Madhav National Park, India	Reddy et al. 2012
10	Bengal tiger *(Panthera tigris tigris)*	Male	650	Genetics	Kanha TR to Nagarjunasagar TR, India	Joshi et al. 2016
11	Bengal tiger *(Panthera tigris tigris)*	Male	280	Photograph	Panna TR to Bandhavgarh TR	Murthy (2017)
12	Bengal tiger *(Panthera tigris tigris)*	Male	250	GPS telemetry	Panna TR	Sarkar et al. (2016)
13	Bengal tiger *(Panthera tigris tigris)*	Male	340	GPS telemetry	Vidarbha Landscape, Central India	Hussain et al. (2022)
14	Bengal tiger *(Panthera tigris tigris)*	Female	78	Camera trap	Ranthambhore TR to Chambal WLS, India	Singh et al. 2013
15	Bengal tiger *(Panthera tigris tigris)*	Female	340	GPS telemetry	Panna TR	Sarkar et al. (2021)
16	Bengal tiger *(Panthera tigris tigris)*	Female	>238	Genetics	TAL to Keoladeo National Park, Rajasthan	Present study

However, observed such a long-distance (> 200 km) dispersal of female tigers is infrequent and unexpected. The longest dispersal distance so far known is of a sub-adult female of 78 km from Ranthambhore Tiger Reserve to the riverine habitat (Singh et al. 2013) and 340 km from Panna Tiger Reserve (Sarkar et al. 2021). As such, there is no functional connectivity between TAL and western India landscape (Jhala et al. 2008), and most of the areas are Gangetic River flood plains (Fig. 1). This area is the mosaic of extensive drainage spread, scrubland, ravines, scrub area of exotic mesquite, and agricultural fields (Fig. 1). The dispersing tigers might have taken advantage of limited escape cover available in the riverbed and extensive drainage networks (Fig. 1). Such matrices of the landscape have probably provided conducive habitat to the transient animals for long-range movement (Singh et al. 2013, Singh et al. 2017). Besides, the Gangetic floodplain area is highly fertile, and sugarcane (a tall grassland analogue) and rice farming dominate the landscape. Tigers use such habitat for dispersal and movement (Wickramanayake et al. 2004). For example, it was reported that an adult tigress had taken up residence in a sugarcane field near Pilibhit Tiger Reserve in TAL and raised three cubs (Chanchani et al. 2014). The feral cattle, livestock, small mammals, nilgai and wild boar are the prey available for tigers in such areas. The approximate cattle density in the landscape is ~77.41 cattle/sq. km (Semwal 2005). Shukla (2013) reported that 20% of tigers of TAL stay in sugar cane fields, and their movement increases with stray cattle movement. The sugarcane fields offer a perfect refuge for tigresses for breeding because of the thick cover of tall cane crops, easy food, water and complete protection from other male tigers (Shukla, 2013). The tigers disperse mainly during the monsoon seasons when the livestock are left to graze freely during the peak vegetation growing seasons. Hence, they form easy prey for dispersing tigers (Bargali & Ahmed, 2018). Thus, tall canopy cane fields and feral livestock probably support the tigers to disperse long distances.

Similar to our observations of a female tiger moving through the agricultural landscape, Sarkar et al. (2021) reported that female dispersed from Panna Tiger Reserve has also moved using forest patches, water channels, and agricultural fields and avoided human settlements. Hussain et al. (2022) reported the use of agriculture landscape matrices by dispersing male tigers in Central India, and the overall movement rate was significantly faster during the night (0.44 km/h) than during the day (0.21 km/h).

However, long-distance dispersal by females is a social state as they can contribute to range expansion, an outbreeding strategy, or counter strategies to avoid infanticide to ensure the survival of their progeny (Singh et al. 2014). TAL is a linear habitat of c. 810 km with a width of around 8 to 16 km, and the Corbett Tiger Reserve is a source population in this area with the highest tiger density of 14 individuals/100 km2 (Jhala et al., 2020). Recolonization to the adjoining habitats from a source population was also reported when the PAs attained carrying capacity or when anthropogenic disturbances were controlled (Harihar et al. 2009). Under such a scenario, individuals of both sexes are known to move in adjoining habitats. In support of this, Bisht et al. (2018) monitored the tiger population using a camera trap for six years in Corbett Tiger Reserve, and they reported high reproduction with 54.8 (SE 5.1)% females and high turnover rates (32%–48%) between successive years. Considering population demography and observed ranging behaviour, we presume that one of the females of this landscape might have taken advantage of the intense drainage network for dispersal of the Gangetic plain and finally settled in KNP, which has adequate wild and domestic prey species (Singh et al. 2016, 2017). Hence, we suggest (i) the identification of potential dispersal routes for connecting the different landscapes by regular monitoring through presence–absence surveys and the use of a non-invasive genetic sampling approach in more significant landscapes, (ii) understanding human attitudes and perceptions regarding tiger conservation in these potential dispersal routes and (iii) provide adequate protection to dispersal individuals. Such strategies would ensure managing the tiger population in a meta-population framework.

ACKNOWLEDGEMENTS

We thank the Director, Dean and Research Coordinator of the Wildlife Institute of India for their continuous support. We are thankful to the Rajasthan Forest Department, Park Officials, and field staff of Keoladeo National Park (KNP), Rajasthan, India, for permission and for providing samples for DNA analysis.

Declarations:
Ethical statement:

Tiger scat samples were collected noninvasively without animal capture or handling. Therefore, sample collection did not require any handling of the animals. All necessary permissions to collect and store the samples at the national wildlife reference sample repository were obtained from the Ministry of Forest, Environment and Climate Change, Government of India and Forest Department, Uttarakhand (letter No. 1/29/2003-PT).

REFERENCES

Bargali H.S. & Ahmed T. 2018. Patterns of livestock depredation by tiger (Panthera tigris) and leopard (Panthera pardus) in and around Corbett Tiger Reserve, Uttarakhand, India. PLoS ONE 13 (5): e0195612. https://doi.org/10.1371/journal. pone.0195612.

Bisht S., Banerjee S., Qureshi Q., & Jhala Y. 2019. Demography of a high-density tiger population and its implications for tiger recovery. Journal of Applied Ecology, 56(7), 1725-1740.

Chanchani P., Warrier R., Bista A., Nair S., Lodhi N., & Gupta, M. 2014. Status of

Tigers in Pilibhit Forest Division, Terai Arc Landscape, Uttar Pradesh, India.

Chatterjee M., Krishnendu B., Pandey P. C., Singhai S., Ashraf N. V. K. & Kaul R. 2017. Living with the wild; mitigating conflict between humans and big cat species in Uttar Pradesh. Wildlife Trust of India, National Capital Region, Conservation Action Series, 20171220, 126.

Clobert, J. (Ed.). 2012. Dispersal ecology and evolution. Oxford University Press.

Gaubert P., Njiokou F., Ngua G., Afiademanyo K., Dufour S., Malekani J., ... & Antunes A. 2016. Phylogeography of the heavily poached African common pangolin (Pholidota, Manis tricuspis) reveals six cryptic lineages as traceable signatures of Pleistocene diversification. Molecular Ecology, 25(23), 5975-5993.

Goodrich J., Lynam A., Miquelle D., Wibisono H., Kawanishi K., Pattanavibool A.,

Htun S., Tempa T., Karki J., Jhala Y. & Karanth, U. 2015. Panthera tigris. The IUCN Red List of Threatened Species 2015: e.T15955A50659951. http:// dx.doi. org/10.2305/IUCN.UK.2015 2.RLTS.T 15955A50659951. en. Downloaded on 08 July 2019.

Gour D.S., Bhagavatula J., Bhavanishankar M., Reddy P.A., Gupta J.A., Sarkar M.S.,

Hussain S.M., Harika S., Gulia R., & Shivaji, S. 2013. Philopatry and dispersal patterns in tiger (Panthera tigris). PloS one 8, e66956.

Hall T. A. 1999. BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. In Nucleic acids symposium series, Vol. 41, No. 41, pp. 95-98.

Harihar A., Pandav B. & Goyal S. P. 2009. Responses of tiger (Panthera tigris) and their prey to removal of anthropogenic influences in Rajaji National Park, India. European Journal of Wildlife Research, 55(2), 97-105.

Hussain Z., Ghaskadbi P., Panchbhai P., Govekar R., Nigam P., & Habib B. 2022. Long-distance dispersal by a male sub-adult tiger in a human-dominated landscape. Ecology and Evolution, 12, e9307. https://doi.org/10.1002/ece3.9307.

Jhala Y.V., Gopal R., & Qureshi Q. 2008. Status of tigers, co-predators and prey in India. National Tiger Conservation Authority and Wildlife Institute of India. TR08/001:1-164.

Jhala Y.V., Qureshi Q. & Gopal R. 2014. The status of tigers in India. National Tiger Conservation Authority, New Delhi and Wildlife Institute of India, Dehradun.

Joshi, A. R., Dinerstein, E., Wikramanayake, E., Anderson, M. L., Olson, D., Jones, B. S., ... & Hahn, N. R. (2016). Tracking changes and preventing loss in critical tiger habitat. Science advances, 2(4), e1501675.

Levin S. A., Muller-Landau H. C., Nathan R., & Chave J. 2003. The ecology and evolution of seed dispersal: a theoretical perspective. Annual Review of Ecology, Evolution, and Systematics, 34(1), 575-604.

Lidicker W.Z. 1975. The role of dispersal in the demography of small mammals. In: Petrusewicz, K., Golley, E. B., Ryszkowski, L. (Eds.), Small Mammals: Productivity and Dynamics of Populations. Cambridge University Press, London, Pp. 103-128.

Kumar V.P., Asch B.V., Shukla M., Pandey P., Vipin, Sharma C.P. & Goyal, S.P. 2016. Geographical Assignment and Molecular Tracking in Wildlife Offences: A Case Study of Seized Elephant Tail Hair. International Journal of Forensic Sciences, 1(2): 000112.

Mishra S., Singh S.K & Goyal S.P. 2012. *Panthera tigris* genome: Implication in wildlife forensics. Final Report submitted to the Wildlife Institute of India, Dehradun

Murthy R. S. 2017. Identification Report of Bandhavgarh's Tiger-71. Madhya Pradesh State Biodiversity Board, Bhopal, India.

Nathan R., Perry G., Cronin J. T., Strand A. E., & Cain, M. L. 2003. Methods for estimating long-distance dispersal. Oikos, 103(2), 261-273.

Noss R. F., Quigley H. B., Hornocker M. G., Merrill T., & Paquet, P. C. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology, 10(4), 949-963.

Qureshi Q., Jhala Y. V., Yadav S. P., & Mallick A. (2023). Status of tigers in India–2022: Photo- captured tigers, summary report. National Tiger Conservation Authority and Wildlife Institute of India, Dehradun. TR. No./2023/03.

Pandey P., Goel D., Singh R., Singh S. K., & Goyal S. P. 2018. Use of molecular-based approach in resolving subspecies ambiguity of the rescued tiger cubs from Arunachal Pradesh, India and their relationship with other population. Current Science, 2368- 2373.

Patil N., Kumar N.S., Gopalaswamy A. M. & Karanth K. U. 2011. Conservation news 'Dispersing tiger makes a point'. Oryx 45:472–475.

Reddy P.A., Gour D.S., Bhavanishankar M., Jaggi K., Hussain M.S., Harika K., & Shivaji S. 2012. Genetic evidence of tiger population structure and migration within an isolated and fragmented landscape in northwest India. PLoS ONE 7 (1):e29827.

Sarkar M. S., Niyogi R., Masih R. L., Hazra P., Maiorano L., & John, R. 2021. Long-distance dispersal and home range establishment by a female sub-adult tiger (*Panthera tigris*) in the Panna landscape, Central India. European Journal of Wildlife Research, 67(3), 1–7. https://doi.org/10.1007/s10344-021-01494-2.

Sarkar M. S., Ramesh K., Johnson J. A., Sen S., Nigam P., Gupta S. K., Murthy R. S., & Saha, G. K. 2016. Movement and home range characteristics of reintroduced tiger (*Panthera ti*gris) population in Panna Tiger Reserve, Central India. European Journal of Wildlife Research, 62(5), 537–547. https://doi.org/10.1007/s10344-016-1026-9.

Seidensticker J., Jackson P., & Christie S. (Eds.). 1999. Riding the tiger: tiger conservation in human-dominated landscapes. Cambridge University Press.

Semwal R. L. 2005. The Terai Arc Landscape in India, Securing Protected Areas in the Face of Global Change. WWF-India, New Delhi. 47pp.

Shah, S., Nayak, S., & Borah, J. (2015). Tiger dispersals in the semiarid landscape of northwest India. Cat News.

Sharma R., Stuckas H., Bhaskar R., Rajput S., Khan I., Goyal S. P., & Tiedemann R. 2009. mtDNA indicates profound population structure in Indian tiger (*Panthera tigris tigris*). Conservation genetics, 10, 909-914.

Sharma R., Stuckas H., Bhaskar R., Khan I., Goyal S. P., & Tiedemann R. 2011. Genetically distinct population of Bengal tiger (*Panthera tigris tigris*) in Terai Arc Landscape (TAL) of India. Mammalian Biology, 76, 484-490.

Singh S. K., Mishra S., Aspi, J., Kvist L., et al. 2015. Tigers of Sundarbans in India: is the population a separate conservation unit? PloS one, 10(4), e0118846.

Singh A., Mukherjee A., Dookia S., & Kumara H. N. 2017. An updated account of mammal species and population status of ungulates in Keoladeo National Park, Bharatpur, Rajasthan. Current Science, 103-111.

Singh A., Mukherjee A., Dookia S., & Kumara H. N. 2016. High resource availability and lack of competition have increased population of a meso-carnivore—a case study of golden jackal in Keoladeo National Park, India. Mammal Research, 61, 209-219.

Singh R., Nigam P., Qureshi Q., Sankar K., Krausman P.R., & Goyal S.P. 2014. Strategy of female tigers to avoid infanticide. Curr. Sci. 107, 1595–1597

Singh R., Qureshi Q., Sankar K., Krausman P.R., & Goyal S.P. 2013. Use of camera traps to determine dispersal of tigers in semi-arid landscape, western India. Journal of Arid Environments 98, 105-108.

Shukla R. 2013. Sugarcane Tiger: The Phenomenon of Wildlife in Tarai Farmlands. IBDC Publishers, 350 pp

Smith J. L. D. 1993. The role of dispersal in structuring the Chitwan tiger population. Behaviour, 124(3-4), 165-195.

Smith J.L.D., McDougal, C.W., & Sunquist M.E. 1987. Female land tenure system in tigers. In Tigers of the World (eds R.L. Tilson & U.S. Seal), pp. 97–109. Noyes Publications, Saddle River, USA.

Sunquist M. E. 1981. The social organization of tigers (*Panthera tigris*) in Royal Chitawan National Park, Nepal.

Tamura K., Dudley J., Nei M., & Kumar, S. 2007. MEGA4: Molecular evolutionary genetics analysis (MEGA) software version 4.0. Molecular biology and evolution, 24(8), 1596- 1599.

Tilson R., & Nyhus P. J. (Eds.). 2009. Tigers of the world: the science, politics and conservation of *Panthera tigris*. Academic Press.

Trakhtenbrot A., Nathan R. Perry G., & Richardson D. M. 2005. The importance of long- distance dispersal in biodiversity conservation. Diversity and Distributions, *11*(2), 173-181.

Vasudev D., Nichols J.D., Ramakrishnan, U., Ramesh K., & Vaidyanathan, S. 2017. Assessing Landscape Connectivity for Tigers and Prey Species: Concepts and Practice. In Methods for Monitoring Tiger and Prey Populations; Karanth, K.U., Nichols, J.D., Eds.; Springer: Singapore; pp. 255–288. ISBN 978-981-10-5436-5.

Wang T., Feng L., Mou P., Ge J., Li C., & Smith J.L. 2015. Long-distance dispersal of an Amur tiger indicates potential to restore the North-east China/Russian Tiger Landscape. Oryx 49, 578 –579.

Wasser S. K., Brown, L., Mailand C., Mondol S., Clark, W., Laurie, C. & Weir B.S. (2015). Genetic assignment of large seizures of elephant ivory reveals Africa's major poaching hotspots. Science 349, no. 6243: 84-87.

Watts A. G., Schlichting P. E., Billerman S. M., Jesmer B. R., Micheletti S., Fortin M. J., ... & Murphy, M. A. (2015). How spatio-temporal habitat connectivity affects amphibian genetic structure. Frontiers in Genetics, 6, 275.

Weaver J. L., Paquet P. C., & Ruggiero L. F. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. Conservation Biology, 10(4), 964-976.

Wikramanayake E.D., Dinerstein E., Robinson J.G., Karanth K.U., Rabinowitz A., Olson D., Mathew T., Hedao P., Conner M., Hemley G., & Bolz D. 1998. An ecology-based method for defining priorities for large mammal conservation: the tiger as a case study. Conservation Biology 12:865–878.

Wikramanayake E.D., McKnight M., Joshi A., Gurung B., & Smith D. 2004. Designing a Conservation Landscape for Tigers in Human-Dominated Environments. Conservation Biology 18:839–844.

Wikramanayake E.D., Manandhar A., Bajimaya S., Nepal S., Thapa G., & Thapa, K. 2010. The Terai Arc Landscape: A tiger conservation success story in a human-dominated landscape, in Tigers of the World: The Science, Politics, and Conservation of *Panthera tigris*, R. Tilson, P. Nyhus, Eds. Elsevier/ Academic Press, Oxford, 2nd ed. Pp. 161–172.

Zhang H., Miller M. P., Yang F., Chan H. K., Gaubert P., Ades G., & Fischer G. A. 2015. Molecular tracing of confiscated pangolin scales for conservation and illegal trade monitoring in Southeast Asia. Global Ecology and Conservation, 4, 414-422.

Zhao K., Ishida Y., Green C. E., Davidson A. G., Sitam F. A., Donnelly C. L., ... & Roca A. L. 2019. *Loxodonta* Localizer: a software tool for inferring the provenance of African elephants and their ivory using mitochondrial DNA. Journal of Heredity, 110(7), 761-768.