Links in a sink: Interplay between habitat structure, ecological constraints and interactions with humans can influence connectivity conservation for tigers in forest corridors

Author links open overlay panelMahi Puri [a b], Arjun Srivathsa [a c d], Krithi K. Karanth [b e], Imran Patel [b], N. Samba Kumar [b]
Show more

https://doi.org/10.1016/j.scitotenv.2021.151106Get rights and content

Highlights

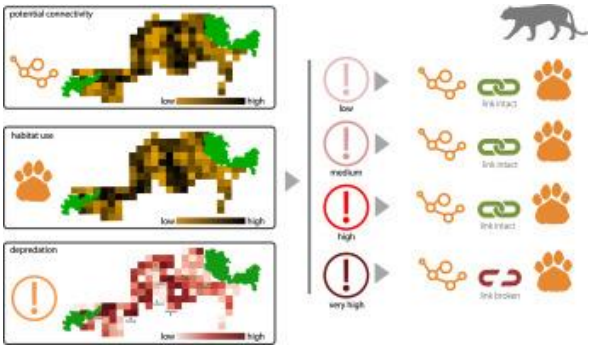
- Interactions with humans can impact connectivity through corridors for tigers.
- We examined links between connectivity, tiger habitat use and tiger-human interactions.
- We combined graph-theoretic methods, occupancy models and multiple data sources.
- Connectivity and habitat use showed low correlation at high levels of conflict.
- Human-carnivore interactions are important for planning connectivity conservation.

Abstract

Global land-use changes and rapid infrastructure development necessitate identification and conservation of wildlife corridors. Connectivity through corridors is shaped by

species' structural, ecological and behavioral constraints. In multi-use landscapes, species' interactions with humans could additionally influence connectivity. Using the tiger *Panthera tigris* as a case study, we make simultaneous assessments of potential connectivity, habitat use and examine their links with the species' negative interactions with humans in central India. We assessed potential connectivity across 10, 000 sq. km of the Kanha–Pench forest corridor using graph-theoretic methods. Combining indirect sign surveys and occupancy models, we examined habitat use, and evaluated its congruence with potential connectivity. Next, we estimated spatial probabilities of livestock depredation through application of multi-state occupancy models to interview-based survey data from local residents. Habitat use by tigers was negatively associated with forest fragmentation and anthropogenic disturbance. Livestock depredation was positively associated with size of settlements and areas most frequented by tigers, and negatively with anthropogenic disturbance within forests. We found high congruence between connectivity and habitat use (r = 0.80); but the strong correlation did not hold in areas with very high levels of livestock depredation levels. Our results indicate that when areas of high use by tigers are constrained by limited connectivity, there are higher chances of human-tiger conflict, and these areas may be ecological traps for the species. Interactions with humans can be crucial in mediating connectivity for large carnivores in shared habitats. Our findings present an opportunity to consolidate areas where carnivore conservation and local livelihood needs can be balanced. Our framework also provides a foundation for spatial prioritization that incorporates a plurality of dimensions, with utility for connectivity conservation of other wide-ranging carnivores.

Graphical abstract



Download: Download high-res image (248KB)
Download: Download full-size image

Introduction

Creating and conserving habitat corridors has been of interest to conservation biologists and wildlife managers for nearly four decades (Noss, 1983; Noss and Harris, 1986).

Multiple studies transcending taxonomic groups have established the utility and need for carefully designed habitat corridors (see Gilbert-Norton et al., 2010). The benefits vary by spatial scale, species, and landscapes. Corridors facilitate movement of individuals, dispersal, maintaining metapopulation dynamics, retaining genetic diversity, and in the conservation context, increasing the overall habitat available for threatened or endangered species (Hilty et al., 2012). Human population growth, coupled with global land-use change, has engendered massive agriculture expansion and infrastructure development, particularly in developing countries (Dobrovolski et al., 2013; Laurance et al., 2015). In this scenario, designating and maintaining habitat corridors to ensure connectivity for wildlife can pose formidable challenges.

Connectivity through habitat corridors may be interpreted as structural or functional, based on their attributes and the mode of assessment (Calabrese and Fagan, 2004; Fletcher et al., 2016). Structural connectivity is inferred through analysis of the landscape or habitat features, based on patch and distance metrics (Calabrese and Fagan, 2004; Kindlmann and Burel, 2008). Relying solely on structural connectivity measures for identifying corridors has received much criticism, because (1) they may not necessarily reflect the true process of species movement or use of the corridor, and (2) they could entail assessment biases, depending on the methods employed (Zeller et al., 2012). Studies have progressively advocated for incorporating species' presence, behavior, and movement in heterogeneous landscapes to make inferences about functional connectivity (i.e., combining attributes of the landscape configuration with information on species occurrence and movement; Baguette et al., 2013; Vasudev et al., 2015; Gupta et al., 2019). There is a need, therefore, for empirical evaluations that determine functionality and utility of habitat corridors, to substantiate the efforts invested in conserving them.

Recent conceptual developments in the fields of landscape ecology and connectivity conservation have expanded the definition of corridor functionality to incorporate anthropogenic factors, because species occurrence is not shaped by ecological processes and landscape attributes alone (Ghoddousi et al., 2021). Interactions with people can indirectly influence the permeability of corridors by coercing animals into using unsafe areas (ecological traps; Northrup et al., 2012) or through avoidance of areas with high risk of mortality (landscape of fear; Miller and Schmitz, 2019). Assessments of corridor functionality, and investments in the planning and management of effective corridors can, therefore, be improved with an enhanced understanding of the impact of human–wildlife interactions.

Large carnivores typically have vast geographic ranges that overlap with human-dominated landscapes (Ripple et al., 2014). Fragmentation of natural habitats, a consequence of the expanding human footprint (Fahrig, 2003; Geldmann et al., 2014;

Venter et al., 2016), has necessitated conservation of corridors that connect carnivore populations across habitat patches. In this context, the tiger *Panthera tigris* makes for an ideal case study. It is a globally important species because of its ecological role, charismatic appeal, endangered status, and the substantial financial and management resources invested towards its conservation (Gittleman, 2001; Walston et al., 2010). An estimated 70% of the world's wild tigers are currently in India, mostly restricted to protected areas (PAs) that constitute ~4% of the country's land area. Recognizing the crucial role of linking tiger populations across PAs, several studies have sought to examine potential and realized connectivity (Joshi et al., 2013; Dutta et al., 2016; Reddy et al., 2017) to identify tiger corridors. These corridors are usually in human-dominated, multi-use forest landscapes that cannot be easily consolidated for wildlife movement. Unfortunately, previous assessments of connectivity do not explicitly address human–tiger interactions (including livestock depredation, human injury and death), a key component of the equation, while identifying or recommending designation of tiger corridors.

Conservation of carnivore corridors pose unique challenges because the core issue is often at the confluence of vulnerabilities associated with the physical habitat, peculiarities of animal behavior and the complex interactions between people and nature (see Ghoddousi et al., 2021). Recognizing the gaps in current understanding of the interplay between landscape-metric based potential connectivity, its congruence (or lack of) with ground-based assessment of carnivore habitat use, and the role of anthropogenic stressors, we ask the following questions–

(1)

Does potential connectivity modelled from land-cover metrics and resistance surfaces corroborate actual habitat use patterns?

(2)

Whether– and if so, how– negative interactions with humans (i.e., anthropogenic stressor) alter the equation between potential connectivity and habitat use?

With the tiger as our focal species, we first assess potential connectivity (a metric of functional connectivity) in a previously identified forest corridor in central India, using methods based on graph theory. In the same landscape, we examine habitat use by tigers combining data from indirect sign surveys with site occupancy models; we then evaluate the magnitude of congruence between potential connectivity and habitat use. Next, we estimate probabilities of livestock depredation by tigers (negative interactions with humans) applying multi-state occupancy models to data from interview surveys of local residents. Finally, we examine the links between predicted depredation patterns, potential connectivity and habitat use by tigers in the forest corridor. Based on these

links, we discuss how corridor habitats could be consolidated for facilitating tiger movement while also minimizing losses to people.

Section snippets

Study area

The central Indian highlands, comprising 16 PAs and 35 identified corridors, is among the key high-priority landscapes for global tiger conservation (Dutta et al., 2016; Joshi et al., 2016; Sanderson et al., 2010; Fig. 1). We focused on the unprotected forests between Kanha (940 sq. km) and Pench (411 sq. km) reserves in the State of Madhya Pradesh (IUCN category II PAs). Kanha supports 103–113 tigers, and Pench has 77–97 tigers (Jhala et al., 2020). While the two PAs are source sites, the

Potential connectivity based on centrality metrics

The resistance surface map provided a spatial and quantitative measure of landscape permeability for tigers (Fig. 4, top panel). Areas of highest resistance are represented by human settlements, and areas with least resistance (i.e., high conductance) are forest habitats. Betweenness centrality analysis enabled us to map and identify areas with high and low connectivity at fine spatial resolution. Visual representation of betweenness centrality across the region showed ‘pinch points’ or

Discussion

The efficacy of habitat corridors, and therefore the extent of functional connectivity, depends on factors that both facilitate as well as impede movement of animals. Besides ecological limitations, it is important to identify critical human-induced movement constraints that could preclude effective dispersal of animals through heterogeneous landscapes (Ghoddousi et al., 2021). Yet, connectivity assessments for tigers have thus far sparingly incorporated these factors. Our study investigated

Funding

This work was supported by the DeFries-Bajpai Foundation, Rufford Foundation, Ravi Sankaran Inlaks Fellowship and IDEA-Wild. Funding agencies had no role in the study design, collection, analysis and interpretation of data, in writing and in the decision to submit the article for publication.

Ethics statement

Madhya Pradesh State Forest Department provided necessary research permits to carry out the study. Sign surveys were completely non-invasive and did not involve capture or handling of animals; animal care and use committee approval was not required. Interviews were conducted following informed oral consent of the local residents.

Data accessibility

Data will be made available on a public digital repository upon acceptance.

CRediT authorship contribution statement

Mahi Puri – Conceptualization, Data collection, Formal analysis, Funding acquisition, Methodology, Project administration, Writing – original draft, Writing – review & editing; Arjun Srivathsa – Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing; Imran Patel – Data collection; Krithi Karanth – Methodology, Supervision, Writing – review & editing; N Samba Kumar – Methodology, Supervision, Writing – review & editing.

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.

Acknowledgements

We are grateful to the Madhya Pradesh State Forest Department for providing research permits and supporting the study. M.P. and A.S. were supported by the University of Florida. A.S. was supported by Wildlife Conservation Society's Christensen Conservation Leaders Scholarship and Wildlife Conservation Network's Sidney Byers Fellowship. We thank J.D. Nichols and J.E. Hines for useful discussions, advice and analytical support. Centre for Wildlife Studies and Wildlife Conservation Society-India

References (87)

F. Adriaensen *et al.*

The application of ‘least-cost’ modelling as a functional landscape model
Landsc. Urban Plan.
(2003)
T. Caro *et al.*
Realities of documenting wildlife corridors in tropical countries
Biol. Conserv.
(2009)
R.S. Chundawat *et al.*
Size matters: scale mismatch between space use patterns of tigers and protected area size in a tropical dry Forest
Biol. Conserv.
(2016)
R. Dobrovolski *et al.*
Global agricultural expansion and carnivore conservation biogeography
Biol. Conserv.
(2013)
A. Ghoddousi *et al.*
Anthropogenic resistance: accounting for human behavior in wildlife connectivity planning
One Earth
(2021)
J.M. Goodrich *et al.*
Conflicts between Amur (Siberian) tigers and humans in the russian Far East
Biol. Conserv.
(2011)
W.F. Laurance *et al.*
Reducing the global environmental impacts of rapid infrastructure expansion
Curr. Biol.
(2015)
J.R. Miller *et al.*
Landscape of fear and human-predator coexistence: applying spatial predator-prey interaction theory to understand and reduce carnivore-livestock conflict
Biol. Conserv.
(2019)
M. Puri *et al.*
The balancing act: maintaining leopard-wild prey equilibrium could offer economic benefits to people in a shared forest landscape of Central India
Ecol. Indic.
(2020)

A. Rabinowitz *et al.*

A range-wide model of landscape connectivity and conservation for the jaguar, Panthera onca

Biol. Conserv.

(2010)

View more references

Cited by (19)

Incorporating barriers restoration and stepping stones establishment to enhance the connectivity of watershed ecological security patterns

2024, Applied Geography

Show abstract

The negative impacts of human activities on the ecological corridor in the karst highly urbanized area are gradually diminishing: A case study from the karst mountain cities in Southwest China

2023, Ecological Indicators

Citation Excerpt :

> This outcome is a result of strengthened government conservation measures and the relatively stable land use within these protected areas. Furthermore, to maintain local ecological safety and biodiversity, policy-planned protected areas such as forest parks and nature reserves are often located in areas with lower human disturbance and better ecological conditions.Ecological corridors serve as bridges for species migration and play a crucial role in maintaining regional ecological security (Puri et al., 2022). Effectively utilizing these corridors, including enhancing their selectivity and integration, can help balance the relationship between human activities and biodiversity (Peng et al., 2017).

Show abstract

Assessment of the cultural-natural importance of the scenic spots from a network perspective

2023, Landscape and Urban Planning

Show abstract

Prioritizing ecological conservation strategies to enhance national ecological connectivity in China

2023, Ecological Indicators

Citation Excerpt :

> This paper's main purpose is to create the first national eco-corridor map. With the acquisition of a large number of experimental data on the diffusion behavior (Chen et al., 2015; Puri et al., 2022), the method of choosing resistance factors and standardizing resistance layers will be improved in the future and the results of eco-corridor will be more likely reflect reality. As reviewed by the Zeller et al. (2012), we all understood the risk or uncertainties of fully depending on the expert's opinion when developing the resistance surface.

Show abstract
Topcats and underdogs: intraguild interactions among three apex carnivores across Asia's forestscapes
2023, Biological Reviews
Evolution Analysis of Ecological Networks Based on Spatial Distribution Data of Land Use Types Monitored by Remote Sensing in Wuhan Urban Agglomeration, China, from 2000 to 2020
2022, Remote Sensing