

Reply to Goswami et al., Harihar et al., and Karanth et al.: Fine-scale interactions between tigers and people

We thank Goswami et al. (1), Harihar et al. (2), and Karanth et al. (3), for their interest in our study (4). However, unfortunately their critiques are misinterpretations and misrepresentations of our report. Because of space limits, we can only comment on their main points briefly.

Karanth et al. (3) claim that we prescribed “tiger population sinks over sources as a future strategy.” We do not offer such a prescription. To the contrary, we greatly value the source-sink approach in conservation [e.g., see the book *Sources, Sinks and Sustainability* edited by, among others, J.L., (5)]. In fact, our report explicitly stated that “the park is an important refuge from high levels of disturbance for tigers” (ref. 4, page 15362).

Our study reported that in and around Nepal’s Chitwan National Park, ecological mechanisms (e.g., tigers temporally avoiding people) and policies (e.g., grazing restrictions, antipoaching patrols) have allowed tigers to spatially coexist with human presence at fine scales. We explicitly defined fine-scale spatial coexistence: tigers “use the exact same point locations” as people (4). However, Harihar et al. (2) obfuscate our definition by defining coexistence as a vague “interspecific dynamic process.”

Harihar et al. (2) question the novelty of our study by citing a study by Karanth and Sunquist (6), but that study was conducted in “disturbance-free habitats,” as stated by the authors. Thus, temporal rather than spatial segregation from human activities in Chitwan reported in our article is indeed a unique finding, and has been recommended “as being of special significance” by Faculty of 1000 (7).

Karanth et al. (3) state that “Even in Chitwan, tiger densities were much higher historically, under stricter regulation of extractive uses.” Their statement is contradictory to the facts. First, the article by Barber-Meyer et al. (8) as cited by Karanth et al. is incorrectly cited. The article does not evaluate tiger density; in fact, it never mentions tiger density in Chitwan, changes in tiger density, or changes in regulation in Chitwan. Second, regulation of extractive uses in Chitwan has become stricter over time since the establishment of the park in 1973 and the buffer zone in 1996. As a result, although the tiger population has been declining worldwide, the tiger population in Chitwan has been growing (9, 10). The tiger density in 2011 in Chitwan was ~60% greater than in the mid 1970s, when the park was established (4, 11), and 146% greater than in the adjoining and ecologically similar Valmiki Tiger Reserve in India (12).

Goswami et al. (1) and Harihar et al. (2) assert that we disregarded the issue of tiger attacks on people in our study. However, our study’s objective was to evaluate the “capacity and mechanisms for tigers to coexist with humans at fine spatial scales” (ref. 4, page 15360). In another recent study we in-

vestigated the complex cognitions and emotions people have toward tigers to help mitigate tiger–human conflict in Chitwan (13). Tiger–human coexistence at fine scales does not mean there are no tiger–human conflicts at other scales or at other locations. It is not surprising that tiger attacks on people have increased because both tiger and human populations have increased substantially in Chitwan. The probability of a negative tiger–human encounter logically increases as the numbers of both tigers and people increase. Supporting high (and increasing) tiger densities despite the human population tripling in size from

1971 to 2011 (14) in Chitwan has been widely praised (15).

Harihar et al. (2) claim that 23–30 tigers were poached from 2005 to 2009 in Chitwan. However, this claim is misleading because these numbers are based on tiger parts (e.g., bones, skins) seized by authorities, and in most cases the actual places where these tigers came from cannot be determined. In fact, the World Wildlife Fund recently gave Nepal a “green” score for progress in key aspects of compliance with and enforcement of poaching regulations (16).

Goswami et al. (1) and Harihar et al. (2) confuse detection with occupancy. Our report noted that “human-related covariates did influence the probability of detecting tigers” (ref. 4, page 15361) because tigers were more wary near human settlements. However, the probability of tigers occupying (being present at) locations near or further from human settlements did not significantly differ. Furthermore, Harihar et al. (2) incorrectly compare our occupancy analysis with Barber-Meyer et al. (8), cited in their letter, because the covariates used in Barber-Meyer et al. (8) were completely different from ours.

Harihar et al. (2) assert that the two areas (i.e., inside vs. outside the park) in our study site are not really different from each other. However, the types and degree of human presence (e.g., local residents were three times more prevalent outside the park than inside) and the land-management practices and policies (e.g., exclusion policies inside the park vs. community forestry outside the park) in each area are quite different.

Goswami et al. (1) and Harihar et al. (2) allege that our study provides an inaccurate picture of tiger–human spatial overlap because we did not sample from within human land-uses. It is widely known that tigers cannot exist in nonhabitat areas. Because our research objective was to assess spatial overlap at fine scales, there was no need to sample cities or urban areas that are not suitable habitats for tigers. Rather, we sampled forested areas used by people (for different purposes, such as collection of natural resources and in different magnitudes).

Unlike what Karanth et al. (3) and Harihar et al. (2) claim, our methods of estimating tiger densities adequately addressed issues related to geographic closure and sparse data. First, the spatial capture-recapture model we used does not rely on the

Author contributions: N.H.C., B.K.S., J.B.K., N.M.B.P., and J.L. wrote the paper.

The authors declare no conflict of interest.

¹To whom correspondence should be addressed. E-mail: liujie@msu.edu.

assumption of geographic closure, but instead accounts for animal movement and detection probability based on activity centers (17). Furthermore, except for one tiger, tigers identified inside and outside the park were detected exclusively within each area. Second, the spatial capture-recapture model uses Bayesian inference, which is ideally suited for sparse data such as ours (18, 19). For example, Sollmann et al. (18) reliably estimated jaguar density from five animals. Moreover, given the tiger's home range size of $\sim 20 \text{ km}^2$ in Chitwan (11), empirical data and simulations (19) suggest that the areas sampled by camera traps inside ($\sim 50 \text{ km}^2$) and outside ($\sim 30 \text{ km}^2$) the park were more than sufficient to generate reliable density estimates in both areas. We did not use "naive tiger densities" because they are misleading (3).

Although protected areas and managing human activity for tiger conservation are certainly needed, excluding all activities by millions of people from across the tiger's remaining range spanning 13 countries is impractical. Nearly 80% of the tiger's current range is on human-dominated areas beyond protected-area boundaries (20). Complementing existing conservation strategies (e.g., excluding all consumptive activities in some areas) with new approaches informed by multiscale research on human-tiger interactions is needed to enable tigers to regain lost ground. To explore new approaches that conserve tigers yet meet human needs, as discussed in our report, it is important to study long-term dynamics of coexistence, including thresholds and long-term impacts on tigers and people in Chitwan and elsewhere.

Neil H. Carter^a, Binoj K. Shrestha^b, Jhamak B. Karki^c, Narendra Man Babu Pradhan^d, and Jianguo Liu^{a,1}

^aCenter for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824; ^bSchool of Life Sciences, Arizona State University, Tempe, AZ 85287; ^cDepartment of National Parks and Wildlife Conservation, Ministry of Forests and Soil Conservation, Government of

Nepal, Babarmahal, Kathmandu, Nepal; and ^dWorld Wildlife Fund–Nepal Programme, Baluwatar, Kathmandu, Nepal

- Goswami VR, et al. (2012) Conflict of human-wildlife coexistence. *Proc Natl Acad Sci USA* 110:E108.
- Harihar A, et al. (2012) Conflating "co-occurrence" with "coexistence". *Proc Natl Acad Sci USA* 110:E109.
- Karanth KU, et al. (2012) Sinks as saviors: Why flawed inference cannot assist tiger recovery. *Proc Natl Acad Sci USA* 110:E110.
- Carter NH, Shrestha BK, Karki JB, Pradhan NMB, Liu J (2012) Coexistence between wildlife and humans at fine spatial scales. *Proc Natl Acad Sci USA* 109(38):15360–15365.
- Liu J, Hull V, Morzillo AT, Wiens JA (2011) *Sources, Sinks and Sustainability* (Cambridge Univ Press, New York, NY).
- Karant KU, Sunquist ME (2000) Behavioral correlates of predation by tiger, leopard and dhole in Nagarhole National Park, India. *J Zool (Lond)* 250(2):255–265.
- Fischer J (2012) F1000 Prime Recommendation of Carter NH, et al., *Proc Natl Acad Sci USA*, 109(38):15360–15365. Faculty of 1000, 29 Oct 2012 (f1000.com/prime/717960732#eval793463596), 10.3410/f.717960732.793463596.
- Barber-Meyer SM, et al. (2012) Influence of prey depletion and human disturbance on tiger occupancy in Nepal. *J Zool (Lond)*, 10.1111/j.1469-7998.2012.00956.x.
- DNPWC (2007) *Tiger Conservation Action Plan for Nepal 2008–2012* (Department of National Parks and Wildlife Conservation, Ministry of Forests and Soil Conservation, Government of Nepal, Nepal).
- World Bank (2011) *World Development Report 2012: Gender Equality and Development* (The International Bank for Reconstruction and Development/The World Bank, Washington, DC).
- Sunquist ME (1981) The social organization of tigers (*Panthera tigris*) in Royal Chitawan National Park, Nepal. *Smithson Contrib Zool* 336:1–98.
- Jhala Y, Qureshi Q, Gopal R (2011) Can the abundance of tigers be assessed from their signs? *J Appl Ecol* 48(1):14–24.
- Carter NH, Riley SJ, Liu J (2012) Utility of a psychological framework for carnivore conservation. *Oryx* 46(4):525–535.
- CBS (2012) Central Bureau of Statistics. Available at <https://sites.google.com/site/nepalcensus>. Accessed August 1, 2011.
- Dinerstein E, Rijal A, Bookbinder M, Kattel B, Rajuria A (1999) Tigers as neighbours: Efforts to promote local guardianship of the endangered species in lowland Nepal. *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes*, eds Seidensticker J, Christie S, Jackson P, pp 316–333.
- Nowell K (2012) Wildlife crime scorecard: Assessing compliance with and enforcement of CITES' commitments for tigers, rhinos and elephants. *WWF Report*. Available at http://awsassets.panda.org/downloads/wwf_wildlife_crime_scorecard_report.pdf. Accessed October 20, 2012.
- Gardner B, Royle JA, Wegan MT (2009) Hierarchical models for estimating density from DNA mark-recapture studies. *Ecology* 90(4):1106–1115.
- Sollmann R, et al. (2011) Improving density estimates for elusive carnivores: Accounting for sex-specific detection and movements using spatial capture-recapture models for jaguars in central Brazil. *Biol Conserv* 144(3):1017–1024.
- Sollmann R, Gardner B, Belant JL (2012) How does spatial study design influence density estimates from spatial capture-recapture models? *PLoS ONE* 7(4):e34575.
- Forrest JL, et al. (2011) Single species conservation in a multiple use landscape: Current protection of the tiger range. *Anim Conserv* 14(3):283–294.