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Community knowledge reveals convergent decline of large carnivores despite near-universal ranges in high-altitude Arunachal Pradesh, India

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Abstract

Large carnivores in the high-altitude Eastern Himalayas are difficult to monitor with conventional field methods, leaving their status poorly resolved. We used structured participatory interviews to document mammal distribution, community-perceived population change, and local threats across high-altitude terrain above 3,500 m in Arunachal Pradesh, north-east India. Across 2,434 interviews in 312 grid cells (10 × 10 km; median six respondents per cell), we recorded contemporary presence in 2017, recalled historical presence around 1998, perceived population trends, and threat severity for 16 mammal species. Contemporary distribution was analysed with a single-season community occupancy model, using respondents as within-cell replicates and conditioning detection on respondent certainty. Perceived change was assessed with two independent measures: a reporting-frequency generalised linear mixed model with grid-cell and respondent random effects, and the proportion of respondents reporting decline. Contemporary ranges were near-universal for most species: estimated occupancy was near its ceiling, and no environmental covariate was distinguishable from zero. Against this broad range persistence, four large carnivores showed convergent decline on both measures: tiger (*Panthera tigris*), Tibetan wolf (*Canis lupus chanco*), snow leopard (*Panthera uncia*) and common leopard (*Panthera pardus*). Reporting frequency declined significantly for tiger (77% to 45%) and Tibetan wolf (27% to 16%), and 82–100% of respondents who expressed a trend perceived declines across the four carnivores. Prey species were largely stable in range, although several were perceived to have declined in abundance. Perceived retaliatory killing co-occurred with grazing pressure across grid cells (Pearson's r = 0.57), strongest for wolves. These results indicate that decline is manifesting as reduced encounter frequency rather than range contraction — an early-warning window in which targeted action on livestock conflict may still be effective. Local ecological knowledge, analysed with frameworks matched to its structure, provides a defensible, low-cost basis for detecting large-carnivore change where instrumented monitoring is difficult.

1. Introduction

The Eastern Himalayas are among the world's most species-rich and threatened mountain ecosystems. Steep elevational gradients compress habitats from subtropical forest to permanent snowfields across short horizontal distances, supporting exceptional concentrations of endemic vertebrates (Mittermeier et al. 2004; Myers et al. 2000). The region is also changing rapidly: extensive, often unrecorded deforestation is projected to erode a substantial fraction of its endemic biodiversity this century (Pandit et al. 2007).

Arunachal Pradesh, India's north-eastern frontier state, lies at the core of this hotspot and supports a large-mammal assemblage of global conservation significance, including snow leopard, tiger, clouded leopard, red panda, and several ungulate taxa occurring at or near the limits of their ranges. Yet quantitative estimates of species occurrence and population trend remain sparse across the state. Earlier fieldwork documented the high-altitude mammal fauna and its threats but rarely quantified occurrence or trend (Mishra et al. 2006), and recent camera-trap surveys have characterized mammal

distributions mainly in the state's forested, lower-elevation zones (Ahmad and Gopi 2025). Rugged terrain, restricted access, and limited research infrastructure have constrained systematic wildlife surveys in the remote high-altitude band, even though such surveys have produced occurrence baselines in more accessible parts of the Indian Himalaya (Sharma and Singh 2020)

Large carnivores are especially poorly resolved and are also among the most threatened mammal groups. Most of the world's large carnivore species are declining and have undergone major range contractions through persecution and prey loss (Ripple et al. 2014; Wolf and Ripple 2017). In high-altitude Arunachal Pradesh, their low densities and vast, inaccessible ranges make camera-trap or sign-based surveys difficult to scale for detecting landscape-level change.

Participatory ecological surveys offer a practical complementary strategy in these settings (Danielsen et al. 2009). Interview-based local ecological knowledge can provide reliable and cost-effective information on the abundance, distribution, and trends of large-bodied wildlife across spatial extents that instrumented methods cannot easily match (Anadón et al. 2009; Jones et al. 2008; Parry and Peres 2015). Agropastoral and hunter-gatherer communities in the Eastern Himalayas hold detailed, spatially explicit knowledge of wildlife occurrence built through long-term interaction with the landscape. Such knowledge can help identify both where species occur and how their populations are perceived to be changing.

Translating interview records into defensible inference requires matching the analysis to the structure of the data. Three features of landscape-scale interview data are particularly important. First, multiple respondents within a grid cell are not independent observers: they may share access routes, social networks, and collective knowledge, so treating each person as an independent replicate can inflate precision. Second, at a 10 × 10 km grain, a species is recorded as present if any knowledgeable resident knows it occurs anywhere in the cell; for wide-ranging and recognisable taxa, this reporting rate can approach a ceiling, leaving little dynamic range for detecting temporal change in grid-cell occupancy. Third, the historical baseline depends on retrospective recall and is therefore vulnerable to memory decay and shifting baseline effects, in which communities progressively lose track of former abundance (Papworth et al. 2009; Turvey et al. 2010).

These features have a clear implication. For an assemblage whose ranges are near-universal, differencing occupancy between periods is unlikely to provide the most informative signal of change. We therefore separate two questions that the data can answer well. First, we use community occupancy modelling to describe contemporary distribution in 2017, treating respondents as within-cell replicates so that detection is identifiable. This approach parallels recent work combining local knowledge with occupancy estimation for elusive large mammals (Brittain et al. 2020). Second, we assess change directly through respondents' accounts, using both the frequency with which species are reported now versus in recall of the past and respondents' explicit judgements of population decline. Agreement between these independent measures, especially when specific to particular species rather than shared

across the assemblage, makes the inference of decline more robust to the limitations of any single measure.

This study addresses three questions for 16 focal mammal species across the high-altitude terrain of Arunachal Pradesh: (1) What is the contemporary (2017) distribution of the focal assemblage, and is it structured by environmental gradients at the landscape scale (2) Which species show community-perceived decline since approximately 1998, and do independent measures of change converge? (3) What local threats do communities associate with the species that are declining?

By combining a contemporary distribution baseline with convergent evidence of perceived change, the analysis provides a defensible and reproducible framework for monitoring large carnivores and other elusive mammals in landscapes where field-based monitoring remains difficult to implement.

2. Methods

2.1 Study area

We conducted the study in high-altitude terrain above 3,500 m in Arunachal Pradesh, north-east India, along the state's northern boundary with Tibet (China). Surveys were restricted to this elevation band because potential snow leopard habitat and associated high-altitude mammal assemblages are most consistently reported there. The 312 surveyed grid cells (10 × 10 km) covered eleven districts across the state's east–west extent, from approximately 91°E to 97°E along the Tibetan border.

Above 3,500 m, vegetation transitions from upper montane and subalpine conifer forest to rhododendron–juniper scrub, alpine meadows, scree slopes, and permanent snowfields. The study extent includes several notified protected areas, including national parks and wildlife sanctuaries. Local ecological knowledge of this zone is held primarily by transhumant herders who graze livestock seasonally at high elevations and by village residents who use alpine areas for medicinal-plant collection, herding, and other livelihood activities.

2.2 Interview surveys

In 2017, we conducted structured interviews in 128 villages across the study landscape. For each of 16 focal mammal species, interviews recorded respondent-level reports of current presence in 2017 and recalled presence around 1998. The focal species included apex predators, large ungulates, and other conservation-relevant taxa (Table 1). Respondents classified each species record as certain or uncertain based on their confidence. When they expressed an opinion, they also reported whether the local population had decreased, remained stable, or increased. They rated the perceived local severity of eight potential threats as low, medium, or high, including retaliatory killing of carnivores and livestock grazing. The final dataset comprised 2,434 respondent records georeferenced to 10 × 10 km grid cells within a 312-cell spatial sampling framework, with a median of six respondents per cell.

2.3 Contemporary distribution

We estimated the contemporary (2017) distribution of each species using a single-season, multi-species community occupancy model that accounts for imperfect detection (MacKenzie et al. 2002, 2006; Zipkin et al. 2010). The model was fitted with the msPGOcc function in spOccupancy (Doser et al. 2022). To make detection probability identifiable, we retained individual respondents within each grid cell as replicate observations rather than collapsing responses to one record per cell. Detection was modelled as a function of respondent-reported certainty. Occupancy was modelled as a function of mean grid-cell elevation, a human-pressure index combining standardised night-time light intensity and population density, and percentage forest cover in 2000 (Hansen et al. 2013). All covariates were standardised to zero mean and unit variance. Community hyperpriors pooled species-level parameters toward assemblage means, improving estimates for sparsely reported taxa (Dorazio and Royle 2005; Kéry and Royle 2016; Northrup and Gerber 2018). The model describes current known occurrence and was not used to infer temporal change, for the reasons outlined in Section 1. We fitted three chains of 10,000 iterations, with a 5,000-iteration burn-in and thinning by 5.

2.4 Perceived change since 1998

Because contemporary distributions were near-universal (Section 3.1), we evaluated change using respondent accounts rather than occupancy differences. We used two independent indicators: reporting frequency and perceived population trend.

Reporting frequency. For each species, we modelled respondent-level reported presence by survey period, comparing recalled presence around 1998 with reports from 2017. We fitted a binomial generalised linear mixed model with crossed random intercepts for grid cell and respondent (lme4; Bates et al. 2015). This treated each respondent's report as the observation unit while accounting for shared grid-cell knowledge and the paired reports contributed by each respondent. A significant negative period coefficient indicated that a smaller proportion of respondents reported the species in 2017 than in recall of 1998.

Perceived trend. We calculated the percentage of respondents who said a species had decreased (excluding those who were unsure or saw no trend). For each percentage, we calculated a 95% confidence interval to show the estimate's precision. Because this method relies on direct human observation rather than comparing historical records, its potential biases differ from the reporting-frequency analysis.

Convergence. We classified decline evidence as strong when both indicators agreed: a significant reporting-frequency decline (period coefficient < 0, $p < 0.05$) and perceived decline by at least 60% of respondents, with $n \geq 20$. Evidence was classified as moderate when only one criterion was met. Agreement between indicators with different failure modes, especially when restricted to particular species rather than the full assemblage, supported interpretation of decline as a biological signal rather than an artefact of retrospective recall.

2.5 Perceived threats

We summarised respondent severity ratings for each of the eight threats as per-grid-cell severity scores. For the two threats most relevant to the declining carnivores—retaliatory killing and livestock grazing—we estimated the proportion of grid cells where retaliation was perceived and calculated the Pearson correlation between per-cell retaliation and grazing scores. These values represent respondent-perceived threat associations, not measured causes of population change. All analyses were conducted in R v4.4 (R Core Team 2024).

3. Results

3.1 Contemporary distribution is near-universal

Estimated contemporary occupancy was near the upper bound for the full assemblage. Posterior mean occupancy in 2017 was ≥ 0.999 for all 16 species, and the community-level occupancy intercept was 8.1 on the probit scale (95% credible interval 6.8 to 9.8), indicating near-certain presence across the surveyed grid. No environmental covariate was distinguishable from zero at the community level: elevation (0.20; 95% CrI − 1.34 to 1.55), human pressure (1.19; 95% CrI − 0.06 to 3.09), and forest cover (0.15; 95% CrI − 1.57 to 1.61) all had credible intervals spanning zero (Table S1). No covariate excluded zero for any individual species. At the 10 × 10 km grain, the focal mammals are therefore near-universally present across high-altitude Arunachal Pradesh, and their contemporary distribution is not clearly structured by these landscape gradients. This result frames the change analysis: because occupancy is close to its ceiling, distributional differencing has limited power, and the more informative signal lies in encounter frequency and perceived trend.

3.2 Four large carnivores show convergent decline

Four large carnivores declined on both independent measures (Table 1; Fig. 1). Tiger showed the steepest change, with reporting falling from 77% of respondents in recall of 1998 to 45% in 2017 (period effect $p < 0.001$); all 638 respondents who expressed a trend perceived decline. Tibetan wolf reporting declined from 27% to 16% ($p < 0.001$), and all 106 respondents who expressed a trend perceived decline. Snow leopard (81% to 78%; $p = 0.004$; 82% of 200 respondents perceiving decline) and common leopard (89% to 87%; $p = 0.03$; 88% of 113) showed smaller but concordant declines. These four species were the only members of the assemblage for which reporting frequency and perceived trend both indicated decline.

Figure 1 shows this convergence clearly. The four carnivores separate from the rest of the assemblage by combining a substantial drop in reporting frequency with a high proportion of respondents perceiving decline. No prey species combines these two features.

Contemporary reporting of the four carnivores spanned the survey landscape but varied in intensity (Fig. 2). Snow leopard and common leopard were reported by a majority of respondents across most cells, whereas tiger and Tibetan wolf were reported more sparsely and locally, mainly in the western and

central sectors. This spatial pattern is consistent with the change results: the two most steeply declining carnivores are now the most patchily reported.

3.3 Prey and other species are largely stable in range

The remaining twelve species showed at most negligible change in reporting frequency between periods. Their declines were 0.01 or less, compared with 0.02 to 0.32 for the four carnivores (Table 1). The only statistically significant reporting decline among them was in bharal, but this amounted to a single percentage point and was not accompanied by majority-perceived decline.

Several species were nevertheless widely perceived to have declined in abundance while remaining near-universally reported: musk deer (98% of respondents perceiving decline), sun bear (91%), clouded leopard (81%), takin (79%), and Himalayan black bear (77%). This pattern is consistent with reduced abundance within still-occupied cells rather than range contraction. A further group showed neither reporting-frequency decline nor majority-perceived decline, including red goral (36%), serow (28%), dhole (16%), and red panda (10%).

The absence of a convergent decline signal across most prey and smaller taxa is informative. It indicates that the carnivore signal is not simply a blanket, recall-driven tendency to report the past as richer than the present.

3.4 Perceived threats to the declining carnivores

Retaliatory killing of carnivores was perceived as a threat in 63% of surveyed grid cells, predominantly at low severity. Perceived retaliation co-occurred with perceived grazing pressure across grid cells (Pearson's r = 0.57 between the two per-cell severity scores). Because both scores derive from the same interviews, this pattern reflects respondent-perceived co-occurrence rather than a demonstrated driver of decline. Even so, it is consistent with a structural conflict in which seasonal grazing of domestic yaks and sheep overlaps spatially with wolf and snow leopard hunting areas in high-altitude rangelands, increasing livestock depredation and subsequent retaliation. The association was strongest for wolves, the carnivore most directly implicated in livestock conflict in these rangelands.

4. Discussion

4.1 Decline as encounter-frequency loss preceding range contraction

The central result is a convergent, guild-specific signal. Four large carnivores, tiger, Tibetan wolf, snow leopard, and common leopard, were reported by fewer respondents than in recall of the past and were also widely perceived to have declined, even though their ranges remain near-universal at the landscape scale. Taken together, these results locate decline in encounter frequency and perceived abundance rather than in range contraction. Range contraction is the eventual, well-documented signature of large-carnivore decline worldwide (Wolf and Ripple 2017), but it is a lagging indicator. A wide-ranging,

recognisable carnivore can remain known to occur somewhere within a 10 × 10 km cell long after its local density has fallen substantially; grid-cell presence changes only once the species becomes genuinely unknown to residents. Detecting decline while ranges are still intact creates an early-warning window in which management can act before contraction and local extirpation begin.

4.2 Why the pattern is signal, not recall artefact

Retrospective baselines are vulnerable to memory decay and shifting baseline syndrome, in which even large losses of formerly common species may pass unremarked as each generation resets its reference point (Papworth et al. 2009; Turvey et al. 2010). No single interview-based measure can fully escape these biases, but two features of the results reduce this concern. First, the two measures have different failure modes: reporting frequency compares presence records across periods, whereas the perceived-trend question elicits a direct judgement. Yet both measures agree for the same four species. Second, the signal is specific. Most prey and smaller taxa show neither a reporting-frequency decline nor majority-perceived decline. A general tendency to remember the past as richer would be expected to depress reporting across the whole assemblage, not selectively for large carnivores. The guild-specificity of the pattern, and its concentration in taxa most exposed to persecution and conflict, are difficult to reconcile with recall bias alone. Local ecological knowledge is also generally most accurate for large-bodied, culturally salient species (Anadón et al. 2009; Parry and Peres 2015), the taxa on which the central inference rests.

4.3 The declining carnivores

Tiger. Tigers occur at remarkably high elevations across the Eastern Himalayas. In neighbouring Bhutan, they breed from the lowlands to above 4,000 m (Tempa et al. 2013), and the study landscape lies within their range. The steep reporting decline (77% to 45%) and unanimous perceived decline (100% of 638 respondents) make the tiger the clearest signal in the assemblage and a priority for targeted verification and protection.

Tibetan wolf (*Canis lupus chanco* **).** The Tibetan wolf is now recognised as an ancient, high-altitude-adapted lineage of global evolutionary and conservation significance (Werhahn et al. 2020). It was assessed separately by the IUCN in 2023 and listed as Vulnerable, with an estimated 2,275–3,792 mature individuals and a suspected continuing decline (IUCN 2023). In this study, its reporting frequency fell by more than a third (27% to 16%), and every respondent expressing a trend perceived decline. Retaliatory killing linked to livestock depredation is the most plausible driver in these rangelands. Across the Indian trans-Himalaya, the wolf is among the carnivores most heavily implicated in livestock loss and subsequent persecution (Mishra 1997; Suryawanshi et al. 2013). Although Tibetan wolves are protected under Schedule I of the Indian Wildlife (Protection) Act, enforcement is limited in remote high-elevation grazing areas, and the wolf attracts less conservation attention and public sympathy than sympatric felids.

Snow leopard and common leopard. Both species showed smaller but concordant declines on the two measures. The snow leopard was downlisted globally from Endangered to Vulnerable in 2017 but

remains in continuing decline, with fewer than an estimated 4,000 mature individuals across its range (McCarthy et al. 2017). For a landscape whose conservation identity is built around the snow leopard, an 82% majority perceiving decline, combined with a significant although modest drop in reporting frequency, warrants sustained monitoring rather than reassurance from its still-near-universal range. This also underscores a broader point: perceptions of large-carnivore status can diverge from measured trends (Suryawanshi et al. 2013), which is why convergence across independent measures matters.

4.4 Conflict as the management lever

The co-occurrence of perceived retaliatory killing with grazing pressure, strongest for wolves, points to livestock conflict as the most tractable management lever for the declining carnivores. Livestock depredation and the retaliation it provokes are long-recognised as dominant threats to snow leopards and wolves across the Indian trans-Himalaya (Mishra 1997; Suryawanshi et al. 2013). Practical measures should target the mechanism most directly implicated by the community accounts. These include predator-proof corralling at seasonal pastures and community-based compensation or insurance schemes adapted to migratory high-altitude herders. Context-specific versions of these interventions have reduced conflict elsewhere in the region (Bijoor et al. 2021). Because retaliation was reported predominantly at low severity and across a majority of cells, the conflict appears diffuse rather than acute. This favours landscape-wide, incentive-based approaches over localised enforcement.

4.5 Value and limits of local ecological knowledge

This study illustrates both the reach and the constraints of local ecological knowledge for monitoring elusive mammals. Its reach is evident in the scale of inference: a single interview campaign resolved contemporary distribution and detected a coherent large-carnivore decline across a landscape where instrumented monitoring at comparable extent would be prohibitively costly. Similar efficiencies have been demonstrated repeatedly for interview-based monitoring of elusive large mammals (Brittain et al. 2020; Jones et al. 2008; Parry and Peres 2015). The principal constraint is the retrospective baseline. The 1998 comparison rests on recall, and although convergence and guild-specificity argue against a pure artefact, some component of the estimated change may still reflect biased historical reporting. Two further limitations affect interpretation. Apparent distribution depends on interview effort, which is higher in accessible, lower-elevation, more-settled cells, so contemporary occupancy is partly confounded with sampling geography. At a 10 × 10 km grain with near-universal occupancy, the data speak to encounter frequency and perceived trend, not to fine-scale range or density. These limitations affect precision and resolution, but not the direction of the carnivore signal, which is supported by two independent measures.

4.6 Conservation implications and future directions

Community knowledge identifies four large carnivores, tiger, Tibetan wolf, snow leopard, and common leopard, as priorities for conservation attention in high-altitude Arunachal Pradesh. It also points to livestock conflict, especially for wolves, as the most actionable pressure. We recommend three complementary next steps: targeted camera-trap verification of the carnivore declines in a representative

subset of grid cells, prioritising tiger and Tibetan wolf; a repeat interview campaign on the same grid during 2026–2027 to convert the retrospective comparison into a prospective, contemporaneous time series; and community-based conflict-mitigation trials in high-altitude rangelands where retaliation and grazing most strongly co-occur. Detecting decline while ranges remain intact is an opportunity; acting before contraction begins is the task.

5. Conclusions

Analysed with frameworks matched to its structure, local ecological knowledge from 2,434 interviews across high-altitude Arunachal Pradesh yields a clear and defensible result: four large carnivores show convergent decline, evident in both reduced reporting frequency and directly perceived population trends, even as the wider mammal assemblage remains near-universally distributed. The decline is appearing as lost encounters rather than lost range, an early-warning signal concentrated in the guild most exposed to persecution and livestock conflict. Participatory knowledge, interpreted through the convergence of independent measures rather than through near-ceiling occupancy differencing, offers a low-cost and reproducible basis for monitoring elusive large carnivores where conventional field methods cannot reach.

Table 1. Contemporary distribution and community-perceived change for 16 mammal species across high-altitude Arunachal Pradesh. Occupancy 2017 = posterior mean occupancy from the single-season community model. Reporting 1998 / 2017 = fraction of respondents reporting the species; Δ = decline in reporting frequency; p = period effect from the reporting-frequency GLMM. Perceived decline = percentage of respondents perceiving population decline (n expressing a trend). Signal: strong = both measures indicate decline; moderate = one measure; none = neither. Species ordered by reporting-frequency decline.

Species	Occ. 2017	Rep. 1998	Rep. 2017	Δ	p	% decline (n)	Signal
Tiger	1.00	0.77	0.45	0.32	<0.001	100 (638)	strong
Tibetan wolf	1.00	0.27	0.16	0.11	<0.001	100 (106)	strong
Snow leopard	1.00	0.81	0.78	0.03	0.004	82 (200)	strong
Common leopard	1.00	0.89	0.87	0.02	0.034	88 (113)	strong
Bharal	1.00	0.62	0.61	0.01	0.013	47 (51)	moderate
Himalayan black bear	1.00	1.00	0.99	0.01	0.60	77 (267)	moderate
Musk deer	1.00	0.96	0.95	0.01	0.20	98 (831)	moderate
Clouded leopard	1.00	0.87	0.87	0.00	0.26	81 (133)	moderate
Takin	1.00	0.96	0.95	0.00	0.36	79 (162)	moderate
Sun bear	1.00	0.34	0.34	0.00	0.88	91 (124)	moderate
Dhole	1.00	0.99	0.99	0.00	0.55	16 (68)	none
Chinese goral	1.00	0.01	0.01	0.00	0.55	— (0)	none
Serow	1.00	0.98	0.98	0.00	0.28	28 (86)	none
Red goral	1.00	0.64	0.64	0.00	1.00	36 (66)	none
Himalayan goral	1.00	0.58	0.58	0.00	1.00	0 (28)	none
Red panda	1.00	1.00	1.00	0.00	—	10 (88)	none

Declarations

Competing interests.

The authors declare that they have no competing interests.

Ethics approval.

Approval for the study was obtained from WWF-India's ethics committee. The study involved voluntary, non-invasive interviews with adult community members and did not collect biological samples or sensitive personal data. Interviews were conducted in accordance with WWF-India's institutional guidelines and standard ethical practice for social-science research on local ecological knowledge.

Consent to participate.

Verbal informed consent was obtained from every participant before each interview, following an explanation of the study's purpose and of the voluntary and anonymous nature of participation.

Consent for publication.

Not applicable; no individually identifiable personal data are reported.

Clinical trial number

not applicable.

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Author Contribution

Conceptualization: R.K.S. Methodology: R.K.S. Investigation: R.P. Formal analysis: R.K.S. and A.D. Data curation: R.K.S., R.P. and A.D. Writing original draft: R.K.S. Writing – review and editing: R.K.S., R.P. and A.D. All authors reviewed and approved the final manuscript.

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Data Availability

The interview datasets generated and analysed during the current study are not publicly available because they contain sensitive information including the locations of species vulnerable to hunting and poaching, village locations, and individual respondent details the release of which could facilitate wildlife crime or compromise the confidentiality of participating communities. Anonymised, aggregated data supporting the findings of this study, together with the analysis code, are available from the corresponding author on reasonable request.

References

1. Ahmad A, Gopi GV (2025) Understanding multi-scale and multi-species habitat selection by mammals in the eastern Himalayan biodiversity hotspot. Ecol Evol 15:e71247. https://doi.org/10.1002/ece3.71247
2. Anadón JD, Giménez A, Ballestar R, Pérez I (2009) Evaluation of local ecological knowledge as a method for collecting extensive data on animal abundance. Conserv Biol 23:617–625. https://doi.org/10.1111/j.1523-1739.2008.01145.x
3. Bates D, Mächler M, Bolker B, Walker S (2015) Fitting linear mixed-effects models using lme4. J Stat Softw 67:1–48. https://doi.org/10.18637/jss.v067.i01
4. Bijoor A, Khanyari M, Dorjay R, Lobzang S, Suryawanshi KR (2021) A need for context-based conservation: incorporating local knowledge to mitigate livestock predation by large carnivores. Front Conserv Sci 2:766086. https://doi.org/10.3389/fcosc.2021.766086
5. Brittain S, Ngo Bata M, De Ornellas P, Milner-Gulland EJ, Rowcliffe M (2020) Combining local knowledge and occupancy analysis for a rapid assessment of the forest elephant Loxodonta cyclotis in Cameroon's timber production forests. Oryx 54:90–100. https://doi.org/10.1017/S0030605317001569
6. Danielsen F, Burgess ND, Balmford A, Donald PF, Funder M, Jones JPG, Alviola P, Balete DS, Blomley T, Brashares J, Child B, Enghoff M, Fjeldså J, Holt S, Hübertz H, Jensen AE, Jensen PM, Massao J, Mendoza MM, Ngaga Y, Poulsen MK, Rueda R, Sam M, Skielboe T, Stuart-Hill G, Topp-Jørgensen E, Yonten D (2009) Local participation in natural resource monitoring: a characterization of approaches. Conserv Biol 23:31–42. https://doi.org/10.1111/j.1523-1739.2008.01063.x
7. Dorazio RM, Royle JA (2005) Estimating size and composition of biological communities by modeling the occurrence of species. J Am Stat Assoc 100:389–398. https://doi.org/10.1198/016214505000000015
8. Doser JW, Finley AO, Kéry M, Zipkin EF (2022) spOccupancy: an R package for single-species, multi-species, and integrated spatial occupancy models. Methods Ecol Evol 13:1670–1678. https://doi.org/10.1111/2041-210X.13897
9. Hansen MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, Thau D, Stehman SV, Goetz SJ, Loveland TR, Kommareddy A, Egorov A, Chini L, Justice CO, Townshend JRG (2013) High-resolution global maps of 21st-century forest cover change. Science 342:850–853. https://doi.org/10.1126/science.1244693
10. IUCN (2023) The IUCN Red List of Threatened Species. Version 2023-1. https://www.iucnredlist.org
11. Jones JPG, Andriamarovololona MM, Hockley N, Gibbons JM, Milner-Gulland EJ (2008) Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. J Appl Ecol 45:1205–1212. https://doi.org/10.1111/j.1365-2664.2008.01487.x
12. Kéry M, Royle JA (2016) Applied hierarchical modeling in ecology: analysis of distribution, abundance and species richness in R and BUGS, volume 1: prelude and static models. Academic, London

13. MacKenzie DI, Nichols JD, Lachman GB, Droege S, Royle JA, Langtimm CA (2002) Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255. https://doi.org/10.1890/0012-9658(2002)083[2248:ESORWDP]2.0.CO;2
14. MacKenzie DI, Nichols JD, Royle JA, Pollock KH, Bailey L, Hines JE (2006) Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier, Amsterdam
15. McCarthy T, Mallon D, Jackson R, Zahler P, McCarthy K (2017) Panthera uncia. The IUCN Red List of Threatened Species 2017. https://doi.org/10.2305/IUCN.UK.2017-2.RLTS.T22732A50664030.en. e.T22732A50664030
16. Mishra C (1997) Livestock depredation by large carnivores in the Indian trans-Himalaya: conflict perceptions and conservation prospects. Environ Conserv 24:338–343. https://doi.org/10.1017/S0376892997000441
17. Mishra C, Madhusudan MD, Datta A (2006) Mammals of the high altitudes of western Arunachal Pradesh, eastern Himalaya: an assessment of threats and conservation needs. Oryx 40:29–35. https://doi.org/10.1017/S0030605306000032
18. Mittermeier RA, Gil PR, Hoffmann M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, da Fonseca GAB (2004) Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions. CEMEX, Mexico City
19. Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858. https://doi.org/10.1038/35002501
20. Northrup JM, Gerber BD (2018) A comment on priors for Bayesian occupancy models. PLoS ONE 13:e0192819. https://doi.org/10.1371/journal.pone.0192819
21. Pandit MK, Sodhi NS, Koh LP, Bhaskar A, Brook BW (2007) Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. Biodivers Conserv 16:153–163. https://doi.org/10.1007/s10531-006-9038-5
22. Papworth SK, Rist J, Coad L, Milner-Gulland EJ (2009) Evidence for shifting baseline syndrome in conservation. Conserv Lett 2:93–100. https://doi.org/10.1111/j.1755-263X.2009.00049.x
23. Parry L, Peres CA (2015) Evaluating the use of local ecological knowledge to monitor hunted tropical-forest wildlife over large spatial scales. Ecol Soc 20:15. https://doi.org/10.5751/ES-07601-200315
24. R Core Team (2024) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna
25. Ripple WJ, Estes JA, Beschta RL, Wilmers CC, Ritchie EG, Hebblewhite M, Berger J, Elmhagen B, Letnic M, Nelson MP, Schmitz OJ, Smith DW, Wallach AD, Wirsing AJ (2014) Status and ecological effects of the world's largest carnivores. Science 343:1241484. https://doi.org/10.1126/science.1241484
26. Sharma RK, Singh R (2020) Over 100 years of snow leopard research: a spatially explicit review of the state of knowledge in the snow leopard range. WWF, Gland, Switzerland.

https://www.worldwildlife.org/publications/over-100-years-of-snow-leopard-research-a-spatially-explicit-review-of-the-state-of-knowledge-in-the-snow-leopard-range

27. Suryawanshi KR, Bhatnagar YV, Redpath S, Mishra C (2013) People, predators and perceptions: patterns of livestock depredation by snow leopards and wolves. J Appl Ecol 50:550–560. https://doi.org/10.1111/1365-2664.12061
28. Tempa T, Hebblewhite M, Mills LS, Wangchuk TR, Norbu N, Wangchuk T, Nidup T, Dendup P, Wangchuk D, Wangdi Y, Dorji T (2013) Royal Manas National Park, Bhutan: a hot spot for wild felids. Oryx 47:207–210. https://doi.org/10.1017/S0030605312001317
29. Turvey ST, Barrett LA, Hao Y, Zhang L, Zhang X, Wang X, Huang Y, Zhou K, Hart T, Wang D (2010) Rapidly shifting baselines in Yangtze fishing communities and local memory of extinct species. Conserv Biol 24:778–787. https://doi.org/10.1111/j.1523-1739.2009.01395.x
30. Werhahn G, Liu Y, Meng Y, Cheng C, Lu Z, Atzeni L, Deng Z, Shi K, Shao X, Lu Q, Joshi J, Man Sherchan A, Karmacharya D, Kumari Chaudhary H, Kusi N, Weckworth B, Kachel S, Rosen T, Kubanychbekov Z, Karimov K, Kaden J, Ghazali M, Macdonald DW, Sillero-Zubiri C, Senn H (2020) Himalayan wolf distribution and admixture based on multiple genetic markers. J Biogeogr 47:1272–1285. https://doi.org/10.1111/jbi.13824
31. Wolf C, Ripple WJ (2017) Range contractions of the world's large carnivores. R Soc Open Sci 4:170052. https://doi.org/10.1098/rsos.170052
32. Zipkin EF, Royle JA, Dawson DK, Bates S (2010) Multi-species occurrence models to evaluate the effects of conservation and management actions. Biol Conserv 143:479–484. https://doi.org/10.1016/j.biocon.2009.11.016

Figures

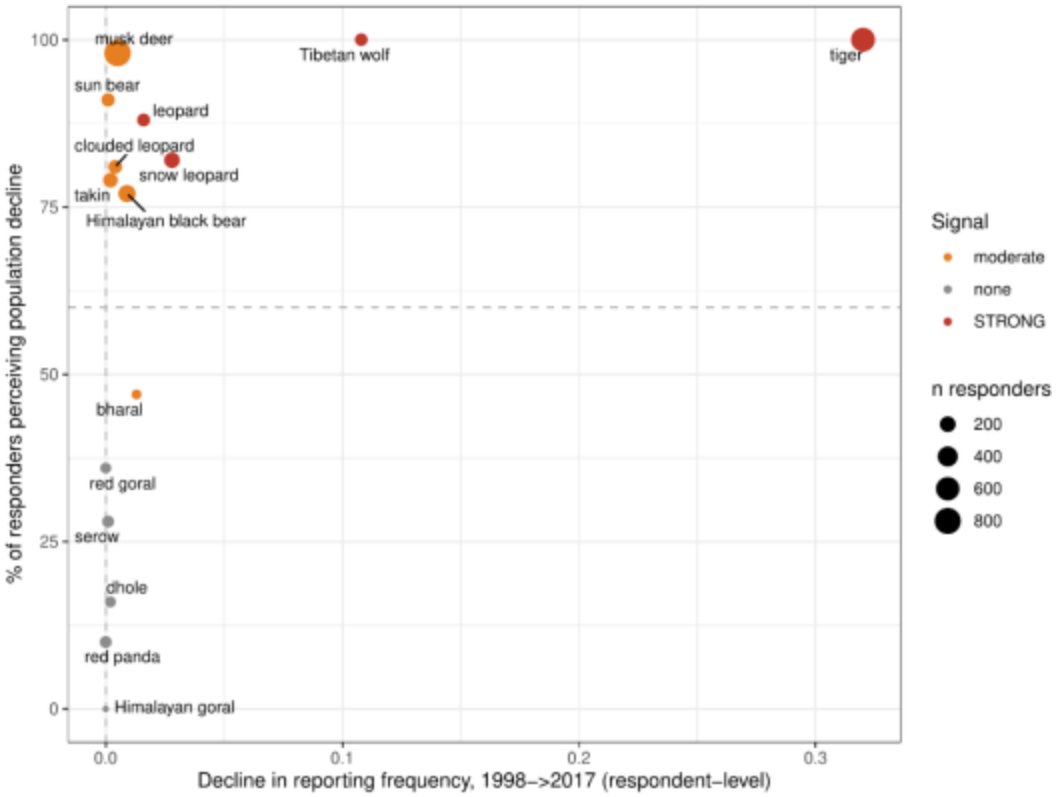


Figure 1

Convergence between two independent measures of community-perceived change for 16 mammal species. The horizontal axis shows the decline in respondent-level reporting frequency from recalled 1998 presence to 2017 reports; the vertical axis shows the percentage of respondents perceiving population decline. Point size reflects the number of respondents expressing a trend. Four large carnivores—tiger, Tibetan wolf, snow leopard, and common leopard—combine marked reporting-frequency declines with high perceived decline, placing them in the upper-right region. Most prey and smaller taxa show neither pattern. Dashed lines indicate zero reporting change and the 60% perceived-decline threshold used to classify signals.

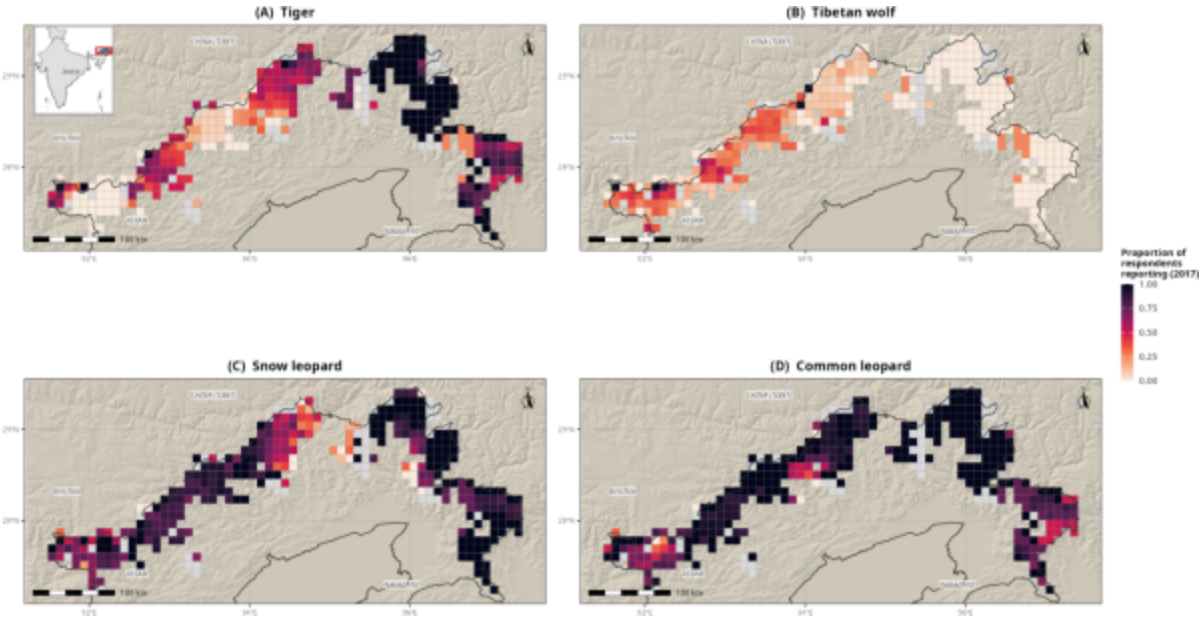


Figure 2

Contemporary (2017) distribution of the four convergently-declining large carnivores across the surveyed grid, shown as the proportion of respondents in each 10 × 10 km cell who reported the species: (A) tiger, (B) Tibetan wolf, (C) snow leopard, (D) common leopard. Darker cells indicate a higher share of respondents reporting the species; grey cells had no matching survey record. Snow leopard and common leopard are reported near-universally, whereas tiger and Tibetan wolf are reported more sparsely and locally. Inset (Panel A): location of the study area (red outline) within India, with Arunachal Pradesh shaded. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

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