Received: 19 February 2024 | Revised: 2 August 2024 | Accepted: 7 August 2024

DOI: 10.1111/cobi.14428

Conservation Biology

CONTRIBUTED PAPER

Association between attitudes toward wildlife and patterns of risk of human–wildlife conflict near Giant Panda National Park

Lan Qiu[1,2] | Qiang Dai[1] | Yihong Wang[1] | Zejun Zhang[2] | Zhisong Yang[3] | Dunwu Qi[4] | Haijun Gu[5] | Xiaodong Gu[5] | Xuyu Yang[5] | Wei Wei[2,6]

[1]Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu, China

[2]Key Laboratory of Southwest China Wildlife Resources Conservation (Ministry of Education), China West Normal University, Nanchong, China

[3]Sichuan Academy of Giant Panda, Chengdu, China

[4]Chengdu Research Base of Giant Panda Breeding, Chengdu, China

[5]Sichuan Station of Wild Life Survey and Management, Chengdu, China

[6]College of Giant Panda, China West Normal University, Nanchong, China

Correspondence
Wei Wei, Key Laboratory of Southwest China Wildlife Resources Conservation (Ministry of Education), China West Normal University, 1 Shida Road, Nanchong 637009, China.
Email: weidamon@163.com

Qiang Dai, Chengdu Institute of Biology, Chinese Academy of Sciences, 9, Section 4, Renminnan Road, Chengdu 610041, China. Email: daiqiang@cib.ac.cn

Article impact statement: Human–wildlife conflict risk and people's attitudes toward wildlife play crucial roles in determining the priority areas for conflict mitigation.

Funding information
National Natural Science Foundation of China, Grant/Award Numbers: 32070520, 32070524, 32370558, 41521003; Fundamental Research Funds for the Central Public-interest Scientific Institution, Grant/Award Number: 2020YSKY-008; Global Environment Facility (GEF) China Protected Land Management Reform Planning Project, China National Park System and Mechanism Innovation Project (C-PAR1)

Abstract

Human–wildlife conflict (HWC) is an escalating humanitarian issue and a conservation concern. In terms of protection and management, areas at high risk of HWC are not necessarily afforded the same resources as areas prioritized for protection. To improve allocation of limited protection resources and HWC mitigation efficiency, we determined management priorities based on HWC risk and people's attitudes toward wildlife around the Giant Panda National Park. We constructed an ensemble species distribution model with 1959 species' distribution loci and 337 conflict event records. This model was used to simulate the spatial distribution patterns of HWC risk and to evaluate the influence of diverse environmental factors. A survey of people's attitudes toward wildlife was conducted in 155 villages around the Giant Panda National Park. Priority areas for HWC management were concentrated near protected areas, where wildlife habitats and populations were recovering and expanding. We obtained 947 questionnaires, which showed that some residents were highly aware of conservation and had a high tolerance for wildlife, even when they were living in areas at high risk of HWC. However, people who had encountered conflicts with wild boar were more likely to have negative attitudes toward other wildlife, even giant pandas (*Ailuropoda melanoleuca*). Thus, HWC may lead to the generalization of negative attitudes toward wildlife conservation. In our study area, environmental (e.g., building fences and changing crop types) and social measures (e.g., insurance and ecocompensation) have been implemented to mitigate HWC. Our results can provide an important basis for the allocation of compensation resources and improvement of HWC management in areas of high conservation priority. Future studies should further explore how to develop more personalized HWC management plans based on the characteristics of different regions.

KEYWORDS
biodiversity conservation, Giant Panda National Park, human–wildlife conflict, interdisciplinary

INTRODUCTION

Humans have coexisted and lived in conflict with wildlife for millennia (Jordan et al., 2020), and humans have benefited from the food resources, livelihoods, and functioning ecosystems provided by biodiversity (Reid et al., 2005). However, the conflict between humans and wildlife has increased drastically because of limited space and natural resources and the expansion of human activities and climate change (Abrahms, 2021; Díaz et al., 2019). In general, human–wildlife conflict (HWC)

Lan Qiu and Qiang Dai contributed equally to this work.

refers to struggles that arise when the presence or behavior of wildlife directly threatens human interests, resulting in discord and adverse consequences for humans (e.g., crop damage, livestock predation, and property destruction) and wildlife (IUCN, 2020). This global problem involves a diverse array of species (Torres et al., 2018). In Africa and southern Asia, for instance, carnivorous animals, such as lions (*Panthera leo*) and leopards (*Panthera pardus*), prey on livestock (Butler, 2000; Patterson et al., 2004) and pose a threat to human safety (Fentaw & Duba, 2017; Liu et al., 2017). Humans worsen these conflicts by driving away or killing wild animals preemptively or in retaliation (Naidoo et al., 2016). These negative interactions between humans and wildlife not only threaten the safety of human life but also cost the global economy billions of dollars annually, while simultaneously contributing to the widespread decline of biodiversity (Ceaușu et al., 2019; Lamb et al., 2020).

Experiences with HWC arouse people's dissatisfaction with wildlife (Kansky et al., 2014; Lischka et al., 2020) and can lead to retaliatory killings and poaching (Naidoo et al., 2016). A negative attitude toward wildlife may become a major obstacle to community support for conservation (Naughton-Treves & Treves, 2005) and bring new challenges and problems to the management of HWC and biodiversity conservation (Cunha et al., 2019). To realize the vision of harmonious coexistence between humans and nature, various solutions have been proposed internationally, such as nature-based solutions (MacKinnon et al., 2008), green infrastructure, and ecological civilization (Wei et al., 2020). A United Nations' Environment Program points out that to achieve sustainable development, nations should incorporate HWC management into sustainable development goals and place it at the core of the new framework of the Convention on Biological Diversity (Gross et al., 2021).

Determining priority areas for HWC management is the key to alleviating conflict and conserving resources. Many studies have predicted the spatial distribution of HWC risk based on ecological spatial assessment models (Di Minin et al., 2021; Naha et al., 2019). In terms of protection and management, however, the areas that urgently need protection resources do not necessarily correspond to those with high HWC risk. Determination of priority areas for management is not only an ecological issue but also involves many intersecting fields, such as sociology, psychology, and economics (Nyhus, 2016). Struebig et al. (2018) propose a HWC socioecological model, which prioritizes the management of villages facing human–tiger conflicts to ensure that protection resources are invested where they are needed most to save tigers and avoid human losses. Although an increasing number of researchers suggest alleviating HWC problems with interdisciplinary methods, there have been few attempts (Ghosal & Kjosavik, 2015).

The Giant Panda National Park (GPNP) in China aims to protect the biodiversity and fragile ecosystems associated with giant pandas (*Ailuropoda melanoleuca*) and their sympatric species, promote the economic and industrial structure of local communities, enhance coordination between environmental protection and socioeconomic development, and realize the harmonious coexistence between humans and nature (Huang et al., 2020). In recent years, conflicts around GPNP have become more frequent. If timely mitigation measures are not taken, people develop widespread and irreversible negative attitudes toward wildlife, which will have a negative impact on the national park (Xu et al., 2019). For example, wild boar (*Sus scrofa*) populations have increased rapidly in recent years, causing huge losses to communities around GPNP (Nie et al., 2019). Currently, the State Forestry and Grassland Administration is preparing to take emergency action to strictly control wild boar populations around GPNP, an unprecedented, large-scale wildlife hunting operation. Therefore, it is urgent to examine the spatial distribution of HWC risks and determine the areas of priority for HWC mitigation to improve the efficiency of such efforts around GPNP.

To determine the priority areas for HWC mitigation around GPNP, we devised a novel interdisciplinary approach that combines sociology, ecology, and psychology. We investigated conflicts between humans and multiple species and explored the relationship between human psychology and wildlife conservation around GPNP. We determined sites where the species occurs, assessed the spatial distribution of HWC risks, and explored the factors that affect people's attitudes toward wildlife. Finally, we used a multiobjective decision-making model to determine the areas of priority for HWC mitigation. The model factors included the risk of HWC and human attitudes toward wildlife. We sought to provide new ideas and tools for GPNP planning and HWC management, reference and a model for the management of HWC elsewhere, and new perspectives for managing protected areas on a global scale.

METHODS

Study area

Our study area was a zone ≥20 km surrounding the GPNP. The GPNP is in the mountains of southwestern China (a global biodiversity hotspot) and was the first of 10 national parks in China. The GPNP covers 27,134 km^2, 3 provinces, and 12 cities and is integrated with giant panda nature reserves (Figure 1).

Key informant interviews and questionnaire survey

To assess the risk of HWC in the study area, key informant interviews were carried out with forestry personnel to determine the main conflict species and conflict types in the study area. We tested our semistructured questionnaire for the public with 50 local people and revised it accordingly. The final questionnaire (Appendix S15) consisted of 3 sections: demographic information, HWC incident details, and attitudes toward 4 mammal species.

Ninety townships were sampled in the study area from August 2020 to April 2021. In each township, 5–10 households (with respondents older than 18 years) were randomly selected to participate. Before interviews began, respondents were asked

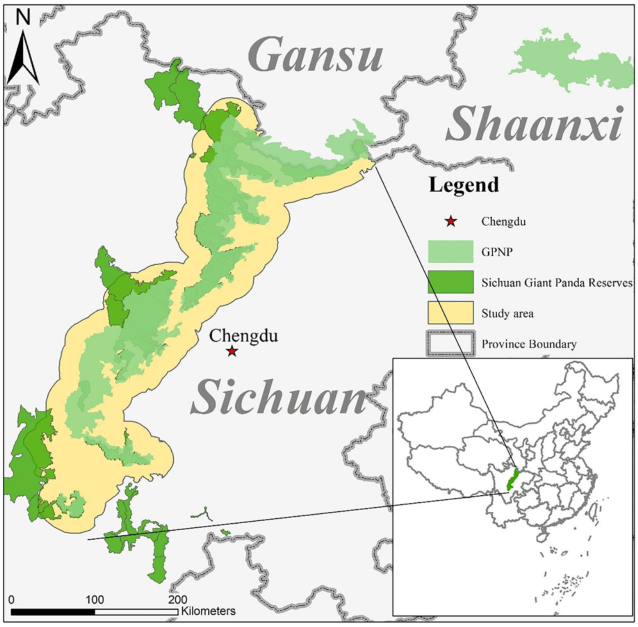

FIGURE 1 Study area in Sichuan province, China (GPNP, Giant Panda National Park).

for their consent to participation following an explanation of the research objectives, assurance that all personal information would remain strictly confidential, and an explanation that they could decline to answer any questions or stop the interview at any time. The central coordinates of the villages where the survey was conducted represented the survey sites to protect the privacy of the respondents. L.Q. conducted the interviews. The survey was conducted with informed consent from the respondents and with the approval of the Science and Technology Department, Chengdu Institute of Biology, CAS. Free, prior, and informed consent was obtained verbally from all participants. We used the Kaiser–Meyer–Olkin (KMO) measure to verify sampling adequacy. The KMO was implemented in the R package REdaS (Maier, 2015).

Demographic data collected were gender, age, ethnicity, occupation, education level, main source of income, and annual per capita household income. These factors influence people's attitudes toward wildlife (Goldman et al., 2010; Ogra, 2008).

The second part of the survey included identification of the conflict species (recognition of species verified with photographs), types of conflicts, conflict location, seasons of occurrence, and measures taken. Respondents took us to the conflict site, where we recorded the latitude and longitude, or marked the conflict location on a map.

In the third part, respondents were asked about their attitudes toward the giant panda, wild boar, Tibetan macaque (*Macaca thibetana*), and black bear (*Ursus thibetanus*). The wild boar, Tibetan macaque, and black bear are the main conflict species in the region, and we assumed attitudes toward them reflect people's attitudes toward HWC. We used attitudes toward giant pandas as an indicator of attitudes toward wildlife conservation as a whole. As a flagship conservation species, the giant panda is not only the most important conservation target of national parks but also a symbol of conservation that attracts much attention. Thus, we believe attitudes toward the giant panda could reflect attitudes toward wildlife conservation in general.

To assess respondent attitudes toward wildlife at different conflict intensities (Struebig et al., 2018), 4 conflict scenarios were used: no threat (ScenA), crop damage (ScenB), livestock preying (ScenC), and attacking humans (ScenD). To measure respondents' tolerance of wildlife (i.e., capacity of respondents to coexist with wildlife), we asked respondents whether they would prefer wildlife to be eradicated, reduced, stay the same, or increased. Answers to questions were on 5-point Likert scales (1, *very negative*; 2, *negative*; 3, *neutral*; 4, *positive*; 5, *very positive*). We therefore used the average score across the responses to represent respondent attitudes toward wildlife. All data were assigned coordinates from the center of the settlement so that household location was protected.

Data collection

Locations of wild boar, Tibetan macaque, and black bear sign were obtained from the fourth national giant panda survey (Forestry Department of Sichuan Province, 2015), and HWC locations were identified by questionnaire survey respondents (i.e., conflict locations). To avoid spatial autocorrelation affecting model predictions, locations that were <1 km apart were excluded (Dai et al., 2019). A total of 1959 sign locations (1239 for wild boars, 223 for Tibetan macaque, and 497 for black bears) and 337 conflict locations (205 for wild boars, 71 for Tibetan macaque, and 61 for black bears) were used in our analyses.

Environmental factors included topography, land cover, and climate data. Topographic data, elevation, slope, and aspect, were obtained from the Geospatial Data Cloud Platform of the Chinese Academy of Sciences Computer Network Information Center (http://www.gscloud.cn). The slope angle was transformed to the sine, and the absolute value was taken after subtracting 180° from the aspect for subsequent analyses (Qiu et al., 2019). The land-cover data were derived from the ESA CCI Land Cover project (ESA, 2017) that reclassified land cover as broadleaved forest, needle-leaved forest, cropland, grassland, shrubland, urban areas, flooded vegetation, water bodies, bare land, and permanent snow. Road data were obtained from the fundamental national geographic information system of China. Climate data were obtained from the standard of WorldClim Bioclimatic variables for WorldClim 2 (Fick & Hijmans, 2017). Protected area boundaries were obtained from the Third (SFA, 2006) and Fourth (Foretry Department of Sichuan Province, 2015) National Giant Panda Surveys. Boundaries of GPNP were obtained from Georeference based on the map in Huang et al. (2020).

All spatial variables were resampled to 90-m resolution in the unified projection coordinate system.

Habitat quality

We built a habitat suitability index (HSI) model for wild boars, Tibetan macaque, and black bears. Each species was assessed separately with MaxEnt based on location points and environmental variables (elevation, slope, aspect, land cover, and distance to roads). Variables were scaled before analyses, and collinearity was assessed using Pearson's correlation coefficients and variance inflation factors (VIFs). All predictors had $|r|$ <0.7 and VIF <3. We set the random test percentage to 25% and used 10-fold cross-validation in MaxEnt. Area under the curve (AUC) of the receiver operating curve was used to evaluate the accuracy of the model (Appendix S1) (Phillips et al., 2006). Yourdon's index was taken as the threshold to delineate habitat patches. MaxEnt was implemented in the R package dismo (Hijmans et al., 2017).

Landscape connectivity

We used the algorithm Circuitscape (www.circuitscape.org) to predict patterns of wildlife connectivity across the habitat–residential area interface based on habitat quality (Appendix S2). The rasters of urban and cropland were extracted from the land-cover data to represent human settlements at different times. The algorithm uses electronic circuit and random walk theory to simulate animal movements across areas of variable resistance (McRae et al., 2008). The Circuitscape model predicts wildlife connectivity by defining wildlife's core habitat as current sources and defining residential areas as ground points. The resistance surfaces for Circuitscape were estimated from HIS scores (1 − HSI) (Wang et al., 2008).

Spatial models of HWC risk

To determine the probability of HWCs, we produced an ensemble species distribution model (ESDM) that combined the predictions of up to 5 different spatial algorithms that predicted presence or absence: generalized linear model (GLM), multivariate adaptive regression splines (MARS), classification tree analysis (CTA), fandom forest (RF), and support vector machine (SVM). All HWC incidents were assigned a value of 1, and 10,000 localities were randomly drawn from the background and assigned a value of 0. Predictor variables included landscape connectivity (Appendix S3), distance to rivers, distance to roads, distance to protected areas, and distance to residential areas. To evaluate the predictive performance of each algorithm, we used a random subset of 70% of the data to calibrate the model and the remaining 30% for evaluation with AUC. This was replicated 10 times to calculate a mean AUC of the cross-validation. Predictions from models with moderate to good fit (AUC > 0.7) were included in the final ensemble, and the weighting of each algorithm prediction was based on its true skill statistic. Ensemble modeling was implemented in the R package SSDM (Schmitt et al., 2017). The study area was divided into low-, medium-, and high-risk areas according to the risk index predicted by ESDM: low (0–0.2), medium (0.2–0.4), and high (0.4–1).

Attitude toward wildlife

The GLMs were employed to investigate the effects of HWC risk, encounter, distance from the reserve, and personal information on attitudes toward wild boar, black bear, and Tibetan macaque. Based on Pearson's correlation coefficients employed to test the cointegration between the factors, we excluded distance to protected area in the GLM due to its high multicollinearity with risk. The models of variable combinations were analyzed to select the best fit models based on the Akaike information criterion (AIC). Models with ΔAIC <2 were considered to the best fit, and the best fit model was selected for subsequent analysis. If no single model was significantly better than another (ΔAIC $\leq$ 2), a subset of the most likely models was selected for model averaging (Lukacs et al., 2010).

We also examined whether encounters with wild boars, black bears, and Tibetan macaque affected local attitudes toward giant pandas, through a GLM model, as an indicator of the impact of HWC on local attitudes toward conservation as a whole. Model selection and averaging were conducted using the MuMIn package (Bartoń, 2013).

Prioritizing intervention

Based on HWC risks and people's attitudes toward wildlife, we established a TOPSIS (technique to order preference by similarity to ideal solution) model to integrate the ecological and social data to help prioritize interventions with limited resources in conservation. A TOPSIS model is a multicriteria decision-making technique based on the minimization of geometric distances that determines the ideal alternative by computing the relative degree of closeness to an ideal solution (RC_i) (Elsayed et al., 2017). In our study, the ideal situation was one in which the risk of HWC is low and people are tolerant of wildlife. In information theory, the entropy weight represents useful information in the evaluation index, and its value is based on the amount of information used to determine the index's weight (Li et al., 2011). These weights are inputted to the TOPSIS method, and the rank of each index is determined according to its results. A detailed explication of the TOPSIS method is in Elsayed et al. (2017). All analyses were conducted in R 4.0.5 (R Core Team, 2021).

RESULTS

Survey about HWCs and demographic information on interviewees

Of 1003 interviews, 947 were used in our analyses. The average age of respondents was 57 years, and there were 487 males and 460 females. The main source of income for 45.4% of households was farming, and household income was generally low.

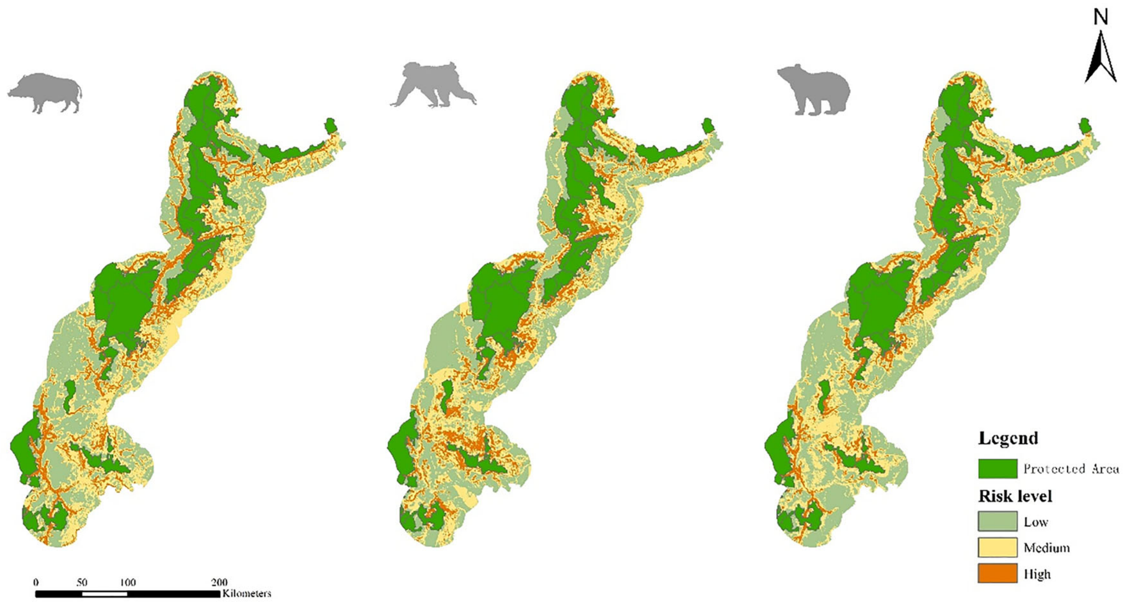

FIGURE 2 Spatial distributions of the risk of wild boar, Tibetan macaque, and black bear human–wildlife conflict in Sichuan province, China.

More than half (56.6%) of the respondents had experienced HWC during the last 5 years. Species involved in these HWC incidents were wild boar, Tibetan macaque, black bear, badgers (*Arctonyx collaris, Meles meles*), and Malayan porcupine (*Hystrix brachyura*). The species most involved in HWC were wild boar, Tibetan macaque, and black bear. The types of incidents included crop damage, fruit tree damage, beehive damage, and livestock predation. The dominant type of incident was crop damage (83.68%). There were 3 incidents of black bears injuring people (Appendix S4). A KMO analysis showed that our sample size was adequate (KMO = 0.71).

TABLE 1 Generalized linear model describing predictors of attitudes toward the giant panda of people who had encounters with 3 other species.

Species encountered	Estimate	SE	*t*
Wild boar	−0.319	0.058	−5.449***
Tibetan macaque	0.025	0.082	0.303
Black bear	0.152	0.088	1.727

Note: Positive estimates indicate preference, and negative estimates indicate avoidance. Significance: $***p \leq 0.001$.

Spatial risk of HWCs

Our ensemble model of HWC combined information from the 5 predictive algorithms with good discriminatory power (Appendix S5). Risk of HWC was most associated with connectivity of the landscape for wildlife movement, distance to rivers, distance to protected areas, distance to roads, and distance to residential areas. The most important factor was distance to roads (Appendix S6). Overall, wild boars had more medium- to high-risk areas than Tibetan macaques and black bears. These areas were concentrated in forests around PAs, but extended into the surrounding human settlements (Figure 2). Tibetan macaques and black bears (more forest dependent than wild boars) were less likely to spread to human residential areas (Appendix S7).

Attitude toward wildlife

The GLMs were used to explore the effects of social and ecological factors on attitudes toward wildlife. Model averaging was performed because there was no single model that was significantly better than another ($\Delta AIC \leq 2$). In general, attitude was driven by whether the respondent had encountered conflicts in the past; gender, age, main source of income, and income level had less effect on attitudes. The results implied that wild boar was the most problematic species for HWC in the study area and that encounters with wild boars resulted in more negative attitudes toward other wild species (Appendix S8). The GLM results suggested that people who had experienced conflicts between humans and wild boars were more likely to have negative feelings about the Tibetan macaques and black bears (second-class protected species in China) and giant pandas ($p < 0.001$) (Table 1).

Prioritizing interventions based on risk and attitude data

Our TOPSIS model showed that prioritization of villages for HWC mitigation was determined by a combination of HWC risk and respondents' attitudes toward wildlife, with risks dominating. The weight associated with wild boars was higher than the weight associated with Tibetan macaques and black bears (Appendix S9). Of the 154 villages we surveyed, 97

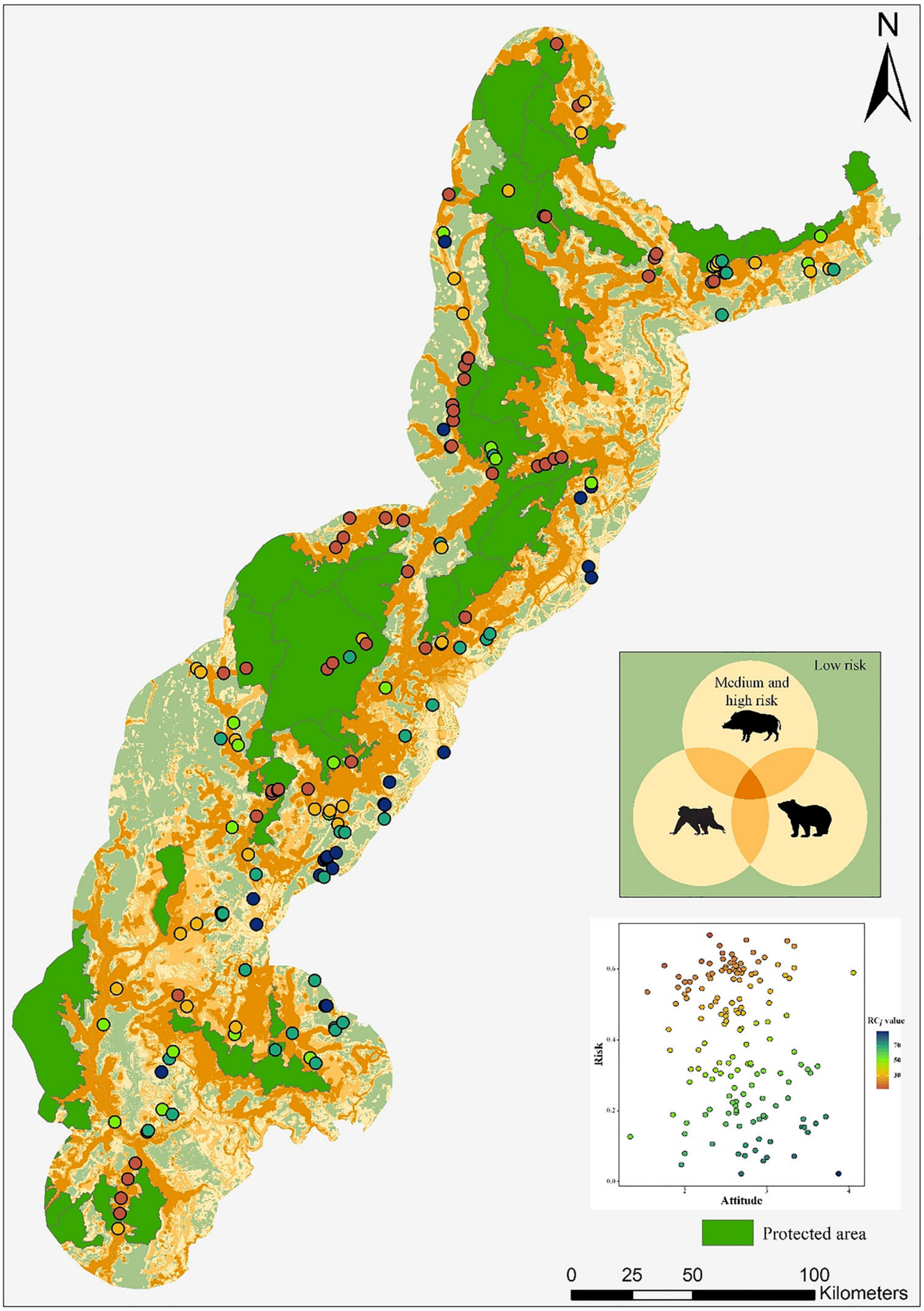

FIGURE 3 Location of villages (points) ($n = 154$) where people participated in a survey on attitudes about human–wildlife conflict (HWC) and spatial representation of risk of human conflict with boars, Tibetan macaque, and black bears (orange, overlapping areas of medium to high risk of HWC; yellow, overlapping areas of medium to high risk of HWC for 2 of the species; light yellow, medium- to high-risk areas of conflict for one of the species; light green, low-risk areas of HWC; red, high priority for HWC mitigation; blue, low priority for HWC mitigation). The relative closeness degree (RC_i) is used to illustrate the relationship between risk of HWC and attitude toward wildlife (relative degree of closeness to the ideal situation [low risk of HWC and highly positive attitude about wildlife]).

were of high priority for adopting HWC control measures ($RC_i \leq 50$). Of these villages, 69.5% were in the medium- to high-risk overlap areas of the 3 wildlife species. Fifteen percent of villages were of low priority for control measures ($RC_i > 50$) due to respondents' high tolerance for wildlife (Figure 3).

DISCUSSION

People's livelihoods and life are threatened by HWC, and their negative emotions about conservation work could arise from this conflict (Ogra, 2008). As a result, urgent action is required to prevent serious adverse effects on HWC. Our results showed

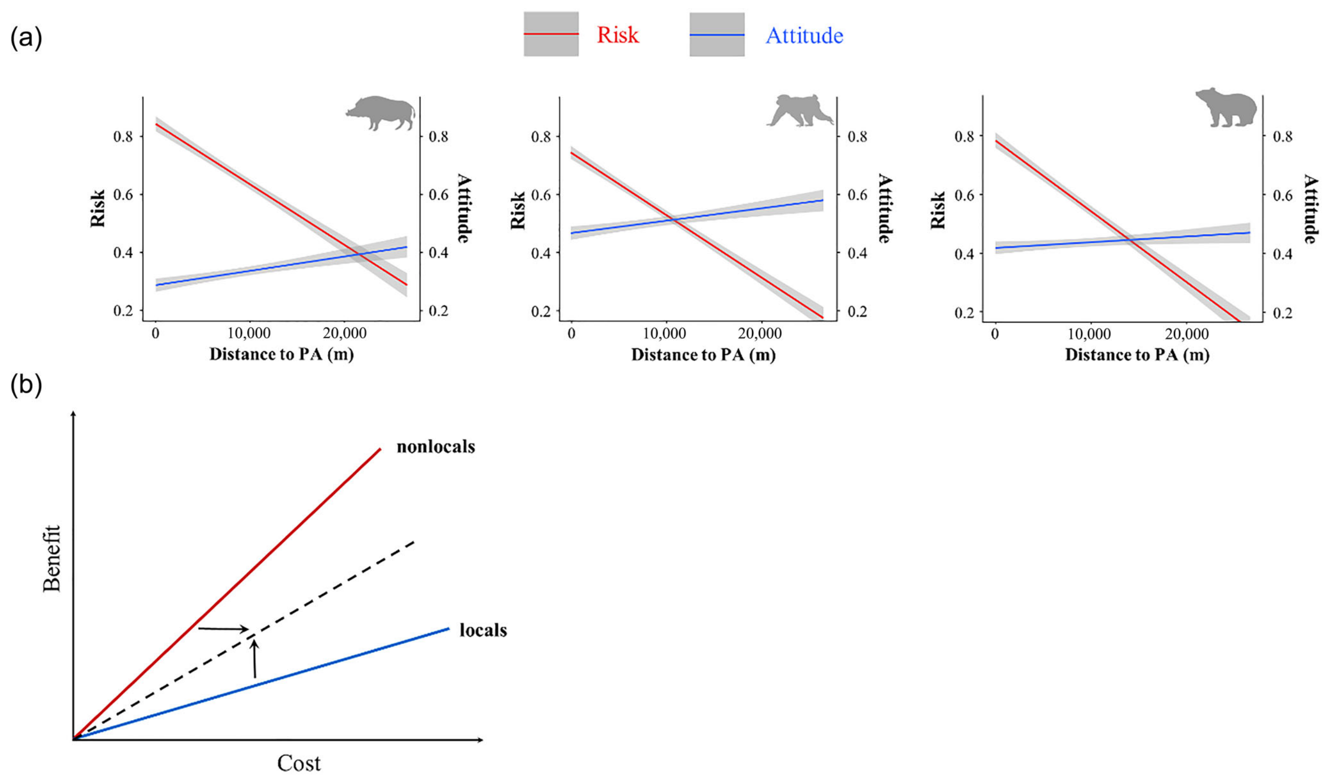

FIGURE 4 (a) Attitudes toward wildlife and risk of human–wildlife conflict (HWC) relative to distance to a protected area (PA) (attitude and risk data normalized; red line, change in risk of HWC; blue, change in attitude toward wildlife; shading, 95% confidence interval) and (b) difference in the human and wildlife coexistence benefit–cost ratio between locals (blue) and nonlocals (red) (dashed line, overlap of cost–benefit curve of locals as it moves up in the direction of the arrow and the cost–benefit curve of nonlocals as it moves to the right in the direction of the arrow).

that priority areas for HWC mitigation do not include only areas of high HWC risk. Also to be considered is the extension of negative attitudes toward HWC species to other species and their management and protection. Such generalization has far-reaching implications for conservation and management across the region.

We found that most areas of priority for management of HWC were near protected areas. In general, the distance to the protected area was significantly negatively correlated with the risk of HWC (Figure 4a). Since 1998, the implementation of various forest protection policies, such as Natural Forest Protection Project, Grain to Green, and the Nature Reserve Construction Project, has yielded remarkable outcomes in the revival of wildlife populations (Wei et al., 2020; Yue et al., 2024). Notably, flagship species, such as the giant panda, snow leopard (*Panthera uncia*), and Tibetan antelope (*Pantholops hodgsonii*), have made significant recoveries, emerging from the brink of extinction (Huang et al., 2021; Mi et al., 2023).

We also found that wild boar, Tibetan macaques, and black bears are spreading from forested areas to human settlements, meaning that wildlife connectivity to residential areas may have increased due to restoration efforts (Appendix S3). Of particular concern is the wild boar, which is capable of thriving in diverse environments, such as forests, scrublands, grasslands, and agricultural fields. Possessing a remarkable tolerance for human activities and exhibiting a robust reproductive capacity, wild boar populations expanded considerably in recent years (Nie et al., 2019).

Numerous approaches have been proposed to mitigate HWC (Bhandari et al., 2019; Sprague & Iwasaki, 2006) that require a huge investment of workforce and material resources, the results of which have not met expectations (Lindsey et al., 2018). We found that 33.69% of respondents took their own measures to mitigate HWC (e.g., building fences, setting off firecrackers, and deploying guard dogs), but the results were relatively ineffective and led to a more negative attitude toward wild animals in general (Appendix S8). To enhance the effectiveness of mitigation, we emphasize the importance of ensuring that scarce protection resources be allocated to the most critical HWC locations.

We proposed 2 approaches to mitigate HWC: environmental measures to reduce the risk of conflict and sociological measures to reduce negative perceptions of wildlife. Environmental measures should aim to mitigate HWC through preventive actions in high-risk areas, such as building fences (Kioko et al., 2008), changing crop types (Yang et al., 2020), and developing eco-tourism (Western et al., 2019). Our survey showed that tea trees were relatively less attractive wild boars, Tibetan Macaques, and black bears than vegetables, such as corn; that areas with tea trees were commonly not affected by these species; and that tea-growing residents were more tolerant of wild animals. Planting such crops in areas where human and animal interactions are common can limit wildlife connectivity to residential areas and mitigate HWC. The effectiveness of monocrops and tree plantations as HWC mitigation has been demonstrated (Yamazaki & Bwalya, 2007).

Sociological measures focus on addressing people's negative attitudes toward wildlife. In areas with low tolerance for wildlife, mitigation measures include compensation (Ring et al., 2010), wildlife accident insurance (Mishra et al., 2003), and environmental protection promotion and education (Espinosa & Jacobson, 2012). We believe that the root cause of people's negative attitudes toward wildlife is that the benefits and costs of coexisting with wildlife are unequally distributed between locals and nonlocals. Locals experience direct economic losses, psychological trauma, and even loss of life from HWC (Ogra, 2008), whereas nonlocals benefit from the ecosystem services of wildlife without a high cost (Bruskotter et al., 2017). By compensating those affected by HWC, part of the cost (Appendix S10) can be transferred to nonlocals, making nonlocals' cost–benefit consistent with locals (dotted lines in Figure 4b). Locals may thus be more willing to accept wildlife protection. Implementing wildlife accident insurance has been attempted in some areas, although residents expressed dissatisfaction due to its complexity and insufficient compensation (Huang et al., 2018). These challenges can be addressed by gradually optimizing the process and increasing insurance coverage compensation. We found areas around the Daxiangling and Tangjiahe nature reserve where the risk of HWC was high but implementation of control measures was a low priority. This can be attributed to effective community nature education in these protected areas, which has fostered positive attitudes and support for wildlife conservation among residents. Raising awareness can reverse hostility, increase tolerance, and promote protective behaviors (Breuer & Ngama, 2020). Espinosa and Jacobson's (2012) research highlights the success of the Andean Bear Conservation Project in South America, which deepened local understanding of bears and facilitated positive attitudes and behaviors toward habitat protection.

Globally, the rising demand for space has intensified the competition between humans and wildlife, leading to habitat loss and fragmentation that exacerbate HWC. Humans face the challenge of coexisting with wildlife, but the pressure to withstand HWC varies from region to region due to differences in biodiversity, social norms, and cultural traditions. Our results suggest that the economic and psychological costs of living with wildlife fall disproportionately on those who live near it (Figure 4b). On a global scale, in countries with large populations of wildlife, local peoples and rural communities that regularly encounter wild animals bear the burden of living with them (Amin, 2016; Jordan et al., 2020). Particularly in developing countries rich in biodiversity, the ecosystem services provided by conservation of wildlife often benefit people from developed countries and urban residents (Karanth & DeFries, 2011).

As a developing country with high biodiversity, China has become one of the most influential players in global environmental biodiversity conservation (Wang et al., 2020) and has invested billions of RMB in developing national park systems, such as the GPNP and Northeast China Tiger and Leopard National Park (Yang et al., 2023). Successes in biodiversity conservation may have resulted in HWC and put greater pressure on management (Esmaeili et al., 2019). For examples, Cheng et al. (2024) demonstrated that as the population of Amur tigers (*Panthera tigris*) increases, predation on livestock increases, thereby intensifying HWC. Some ecological and social measures are being implemented in GPNP, and we believe that with the gradual increase in social awareness of conservation, HWC can be controlled effectively. Spatially explicit assessment of areas of priority for management and measures taken to mitigate HWC can provide an important basis for the protection management department to allocate ecological compensation resources and effectively manage HWC. Our results established a solid foundation for HWC management and decision-making in GPNP and offer valuable insights into HWC mitigation in other regions worldwide.

ACKNOWLEDGMENTS

This study was supported by the National Natural Science Foundation of China (32070520, 32070524, 32370558, and 41521003), the Fundamental Research Funds for the Central Public-interest Scientific Institution (2020YSKY-008), the Global Environment Facility (GEF), the China Protected Land Management Reform Planning Project, and the China National Park System and Mechanism Innovation Project (C-PAR1) (grants to Q.D.). We thank the State Forestry and Grassland Administration and M. J. Struebig and M. Martinez for their suggestions on survey questions.

ORCID

Qiang Dai https://orcid.org/0000-0002-7850-997X
Zejun Zhang https://orcid.org/0000-0003-3555-4647
Dunwu Qi https://orcid.org/0000-0001-9557-4194
Wei Wei https://orcid.org/0009-0003-4017-0223

REFERENCES

Abrahms, B. (2021). Human-wildlife conflict under climate change. *Science*, *373*(6554), 484–485.

Amin, A. (2016). Exploring the role of economic incentives and spillover effects in biodiversity conservation policies in sub-Saharan Africa. *Ecological Economics*, *127*, 185–191.

Bartoń, K. (2013). *MuMIn: Multi-modal inference*. http://cran.r-project.org/web/packages/MuMIn/index.html

Bhandari, S., Mawhinney, B. A., Johnson, D., Bhusal, D. R., & Youlatos, D. (2019). Coexistence of humans and leopards in Shivapuri Nagarjun National Park, Nepal. *Russian Journal of Ecology*, *50*, 590–592.

Breuer, T., & Ngama, S. (2020). Humans and forest elephants in Central Africa: Conflict and co-existence in and around protected areas. In C. Doumenge, F. Palla, & G.-L. Itsoua Madzous (Eds.), *State of protected area in Central Africa* (pp. 174–220). OFAC-COMIFAC, Yaounde, & IUCN.

Bruskotter, J. T., Vucetich, J. A., Manfredo, M. J., Karns, G. R., Wolf, C., Ard, K., Carter, N. H., López-Bao, J. V., Chapron, G., Gehrt, S. D., & Ripple, W. J. (2017). Modernization, risk, and conservation of the world's largest carnivores. *Bioscience*, *67*(7), 646–655.

Butler, J. R. A. (2000). The economic costs of wildlife predation on livestock in Gokwe communal land, Zimbabwe. *African Journal of Ecology*, *38*, 23–30.

Ceaușu, S., Graves, R. A., Killion, A. K., Svenning, J. C., & Carter, N. H. (2019). Governing trade-offs in ecosystem services and disservices to achieve human–wildlife coexistence. *Conservation Biology*, *33*(3), 543–553.

Cheng, W., Gray, T. N. E., Bao, H., Wen, D., Liang, X., She, W., Zhang, W., Roberts, N. J., Gu, J., Qi, J., & Jiang, G. (2024). Drivers of human–tiger conflict risk and potential mitigation approaches. *Ecosphere*, *15*, Article e4922.

Cunha, H. F. A., de Souza, A. F. D., & Cardoso Da Silva, J. M. (2019). Public support for protected areas in new forest frontiers in the Brazilian Amazon. *Environmental Conservation*, *46*(4), 278–284.

Dai, Y., Hacker, C. E., Zhang, Y., Li, W., Li, J., Zhang, Y., Bona, G., Liu, H., Li, Y., Xue, Y., & Li, D. (2019). Identifying the risk regions of house break-ins caused by Tibetan brown bears (*Ursus arctos pruinosus*) in the Sanjiangyuan region, China. *Ecology and Evolution*, *9*(24), 13979–13990.

Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Agard, J., Arneth, A., Balvanera, P., Brauman, K. A., Butchart, S. H. M., Chan, K. M. A., Garibaldi, L. A., Ichii, K., Liu, J., Subramanian, S. M., Midgley, G. F., Miloslavich, P., Molnár, Z., Obura, D., Pfaff, A., … Zayas, C. N. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science*, *366*(6471), Article eaax3100.

Di Minin, E., Slotow, R., Fink, C., Bauer, H., & Packer, C. (2021). A pan-African spatial assessment of human conflicts with lions and elephants. *Nature Communications*, *12*(1), Article 2978.

Elsayed, E. A., Dawood, A. K. S., & Yan, K. (2017). Evaluating alternatives through the application of TOPSIS method with entropy weight. *International Journal of Engineering Trends and Technology*, *46*(2), 60–66.

Espinosa, S., & Jacobson, S. K. (2012). Human-wildlife conflict and environmental education: Evaluating a community program to protect the Andean bear in Ecuador. *The Journal of Environmental Education*, *43*(1), 55–65.

Esmaeili, S., Hemami, M. R., & Goheen, J. R. (2019). Human dimensions of wildlife conservation in Iran: Assessment of human-wildlife conflict in restoring a wide-ranging endangered species. *PloS one*, *14*(8), e0220702.

European Space Agency (ESA). (2017). *Land Cover CCI: Product User Guide: Version 2.0*. https://maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf

Fentaw, T., & Duba, J. (2017). Human–wildlife conflict among the pastoral communities of southern rangelands of Ethiopia: The case of Yabello protected area. *Journal of International Wildlife Law & Policy*, *20*(2), 198–206.

Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*, *37*(12), 4302–4315.

Forestry Department of Sichuan Province. (2015). *The Pandas of Sichuan: The 4th survey report on giant panda in Sichuan Province*. Sichuan Science and Technology Press.

Ghosal, S., & Kjosavik, D. J. (2015). Living with leopards: Negotiating morality and modernity in Western India. *Society & Natural Resources*, *28*(10), 1092–1107.

Goldman, M. J., Roque De Pinho, J., & Perry, J. (2010). Maintaining complex relations with large cats: Maasai and lions in Kenya and Tanzania. *Human Dimensions of Wildlife*, *15*(5), 332–346.

Gross, E., Jayasinghe, N., Brooks, A., Polet, G., Wadhwa, R., & Hilderink-Koopmans, F. (2021). *A future for all: The need for human-wildlife coexistence*. WWF.

Hijmans, R. J., Phillips, S., Leathwick, J., & Elith, J. (2017). *Dismo: Species distribution modeling*. R package.

Huang, C., Li, X. Y., Shi, L. J., & Jiang, X. L. (2018). Patterns of human-wildlife conflict and compensation practices around Daxueshan Nature Reserve, China. *Zoological Research*, *39*(6), 406–412.

Huang, G., Ping, X., Xu, W., Hu, Y., Chang, J., Swaisgood, R. R., Zhou, J., Zhan, X., Zhang, Z., Nie, Y., Cui, J., Bruford, M., Zhang, Z., Li, B., Zhang, L., Lv, Z., & Wei, F. (2021). Wildlife conservation and management in China: Achievements, challenges and perspectives. *National Science Review*, *8*(7), Article nwab042.

Huang, Q., Fei, Y., Yang, H., Gu, X., & Songer, M. (2020). Giant Panda National Park, a step towards streamlining protected areas and cohesive conservation management in China. *Global Ecology and Conservation*, *22*, Article e00947.

International Union for Conservation of Nature (IUCN). (2020). *IUCN SSC position statement on the management of human–wildlife conflict*. IUCN Species Survival Commission (SSC) Human–Wildlife Conflict Task Force.

Jordan, N. R., Smith, B. P., Appleby, R. G., van Eeden, L. M., & Webster, H. S. (2020). Addressing inequality and intolerance in human-wildlife coexistence. *Conservation Biology*, *34*(4), 803–810.

Kansky, R., Kidd, M., & Knight, A. T. (2014). Meta-analysis of attitudes toward damage-causing mammalian wildlife. *Conservation Biology*, *28*(4), 924–938.

Karanth, K. K., & DeFries, R. S. J. C. L. (2011). Nature-based tourism in Indian protected areas: New challenges for park management. *Conservation Letters*, *4*, 137–149.

Kioko, J., Muruthi, P., Omondi, P., & Chiyo, P. I. (2008). The performance of electric fences as elephant barriers in Amboseli, Kenya. *South African Journal of Wildlife Research*, *38*(1), 52–58.

Lamb, C. T., Ford, A. T., Mclellan, B. N., Proctor, M. F., Mowat, G., Ciarniello, L., Nielsen, S. E., & Boutin, S. (2020). The ecology of human–carnivore coexistence. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(30), 17876–17883.

Li, X., Wang, K., Liu, L., Xin, J., Yang, H., & Gao, C. (2011). Application of the entropy weight and TOPSIS method in safety evaluation of coal mines. *Procedia Engineering*, *26*, 2085–2091.

Lindsey, P. A., Miller, J. R. B., Petracca, L. S., Coad, L., Dickman, A. J., Fitzgerald, K. H., Flyman, M. V., Funston, P. J., Henschel, P., Kasiki, S., Knights, K., Loveridge, A. J., Macdonald, D. W., Mandisodza-Chikerema, R. L., Nazerali, S., Plumptre, A. J., Stevens, R., Van Zyl, H. W., & Hunter, L. T. B. (2018). More than $1 billion needed annually to secure Africa's protected areas with lions. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(45), E10788–E10796.

Lischka, S. A., Teel, T. L., Johnson, H. E., Larson, C., Breck, S., & Crooks, K. (2020). Psychological drivers of risk-reducing behaviors to limit human–wildlife conflict. *Conservation Biology*, *34*(6), 1383–1392.

Liu, P., Wen, H., Harich, F. K., He, C., Wang, L., Guo, X., Zhao, J., Luo, A., Yang, H., Sun, X., Yu, Y., Zheng, S., Guo, J., Li, L., & Zhang, L. (2017). Conflict between conservation and development: Cash forest encroachment in Asian elephant distributions. *Scientific Reports*, *7*(1), Article 6404.

Lukacs, P. M., Burnham, K. P., & Anderson, D. R. (2010). Model selection bias and Freedman's paradox. *Annals of the Institute of Statistical Mathematics*, *62*, 117–125.

MacKinnon, K., Sobrevila, C., & Hickey, V. (2008). *Biodiversity, climate change, and adaptation: Nature-based solutions from the World Bank portfolio* (Report Number 46726). The World Bank.

Maier, M. J. (2015). *Companion package to the book "r: Einführung durch angewandte statistik"*. R package version 0.9 3.

McRae, B. H., Dickson, B. G., Keitt, T. H., & Shah, V. B. (2008). Using circuit theory to model connectivity in ecology, evolution, and conservation. *Ecology*, *89*(10), 2712–2724.

Mi, C., Song, K., Ma, L., Xu, J., Sun, B., Sun, Y., Liu, J., & Du, W. (2023). Optimizing protected areas to boost the conservation of key protected wildlife in China. *The Innovation*, *4*(3), Article 100424.

Mishra, C., Allen, P., McCarthy, T. O. M., Madhusudan, M. D., Bayarjargal, A., & Prins, H. H. (2003). >The role of incentive programs in conserving the snow leopard. *Conservation Biology*, *17*(6), 1512–1520.

Naha, D., Sathyakumar, S., Dash, S., Chettri, A., & Rawat, G. S. (2019). Assessment and prediction of spatial patterns of human-elephant conflicts in changing land cover scenarios of a human-dominated landscape in North Bengal. *PLoS ONE*, *14*(2), Article e0210580.

Naidoo, R., Fisher, B., Manica, A., & Balmford, A. (2016). Estimating economic losses to tourism in Africa from the illegal killing of elephants. *Nature Communications*, *7*(1), Article 13379.

Naughton-Treves, L., & Treves, A. (2005). Socio-ecological factors shaping local support for wildlife: Crop-raiding by elephants and other wildlife in Africa. In A. Rabinowitz, R. Woodroffe, & S. Thirgood (Eds.), *People and wildlife, conflict or co-existence?* (pp. 252–277). Cambridge University Press.

Nie, Y., Zhou, W., Gao, K., Swaisgood, R. R., & Wei, F. (2019). Seasonal competition between sympatric species for a key resource: Implications for conservation management. *Biological Conservation*, *234*, 1–6.

Nyhus, P. J. (2016). Human–wildlife conflict and coexistence. *Annual Review of Environment and Resources*, *41*, 143–171.

Ogra, M. V. (2008). Human–wildlife conflict and gender in protected area borderlands: A case study of costs, perceptions, and vulnerabilities from Uttarakhand (Uttaranchal), India. *Geoforum*, *39*(3), 1408–1422.

Patterson, B. D., Kasiki, S. M., Selempo, E., & Kays, R. W. (2004). Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighboring Tsavo National ParkS, Kenya. *Biological Conservation*, *119*(4), 507–516.

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*(3-4), 231–259.

Qiu, L., Han, H., Zhou, H., Hong, M., Zhang, Z., Yang, X., Gu, X., Zhang, W., Wei, W., & Dai, Q. (2019). Disturbance control can effectively restore the habitat of the giant panda (*Ailuropoda melanoleuca*). *Biological Conservation*, *238*, Article 108233.

R Core Team. (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Reid, W. V., Mooney, H. A., Cropper, A., Capistrano, D., Carpenter, S. R., Chopra, K., Dasgupta, P., Dietz, T., Duraiappah, A. K., Hassan, R., Kasperson, R., Leemans, R., May, R. M., McMichael, A. J., Pingali, P., Samper, C., Scholes, R., Watson, R. T., Zakri, A. H., … Zurek, M. B. (2005). *Ecosystems and human well-being: Wetlands and water—Synthesis: A report of the Millennium Ecosystem Assessment*. Island Press.

Ring, I., Drechsler, M., Van Teeffelen, A. J., Irawan, S., & Venter, O. (2010). Biodiversity conservation and climate mitigation: What role can economic instruments play? *Current Opinion in Environmental Sustainability*, *2*(1-2), 50–58.

Schmitt, S., Pouteau, R., Justeau, D., De Boissieu, F., & Birnbaum, P. (2017). ssdm: An r package to predict distribution of species richness and composition based on stacked species distribution models. *Methods in Ecology and Evolution*, *8*(12), 1795–1803.

State Forestry Administration (SFA). (2006). *The 3rd National Survey Report on Giant Panda in China*. Science Press.

Sprague, D. S., & Iwasaki, N. (2006). Coexistence and exclusion between humans and monkeys in Japan: Is either really possible? *Ecological and Environmental Anthropology*, *2*(2), 30–43.

Struebig, M. J., Linkie, M., Deere, N. J., Martyr, D. J., Millyanawati, B., Faulkner, S. C., Le Comber, S. C., Mangunjaya, F. M., Leader-Williams, N., Mckay, J. E., & St John, F. A. V. (2018). Addressing human-tiger conflict using socio-ecological information on tolerance and risk. *Nature Communications*, *9*, Article 3455.

Torres, D. F., Oliveira, E. S., & Alves, R. R. N. (2018). Understanding human–wildlife conflicts and their implications. In R. R. Nóbrega Alves & U. P. Albuquerque (Eds.), *Ethnozoology* (pp. 421–445). Academic Press.

Wang, W., Feng, C., Liu, F., & Li, J. (2020). Biodiversity conservation in China: A review of recent studies and practices. *Environmental Science and Ecotechnology*, *2*, Article 100025.

Wang, Y. H., Yang, K. C., Bridgman, C. L., & Lin, L. K. (2008). Habitat suitability modelling to correlate gene flow with landscape connectivity. *Landscape Ecology*, *23*, 989–1000.

Wei, W., Swaisgood, R. R., Pilfold, N. W., Owen, M. A., Dai, Q., Wei, F., Han, H., Yang, Z., Yang, X., Gu, X., Zhang, J., Yuan, S., Hong, M., Tang, J., Zhou, H., He, K., & Zhang, Z. (2020). Assessing the effectiveness of China's panda protection system. *Current Biology*, *30*(7), 1280–1286.e2.

Western, G., Macdonald, D. W., Loveridge, A. J., & Dickman, A. J. (2019). Creating landscapes of coexistence. *Conservation & Society*, *17*(2), 204–217.

Xu, J., Wei, J., & Liu, W. (2019). Escalating human–wildlife conflict in the Wolong Nature Reserve, China: A dynamic and paradoxical process. *Ecology and Evolution*, *9*(12), 7273–7283.

Yamazaki, K., & Bwalya, T. (2007). Aspects of elephant crop-raiding behaviour in the Kakum Conservation Area, Ghana. *Nature & Faune*, *21*(2), 15–19.

Yang, B., Dai, Q., Xu, Y., Buesching, C. D., Gu, X., Yang, Z., Zhang, Z., & Wei, F. (2023). Need of a paradigm shift to conserve endangered species in China's national park system. *Innovation*, *4*(4), Article 100462.

Yang, H., Lupi, F., Zhang, J., & Liu, J. (2020). Hidden cost of conservation: A demonstration using losses from human-wildlife conflicts under a payments for ecosystem services program. *Ecological Economics*, *169*, Article 106462.

Yue, Y., Yang, Z., Wei, W., Yang, B., Qi, D., Gu, X., Yang, X., Lu, S., Zhang, W., Dai, Q., & Zhang, Z. (2024). The effectiveness of using giant panda as a surrogate for protecting sympatric species. *Journal of Environmental Management*, *351*, Article 119803.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Qiu, L., Dai, Q., Wang, Y., Zhang, Z., Yang, Z., Qi, D., Gu, H., Gu, X., Yang, X., & Wei, W. (2024). Association between attitudes toward wildlife and patterns of risk of human–wildlife conflict near Giant Panda National Park. *Conservation Biology*, e14428. https://doi.org/10.1111/cobi.14428