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Current patterns and mitigation strategies of human-wildlife conflicts in Chinese protected areas

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A R T I C L E I N F O

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A B S T R A C T

Human-wildlife conflicts (HWCs), driven by habitat fragmentation, species recovery, and climate change, have intensified globally and are increasingly prevalent in China, especially in and around protected areas (PAs). This study investigates HWCs in 164 PAs across mainland China, addressing three critical gaps: (1) the relationship between HWC prevalence and biodiversity hotspots, (2) dominant conflict types, and (3) effectiveness of mitigation strategies. Using a nationwide online survey of PA rangers with direct HWC experience, we found that 54.4% of surveyed PAs reported conflicts. Central and southeastern China exhibited the highest frequency and severity. Wild boars (*Sus scrofa*) were the most commonly reported species (40.9%), followed by bears (*Ursus arctos and Ursus thibetanus,* 14.0%) and macaques (*Macaca mulatta and Macaca thibetana,* 13.5%). Over 63% of affected PAs faced multi-species conflicts, with crop damage being the most widespread issue. Generalized linear models revealed that the number of omnivorous species was the strongest predictor of HWC impacts across agriculture, daily life, and personal safety. Irregular PA boundaries also aggravated conflicts. Conversely, an increase in conflict-causing carnivores was associated with reduced impacts on daily life and personal safety, suggesting possible ecological suppression on omnivores. Among mitigation strategies, environmental education was rated by rangers most effective and widely used, followed by human resettlement. In contrast, measures such as economic compensation and animal removal were perceived as less effective. These findings call for a shift in HWC management priorities toward high-conflict areas beyond biodiversity hotspots. Integrated strategies tailored to omnivore-driven conflicts and strengthened education efforts are essential for fostering coexistence in China's PAs, aligning with global conservation goals.

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1. Introduction

Human-wildlife conflicts (HWCs), regarded as negative interactions between humans and wildlife (Madden, 2004), not only threaten human livelihoods and safety, but also put pressure on wildlife, when lethal control measures are employed in response (Nyhus, 2016). Driven by climate change, habitat loss, human encroachment and species recovery (Pooley et al., 2021), HWCs are becoming increasingly frequent and severe worldwide (Treves, 2009). Local people bear the costs of HWCs, including crop damage, livestock depredation, and human casualties (Woodroffe et al., 2005). Those humans living in or near protected areas (PAs) face even greater risks (Sillero-Zubiri et al., 2007), as animal movements for food acquisition or migration intensify, leading to negative human-wildlife interactions (Buchholtz et al., 2020).

Over the past 20 years, China has experienced a sharp increase in HWCs, driven by rapid economic development, ambitious ecological protection policies (Ma et al., 2021) and previous hunting policies (Jiang, 2020). In the 1950s, the government began organizing collective hunts to protect crops (Jiang, 2020). This intensive hunting led to the local extinction of top predators such as tigers and leopards (Greer and Doughty, 1976), disrupting trophic interactions and allowing prey species including wild boars and deer to increase their populations in the following decades (Feng et al., 2019). The situation has exacerbated since 1996 with the implementation of firearm regulations, which deprived local communities of an effective means of limiting prey species populations (Wang et al., 2023). In addition, large-scale cropland and urban expansion have contributed to habitat loss, degradation and increasing damages (Tang et al., 2020). As a consequence, tolerance for conflict-causing species has been reduced. Concurrently, extensive ecological conservation efforts, including the establishment of nearly 11,800 PAs and initiatives like the Grain-for-Green Program, Grasslands Project and the Ecological Conservation Redline (ECR), have restored millions of hectares of potential wildlife habitat (Wang et al., 2020). The ECR, for instance, designates areas requiring the highest level of protection and strictest management, with some human-dominated areas also included in PAs (Gao et al., 2020). While these efforts restore habitats and reduce habitat fragmentation, they also have a positive effect on wildlife populations and have increased the spatial overlap with human communities, exacerbating HWCs (Li et al., 2024).

China, a mega-biodiverse country (Mi et al., 2021), has designated 18% of its land as PAs under different levels of protection (Li and Pimm, 2020). Local communities living off the land face more HWCs than urban residents, with these conflicts exhibiting significant regional differences. In the Himalayan region, where grazing is the primary livelihood, communities face frequent livestock depredation by snow leopards (*Panthera uncia*), wolves (*Canis lupus*), and brown bears (*Ursus arctos*), along with foraging competition between wild ungulates and domestic animals (Lu and Huntsinger, 2023). In the Indo-Burma and Mountains region of Southwest China, where farming dominates, crop raiding by elephants (Li et al., 2018), wild boars, rhesus monkeys and black bears (Ji et al., 2022; Qiu et al., 2024) is common. Beyond these biodiversity hotspots, diverse forms of HWCs occur across many provinces, including human-wild boar conflicts in southeastern and central China (Wang et al., 2023), human-tiger conflicts in the northeast (Cheng et al., 2024) and human-leopard conflicts in the north (Jiang, 2024). The diversity of HWCs presents great challenges for management in and around Chinese PAs. However, studies with a national and PA-based perspective remain relatively scarce, focusing primarily on just a single species (Long and Li, 2025; Pettigrew et al., 2012).

Over past years, research on HWCs in China has expanded, with increasing attention to spatial-temporal patterns and mitigation strategies. Among these, compensation has emerged as the more commonly studied approach. Related research has examined various dimensions, including local acceptance of compensation (Xu et al., 2019), determinants of household satisfaction (Zhang et al., 2024), the impact of compensation policies on farmers (Ma et al., 2024), and the amount of compensation (Lu et al., 2012; Ma et al., 2023). Other research has explored comprehensive mitigation strategies, including community-based interventions (Dai et al., 2022) and landscape planning (Su et al., 2021). However, empirical evaluations of the effectiveness of mitigation measures remain limited. Furthermore, existing research has predominantly focused on large carnivores, leaving a significant gap in understanding mitigation strategies for conflicts involving herbivores and omnivores. Despite these advances, several key questions remain at the national scale: (1) Do HWCs occur less frequently in areas beyond biodiversity hotspots? (2) What are the most prevalent forms of HWCs? (3) What are considered as the most effective mitigation strategies? Addressing these questions requires an understanding HWC patterns across Chinese PAs, including conflict distribution, incident frequency, and the implementation and effectiveness of mitigation strategies. This study aims to fill these gaps through a survey of PA rangers, providing valuable insights to support decision-making by policymakers, NGOs, and funding agencies. Social research is crucial in complementing ecological studies and informing effective HWC management (Ferraz et al., 2022).

2. Methods

2.1. Structured survey

The questionnaire was designed as a PA-level expert survey, targeting rangers or PA staff with direct knowledge of conflict occurrence, impacts, and mitigation practices within their management areas. Accordingly, sample adequacy is evaluated at the PA level. Following China's PA integration and optimization, there are currently 6736 PAs nationwide. Using the standard finite-population sample size formula ($n = \frac{NZ^2p(1-p)}{e^2(N-1)+Z^2p(1-p)}$, where $N = 6736$, $Z = 1.96$ for a 95% confidence level, $p = 0.5$ as the most conservative assumption, and $e = 0.08$, corresponding to an absolute precision of ± 8 %age points), the minimum required sample size is approximately 147 PAs; to account for non-response, we distributed 200 questionnaires. Because conflict risk and management relevance are uneven across PA types, sample allocation was stratified and intentionally prioritized national-level PAs (National Parks, National Park Pilots, and National Natural Reserves), while also including Regional Natural Reserves and Natural Parks to ensure coverage across the PA system. Wherein, the pilot national park refers to areas designated for trial operation before the formal establishment of national parks and are classified as IUCN Category II (Zang et al. 2022). National and regional nature reserves fall under IUCN Category Ia (Strict Nature Reserves), while natural parks are categorized as Category V (Protected Landscapes/Seascapes).

The questionnaire consisted of four parts covering: (1) basic PA and community information, (2) the current situation of HWCs, including conflict-causing taxa, conflict types, frequency, economic losses, and perceived impacts on local residents, (3) existing mitigation strategies and their perceived effectiveness, and (4) wildlife-based tourism, local livelihoods, income conditions, and suggestions for future conflict management. It was designed as a PA–level ranger survey to capture broad patterns of conflict occurrence, impacts, and management practices across different categories of PAs in China. We invited rangers working in these PAs—particularly those managing HWCs—to complete the questionnaire.

The online survey was conducted over five months, from November 2021 to March 2022, using a structured questionnaire distributed via WeChat platform. To ensure data reliability, participation was anonymous and voluntary. The questionnaire included both structured multiple-choice questions and open-ended sections for qualitative insights. It also gathered essential contextual information, including geographical location, PA category, and the number of residents in each PA (Appendix A). The questionnaires were distributed through a WeChat working group composed of PA rangers, but some PAs outside the group could not be reached. Ultimately, 203 rangers from 196 PAs participated in the survey. Among them, the Giant Panda National Park (GPNP)—which spans 12 cities across 3 provinces (Huang et al., 2020) — was represented by 8 samples due to its numerous administrative units. After removing 32 incomplete responses, data from 164 PAs (171 samples) were retained, comprising 5 national parks, 4 national park pilots, 89 national nature reserves, 26 regional nature reserves, and 40 natural parks (Fig. 1). This selection ensures broad coverage of HWCs in various PA categories, making the research highly representative at the national-level PAs (Table 1).

Given the diversity of HWCs in China and the national scope of the study, we categorized conflicts by taxonomic families, such as Suidae, Ursidae, Cercopithecoidea, Felidae, Canidae, Cervidae, Elephantidae, birds, and reptiles. To ensure meaningful data analysis, taxa representing fewer than 10% of total samples were excluded from further analysis. Based on documented HWC records from academic literature, we identified several mammal species commonly involved in such conflicts within each family (Table 3); our results primarily focus on these species. Additionally, birds and reptiles were not thoroughly examined due to their broad diversity and limited data availability. To identify spatial patterns of HWCs, we mapped the distribution of conflict samples using ArcGIS Pro 3.4, and overlaid them with species distribution data from the International Union for Conservation of Nature (IUCN, 2024). We identified the number of PAs located within each species' IUCN distribution range and calculated the conflict causing share as the proportion of PAs reporting HWCs involving that species relative to the total number of PAs within the distribution range. In the analysis, some conflict cases appeared outside the official species distribution ranges, likely due to outdated distribution data. For example, the wolf distribution was last updated in 2018 (Boitani et al., 2023), and since then, some individuals may have expanded into new habitats. Moreover, the survey collected data on HWC incidents attributed to different taxonomic families, such as crop damage and livestock depredation. Using proportion calculation and visualization in RStudio 4.4.2 (R Core Team, R., 2024), we illustrated the proportional occurrence of these incidents across various families.

Due to the complexity of multispecies HWCs—such as crop damage related to wild boars, monkeys, and bears—evaluating the impacts by individual species is challenging. Therefore, our survey focuses on the overall impacts of HWCs. Rangers were asked to report the number of HWC cases over the past two years, categorized into four classes: fewer than 50, 50–500, 501–1000, and more than 1000. Similarly, economic losses over the same period were reported in Chinese yuan (CNY) and grouped into four categories: less than 0.5 million, 0.5–1 million, 1–5 million, and more than 5 million. Given the significant effects of HWCs on agricultural production (both planting and breeding), daily life, and personal safety, rangers were asked to rate the degree of impact in each domain on a scale from 0 (no influence) to 100 (highest influence). Using ArcGIS Pro 3.4, we visualized the spatial distribution of these impacts to reveal geographic patterns across PAs in China.

To understand the perceptions of mitigation effectiveness, rangers were asked to evaluate each strategy on a scale from 0 (least effective) to 10 (most effective). Mitigation strategies were categorised into two main approaches: precautionary and compensation-based. Precautionary methods included removing problematic animals, installing protective facilities, deploying more guards, keeping guard dogs, establishing wildlife feeding points, improving grazing practices, relocating human settlements, and conducting environmental education. Compensation methods included government-led economic compensation, voluntary commercial insurance, community-based economic programs, and incentive policies. We calculated the mean and standard deviation of perceived effectiveness for each strategy and compared their implementation rates across the surveyed PAs.

2.2. Drivers of HWC impacts

In this study, we assessed three types of impacts from human–wildlife conflicts, which served as dependent variables in our models. These include: (1) impact on agricultural production, measured as reported losses from crop damage, livestock depredation, resource competition, and disease transmission; (2) impact on daily life, reflecting disruptions such as infrastructure damage and traffic obstruction; and (3) impact on personal safety, capturing more severe consequences including psychological stress, human injury, and fatalities. All three variables were recorded on a continuous proportion scale based on ranger evaluations. To understand the drivers of HWC impacts on agricultural production, daily life, and personal safety, we selected a range of potential explanatory variables, including percentage variables (cropland, forest, and human settlement coverage), continuous variables (shape index and average human population density within each PA), and categorical variables representing the number of conflict-causing omnivores, herbivores, and carnivores (Table 2).

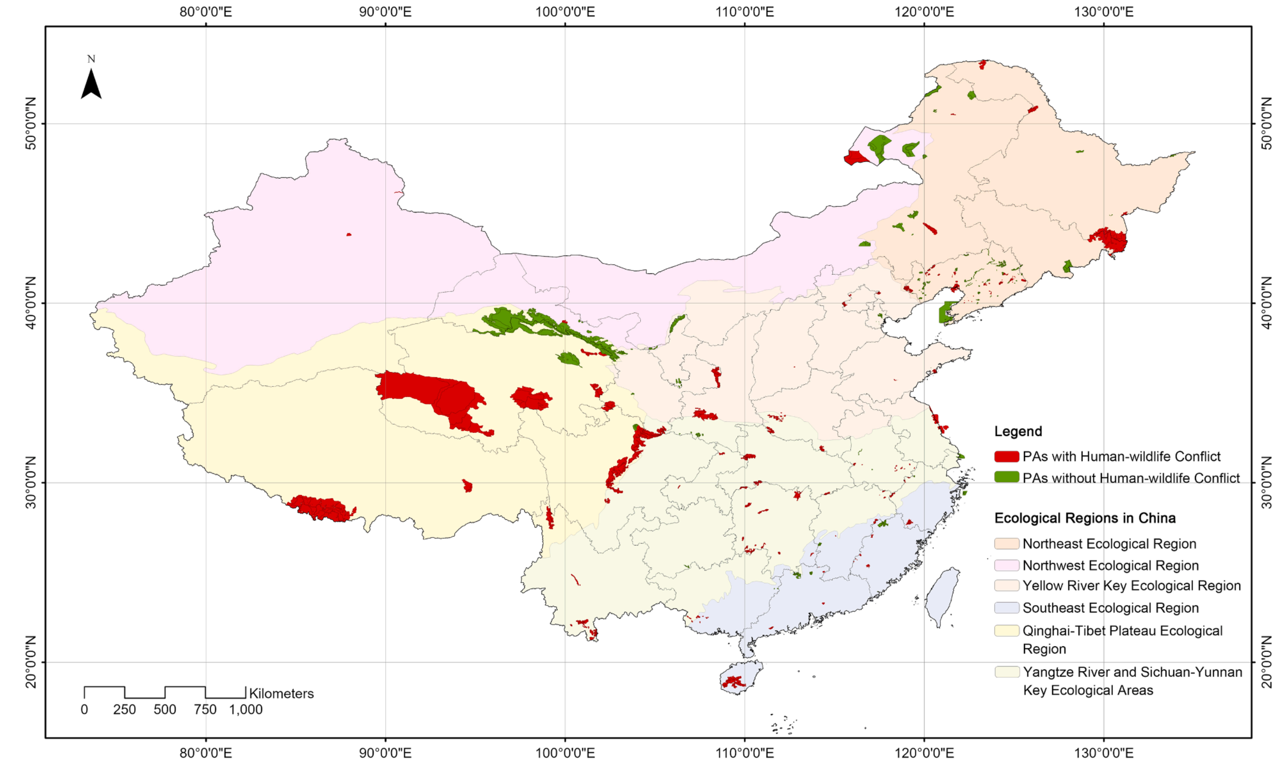

Fig. 1. Distribution of the surveyed PAs (n = 164). PAs with HWCs are shown in red, and those without HWCs in green. As background, we overlaid the ecological regions (Ministry of Natural Resources of the People's Republic of China, 2023). Map lines delineate study areas and do not necessarily depict accepted national boundaries.

Table 1
Overview of surveyed PAs and their categorization.

IUCN Category	PA Type	Total Number	Area/km^2	Area Proportion	Planned Sample Size	Valid Responses
II: National Park	National Park	5	232,254	12.5%	5	5
	National Park Pilot	5	53,284	2.9%	5	4
Ia: Strict Nature Reserve	National Natural Reserve	436	1020,743	55.1%	100	91
	Regional Natural Reserve	1091	182,270	9.8%	40	24
V: Protected Landscape/Seascape	Natural Park	5199	363,810	19.6%	50	40
Total		6736	1852,361	100%	200	164

Source: National Forestry and Grassland Administration (2024)

Land use has long been recognized as a key driver of HWCs (Foley et al., 2005; König et al., 2020). The proportions of cropland, forest, and human settlements within each PA are closely linked to wildlife occupancy and the intensity of human activity (IUCN, 2023), and these data were sourced from the land use dataset compiled by Yang and Huang (2021). The shape index (*si*), calculated as $si = \text{perimeter} / (\sqrt{4\pi A})$ following Bhardwaj and Kumar (2019), reflects the complexity of the boundary between PAs and surrounding human-dominated landscapes, indicating the extent of anthropogenic pressure. GIS data of PAs were obtained from the China National Forestry and Grassland Administration (Zhao et al., 2024). Average human population density within each PA, a key indicator of anthropogenic pressure, was derived from Moehl et al. (2023). To capture the diversity of HWCs, we also included the number of conflict-causing taxonomic families, categorized as omnivores (Suidae, Ursidae, Cercopithecoidea), herbivores (Cervidae, Elephantidae), and carnivores (Felidae, Canidae). These data were directly obtained from the ranger survey.

We used generalized linear model (GLM) with beta distribution with logit link (Douma et al., 2019) to examine the relationships between HWC impacts—specifically on agricultural production, daily life, and personal safety— and the mentioned potential explanatory variables. The dependent variables were rescaled from 0 to 100 to the interval between 0 and 1 to satisfy the assumptions of the Beta distribution. Prior to modelling, correlation tests were conducted to address multicollinearity among predictors. All models were implemented in RStudio 4.4.2 (R Core Team, R., 2024) using the glmmTMB package (Brooks et al., 2017), and model residual diagnostics were checked by using the DHARMa package (Hartig, 2017).

3. Results

3.1. Current pattern of HWCs

According to the survey of 203 rangers, 54.4% of PAs in China report experiencing HWCs, encompassing 171 samples. Among the 93 PAs where conflicts are reported, 63.4% have conflicts involving more than one taxonomic family (Fig. 2a). In terms of frequency (Fig. 2b), Suidae was the most commonly involved family, accounting for 40.9% of cases, followed by Ursidae (14.0%) and Cercopithecoidea (13.5%). To improve accuracy, we overlaid the IUCN distribution ranges of each species and calculated the conflict share as the proportion of PAs reporting HWCs involving that species relative to the total number of PAs within its distribution range

Table 2
Summary of variables used to analyse HWC impacts on agriculture production, daily life and personal safety.

	Type	Definition	Data Source
Y variable			
Impact on agriculture production	Continuous	HWC impact on agricultural production including crop damage, livestock depredation, resource competition and disease spread	Ranger survey
Impact on daily life	Continuous	HWC impact on daily life of local people, including infrastructure damage and traffic obstruction	
Impact on personal safety	Continuous	HWC impact on personal safety of local people, including psychological trauma, human injury and death	
X variable			
Cropland coverage ratio	Percentage	Proportion of cropland in the PA	Yang and Huang (2021)
Forest coverage ratio	Percentage	Proportion of forest in the PA	
Human settlement coverage ratio	Percentage	Proportion of human settlement in the PA	
Shape index (*si*)	Continuous	Corrected perimeter per unit area for the PA ($si = \text{perimeter}/(\sqrt{4}\ \pi A)$) (Bhardwaj and Kumar, 2019)	Zhao et al. (2024)
Human population density	Continuous	Average population density in the PA	Moehl et al. (2023)
Number of conflict-causing omnivores	Categorical	Family number of conflict-causing omnivores (including Suidae, Ursidae, Cercopithecoidea, the value range is 0,1,2,3)	Ranger survey
Number of conflict-causing herbivores	Categorical	Family number of conflict-causing herbivores (including Cervidae, Elephantidae, the value range is 0,1,2)	
Number of conflict-causing carnivores	Categorical	Family number of conflict-causing carnivores (including Felidae, Canidae, the value range is 0,1,2)	

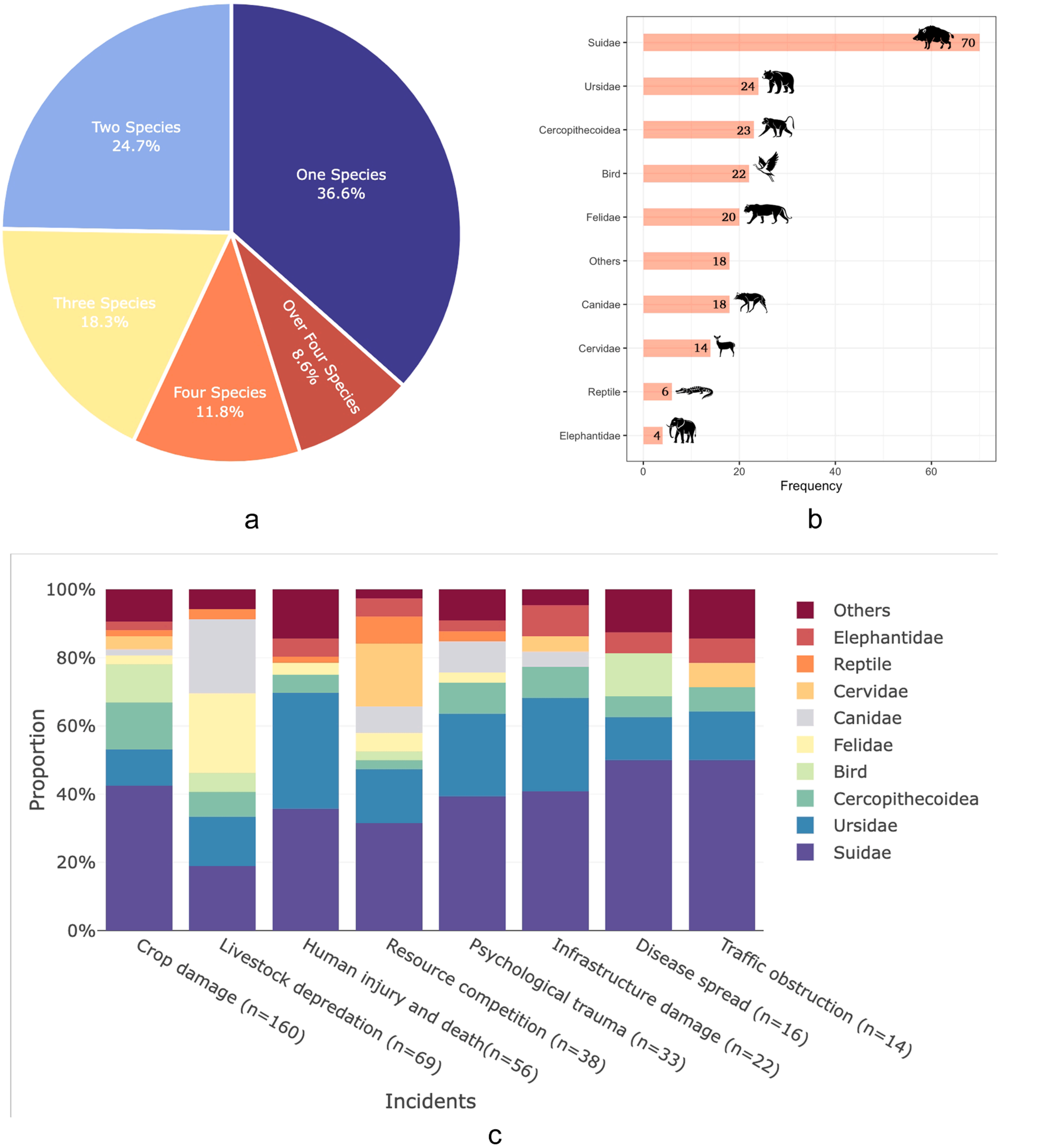

Fig. 2. Results of the ranger survey. (a) Proportion of PAs reporting conflicts with one or multiple wildlife species (n = 93); (b) Frequency of HWCs causing by different taxonomic families (n = 171); (c) Occurrence proportion of different families according to conflict types.

(Appendix B, Fig. B. 2–6). The results indicate that the relative proportions remained similar across most families with differences within 3.5%. A notable exception was Cercopithecoidea family, whose share increased markedly from 13.5% to 32.8% (Table 3). Within each family, individual species generally exhibited similar conflict rates. For instance, the brown bear (19.1%) and the Asia black bear (14.6%) closely align with the overall conflict rate for the Ursidae family (15.0%). The only exception was snow leopards, which exhibited the highest conflict rate (42.9%) relative to their limited distribution.

Based on our results (Fig. 2c), crop damage is the most frequently reported HWC incident, primarily caused by omnivores—such as wild boars, bears, and monkeys—which account for 66.9% of these cases. Livestock depredation is the second common incident, with 43.7% attributed to carnivores and 32.4% to omnivores. Human casualties rank third in frequency and are predominantly associated with wild boars and bears (69.6%), rather than large carnivores, which are responsible for only 3.6% of such cases. In other types of

Table 3
Families and species associated with HWCs in China and their conflict presence in PAs, both nationwide and within species' distribution ranges.

Species associated with HWCs		In distribution range Number of PAs	Number of PAs with HWCs	Share	Full data set (N = 171) Number of PAs with HWCs	Share
Suidae	Wild Boar *(Sus scrofa)*	**158**	**70**	**44.3%**	**70**	**40.9%**
Ursidae		**160**	**24**	**15.0%**	**24**	**14.0%**
	Brown Bear *(Ursus arctos)*	47	9	19.1%	/	/
	Asian black bear *(Ursus thibetanus)*	137	20	14.6%	/	/
Cercopithecoidea		**67**	**22**	**32.8%**	**23**	**13.5%**
	Rhesus Macaque *(Macaca mulatta)*	67	22	32.8%	/	/
	Tibetan Macaque *(Macaca thibetana)*	40	14	35.0%	/	/
Felidae		**154**	**18**	**11.7%**	**20**	**11.7%**
	Tiger *(Panthera tigris)*	138	13	9.4%	/	/
	Leopard *(Panthera pardus)*	143	16	11.2%	/	/
	Snow Leopard *(Panthera uncia)*	21	9	42.9%	/	/
Canidae		**124**	**16**	**12.9%**	**18**	**10.5%**
	Wolf *(Canis lupus)*	123	16	13.0%	/	/
	Dhole *(Cuon alpinus)*	11	2	18.2%	/	/

incidents—such as resource competition, psychological trauma, infrastructure damage, disease transmission, and traffic obstruction—wild boars and bears also play the most important role.

3.2. Current impacts and related drivers of HWCs

PAs in southeastern and central China experienced a relatively high frequency of HWCs, accompanied by significant economic burdens (Fig. 3a). Among the 93 surveyed PAs that reported HWCs, 31.18% recorded more than 50 conflict cases over the two years. Additionally, 37.63% reported economic losses exceeding 0.5 million CNY (Table 4), with the highest financial burdens observed in provinces such as Hunan and Jiangxi.

The majority of rangers believe that HWCs have a greater impact on agricultural production than on daily life or personal safety, particularly in southeastern and central China (Fig. 3b). In contrast, remote regions such as northern China—characterized by lower population density—tend to experience lower overall impacts across all three perspectives.

The GLM analysis of HWC impacts on agricultural production identified the shape index of PAs as a significant positive predictor (0.274, $p = 0.019$), suggesting that more irregular PA shapes with complex zigzag boundaries are associated with greater crop damage. The presence of three conflict-causing omnivorous families was significantly associated with higher agricultural impact (1.641, $p = 0.002$), while the occurrence of one (0.702, $p = 0.067$) and two (0.866, $p = 0.059$) omnivore families showed barely significant effects. Overall, the presence of conflict-causing omnivores demonstrated a stronger explanatory power than the shape index. Other predictors were not statistically significant, including cropland and forest coverage, human population density, and the number of herbivore families.

In the model examining impacts on daily life, the number of omnivorous families again played a dominant role. The presence of two (0.933, $p = 0.033$) or three (1.646, $p < 0.001$) omnivore families significantly increased reported disruptions. Forest coverage showed a marginally negative association (-0.394, $p = 0.081$), suggesting a buffering role in reducing daily conflicts, while human population density showed a marginal positive effect (0.236, $p = 0.065$). Interestingly, the presence of two carnivorous families was associated with significantly lower impacts on daily life (-1.141, $p = 0.032$). Overall, the number of conflict-causing omnivore and carnivore families provided the strongest explanatory power for perceived impacts on daily life.

In the model assessing impacts on personal safety, the number of conflict-causing omnivorous families emerged as a significant positive predictor. One (0.878, $p = 0.011$), two (1.257, $p = 0.001$), and three (1.890, $p < 0.001$) omnivore families were each significantly associated with increasing levels of safety concerns. Forest coverage showed a marginally significant negative association (-0.313, $p = 0.076$), and shape index was positively associated with safety impact (0.212, $p = 0.017$). Conversely, the presence of two carnivorous families was significantly associated with reduced safety impacts (-0.834, $p = 0.043$). Overall, the number of conflict-causing omnivores and carnivores demonstrated greater explanatory power for perceived safety impacts than other variables.

3.3. Current mitigation strategies of HWCs

Environmental education stands out with the highest average effectiveness rating (6.40) and the highest application rate, implemented in 78.5% of the 93 PAs reporting HWCs (Fig. 4). Relocating human settlements ranked second (6.23), followed by incentive policies (5.87) and voluntary commercial insurance (5.81). Standard deviation values indicate substantial variation in perceived effectiveness across most mitigation strategies. Strategies related to grazing, such as improving grazing practices, establishing wildlife feeding points, and keeping guard dogs, were rated relatively low in effectiveness and had limited application. Notably, the removal of problematic animals—though applied in 37.6% of PAs—received the lowest effectiveness score (2.6).

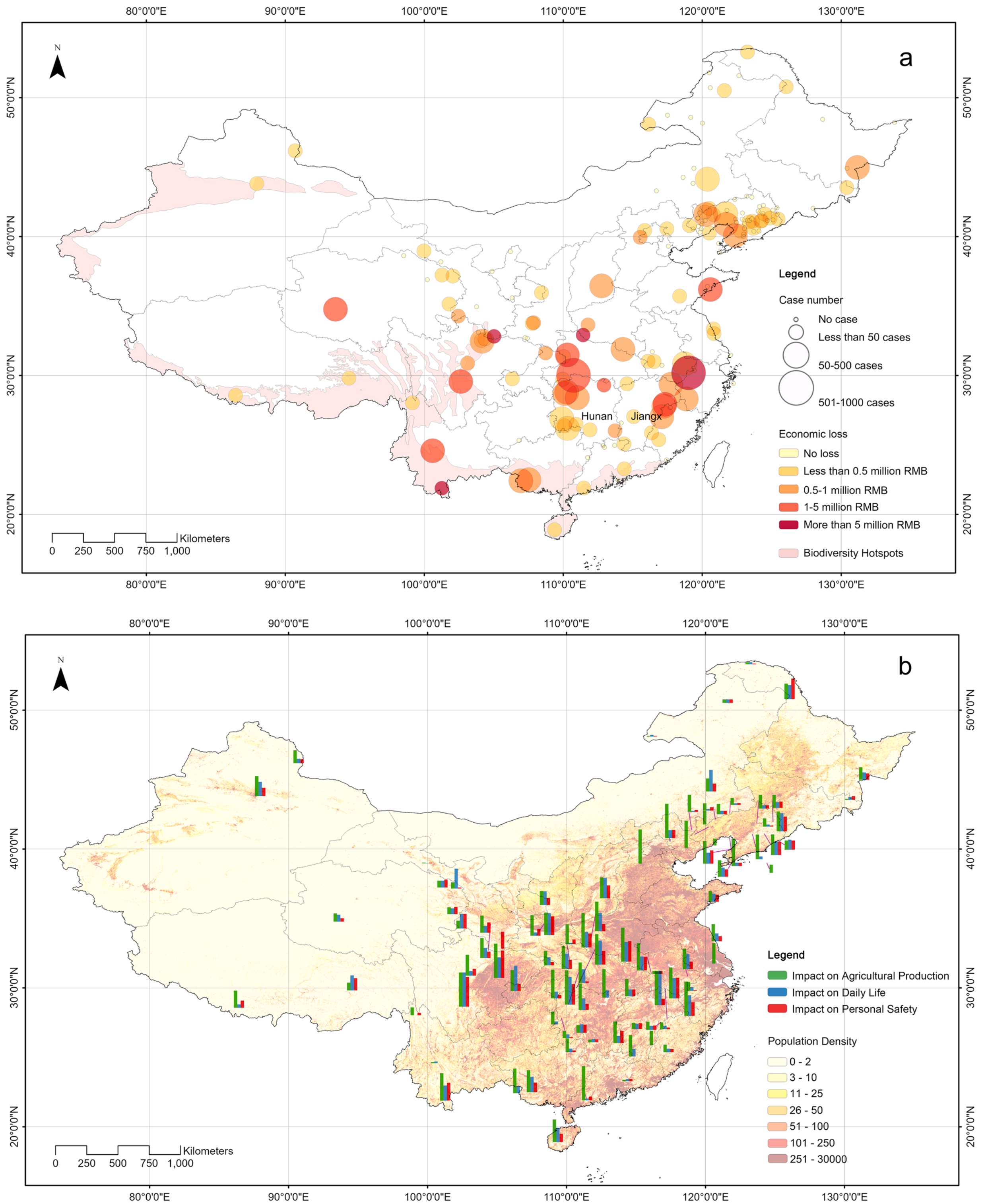

Fig. 3. Distribution of HWC overall impacts: (a) Case numbers and related economic losses overlapping with biodiversity hotspots; (b) Impacts on agricultural production, daily life, and personal safety overlapping with China's population density (Moehl et al. 2023). Map lines delineate study areas and do not necessarily depict accepted national boundaries.

Table 4
Statistic of HWC case number and economic loss in 93 PAs reporting HWCs.

Case number	Number	Share (n = 93)	Economic loss (CNY)	Number	Share (n = 93)
Less than 50 cases	64	68.8%	Less than 0.5 million	58	62.4%
50–500 cases	27	29.0%	0.5–1 million	23	24.7%
501–1000 cases	2	2.2%	1–5 million	8	8.6%
More than 1000 cases	0	0.0%	More than 5 million	4	4.3%

Table 5
GLM coefficients of relationships between potential drivers and different impact perspectives.

Variable		Agriculture Production	Daily Life	Personal Safety
Cropland coverage		0.110	-0.105	0.051
Forest coverage		-0.098	-0.394.	-0.313.
Human settlement coverage		-0.002	-0.346	-0.250
Shape index		0.274*	0.027	0.212*
Human population density		0.026	0.236.	0.004
Number of conflict-causing omnivores	one species	0.702.	0.545	0.878*
	two species	0.866.	0.933*	1.257**
	three species	1.641**	1.646***	1.890***
Number of conflict-causing herbivores	one species	-0.302	0.237	0.082
	two species	1.079	0.972	0.052
Number of conflict-causing carnivores	one species	-0.515	-0.190	-0.386
	two species	-0.867	-1.141*	-0.834*

Note: the numbers are estimate values, and the symbols are significate codes (0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1).

4. Discussion

Our study provides a comprehensive understanding of HWCs in Chinese PAs based on surveys conducted among PA rangers. While each conflict case is context-specific (Zimmermann et al., 2021), identifying general patterns at the national scale remains essential for informing HWC management policies—particularly within China's top-down governance framework. Compared to studies relying on social media data (Lou and Cong, 2024), our survey-based approach provides a more direct and accurate reflection of current conditions, avoiding potential misinformation and species biases often associated with online platforms (Bergman et al., 2022). Our findings reveal that HWCs are widespread across China and have a particularly significant impact on local communities in central and southeastern regions, even more frequently than in biological hotspots (Peng et al., 2021). This spatial discrepancy highlights the need to direct greater attention and resources to these underrepresented areas, where rural populations disproportionately bear the economic and social burdens of conflict. Notably, among the 93 PAs reporting HWCs, 63.4% involve conflicts with more than one wildlife family, indicating these interactions' complex and multifaceted nature. Among all conflict types, human-wild boar conflicts are the most prevalent, and omnivore-related conflicts affect agricultural production, daily life, and personal safety. Environmental education stands out as the most frequently applied and the most effective mitigation strategy.

Among various HWCs, human-wild boar conflict emerges as the most prevalent type, reported in 44.3% of PAs within their distribution range. Wang et al. (2023) estimated that wild boar-related conflicts affected 25 provinces, 147 cities and 399 districts/counties in 2021. These figures align closely with our findings and underscore the widespread nature of this issue. The widespread presence and high frequency of HWCs reflect the wild boar's remarkable adaptability to human-modified environments (Podgórski et al., 2013; Stillfried et al., 2017) and its opportunistic foraging behaviour (Davidson et al., 2022). In addition, strong reproductive capacity in agricultural areas and reduced predation pressure—partly due to the absence of large carnivores— have contributed to population growth under China's strict conservation policies, further exacerbating conflict intensity (Zheng et al., 2023). Macaques (34.3%) and bears (15.0%) are also prominent conflict-causing species. These taxa, like wild boars, are omnivorous and highly adaptable (Zhang et al., 2023), traits that increase their tendency to exploit anthropogenic food sources and approach human settlements (Lamb et al., 2017). All three groups—wild boars, macaques, and bears—contribute substantially to crop damage, while wild boars and bears are more frequently associated with livestock depredation and threats to human safety. Their shared dietary overlap with humans and behavioural plasticity make omnivores critical in shaping HWC dynamics in China.

Snow leopards exhibit the highest proportion of HWCs among the Felidae family, accounting for 42.9% of PAs in their distribution range. Farrington and Tsering (2019) reported that 65.8% of respondents in their survey had experienced livestock depredation by snow leopards, underscoring the high likelihood of human-snow leopard conflicts. This pattern is likely driven by the fact that communities within snow leopard distribution ranges primarily depend on grazing for their livelihoods (Liu et al., 2024). Moreover, bharals (*Pseudois nayaur*), snow leopard's key prey, exhibit significant spatial and temporal overlap with free-ranging livestock, increasing the risk of predation and conflict (Wang et al., 2024).

The findings related to omnivores are also supported by our GLM analysis, which identified the number of conflict-causing omnivorous families as the most influential factor in explaining the impacts of HWCs on agricultural production, daily life and personal safety. The results indicate a positive correlation—namely, the greater the number of omnivorous families present, the more

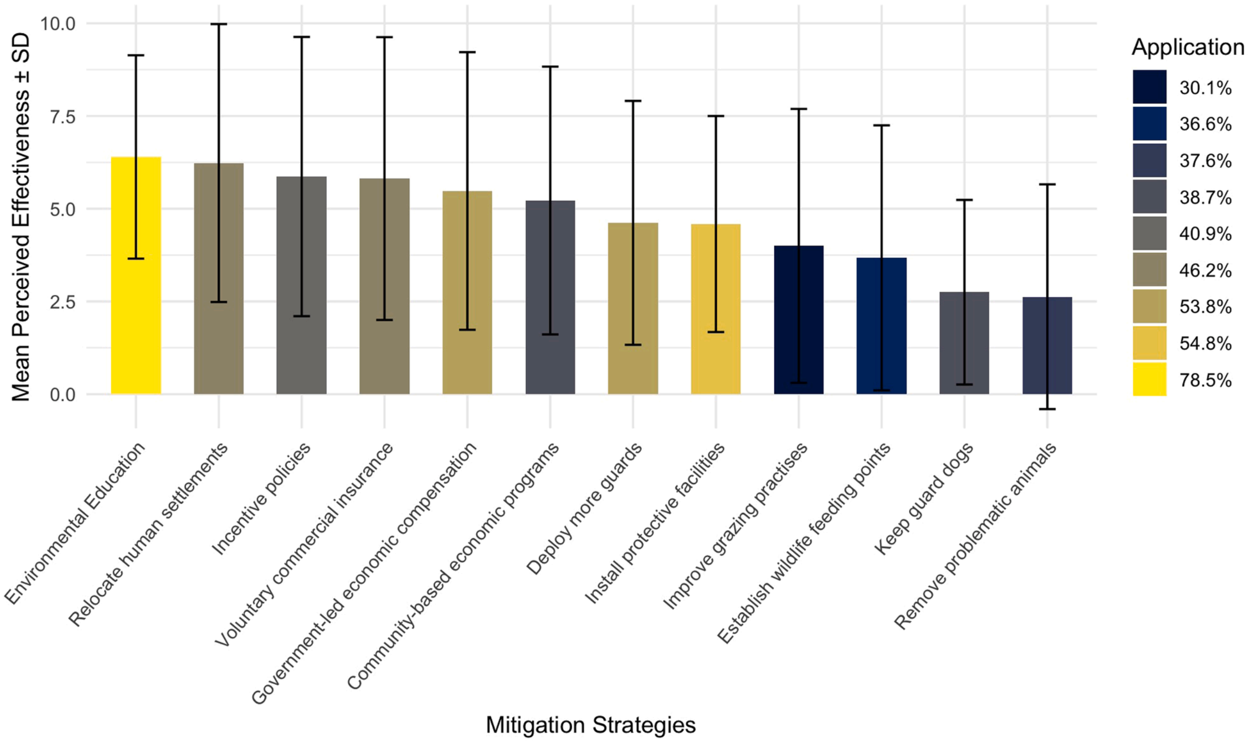

Fig. 4. Perceived effectiveness of different HWC mitigation strategies. Application is defined as the proportion of PAs (out of 93 with reported HWCs) that employed each strategy, indicated by the colour of the bars.

severe the impacts across all three dimensions. In contrast, carnivorous species showed a negative association with perceived impacts on daily life and personal safety, suggesting they may indirectly mitigate conflict through ecological suppression or avoidance behaviours. Ripple et al. (2014) noted that the decline of large carnivores can trigger cascading trophic interactions, often mediated through their prey or sympatric macropredators. The presence of carnivores may help regulate omnivore populations (Hoeks et al., 2020) and suppress their activity levels. Furthermore, compared with omnivores, carnivores were reported to cause fewer conflicts in our survey and generally avoid human-dominated landscapes (Kautz et al., 2021) in their hunting behaviour (Kuiper et al., 2024) and reproductive behaviour (Yovovich et al., 2020). These behavioural patterns may explain the negative relationship between carnivore presence and impacts on daily life and personal safety. However, in terms of agricultural production, carnivores contribute to livestock depredation. Although their presence may reduce crop damage by limiting omnivore activity, this trade-off may explain why the number of carnivorous families was not a significant predictor in the agricultural impact model.

Compared to the number of conflict-causing omnivorous and carnivorous families, the influence of landscape and demographic variables—such as shape index, forest coverage, and human population density—on HWC impacts is considerably weaker. Among these, the shape index of PAs, which reflects the complexity of boundaries between PAs and surrounding human-dominated landscapes (Bhardwaj and Kumar, 2019), showed a positive association with impacts on agricultural production and personal safety. This aligns with findings by Sharma et al. (2020), who reported that greater forest fragmentation contributes to more frequent HWCs, and Acharya et al. (2017), who observed that wildlife attacks were positively associated with higher landscape shape index, which increase as habitat patches become more fragmented. The differing land management practices on either side of PA boundaries may exacerbate fragmentation and create more edge habitats, increasing the potential for human-wildlife encounters. These findings suggest that irregularly shaped PAs with complex, zigzag boundaries are more prone to conflict, highlighting the importance of spatial planning in PA design. Where feasible, adopting more regular and compact PA boundaries could help minimize edge effects and reduce HWC risk. In contrast, the shape index was not significantly associated with impacts on daily life—likely because such impacts (e.g., infrastructure damage, traffic obstruction) typically occur outside or away from PA boundaries, where shape plays a lesser role.

Forest cover emerged as a marginal mitigating factor, slightly reducing the perceived impacts of HWCs on daily life and personal safety. Bombieri et al. (2023) found that the number of human-wildlife attacks has significantly declined in countries with a high proportion of forest cover. Similarly, other studies have shown that deforestation is a major driver of HWCs (Mekonen, 2020), and that forest cover below a certain threshold can exacerbate conflict intensity (Chartier et al., 2011), further highlighting the protective role of forests. From the perspective of agricultural production, forest coverage has shown mixed effects. Some studies report a positive association between forest cover and HWC impacts involving carnivores (Teixeira et al., 2021) and omnivores (Liu et al., 2024), but no significant relationship for herbivore-related conflicts (Gubbi et al., 2014). These contrasting effects may explain why forest coverage was not a significant predictor in our agricultural production model. Moreover, in some surveyed PAs—particularly those located in western and northwestern China—forest ecosystems are not the primary conservation targets. Many of these PAs, such as those in Qinghai and Tibet, are dominated by grassland or desert landscapes, where conservation efforts focus on non-forest ecosystems. Including such PAs in the analysis may therefore reduce the explanatory power of forest cover as a variable. Additionally, several key conflict species in these regions, including snow leopards, brown bears, dholes, and wolves, are not forest dwellers but are primarily associated with grassland or alpine environments. These ecological and regional differences also might explain why forest cover was not identified as a significant predictor in the models. Thus, this does not imply that forest cover has no influence on HWCs; rather, its relevance may be more pronounced in forest-dominated ecosystems where species–habitat relationships differ substantially.

In our study, human population density showed only marginal significance in the model assessing impacts on daily life. Nyhus (2016) noted that the relationship between human population size and HWCs remains inconclusive. Therefore, our findings suggest that population density is not a major factor influencing the perceived impacts of HWCs. Similarly, cropland and human settlement coverage, as well as the number of herbivore families, were not significant predictors in any of the models, indicating their limited explanatory power in this context.

Interestingly, while government-led economic compensation remains a popular approach, its perceived effectiveness is moderate compared to non-monetary strategies such as environmental education and human resettlement. Environmental education emerged as both the most effective and widely adopted strategy, highlighting its potential to foster coexistence through non-lethal means and reduce retaliatory behaviour toward wildlife. Previous studies have demonstrated that environmental education can foster promote more positive attitudes toward wildlife (Freund et al., 2019; Salazar et al., 2024; Walwambe and Barakagira, 2024), thereby helping to mitigate conflict (Dieser and Bogner, 2019). Kansky et al. (2016) argued that without tangible monetary benefits, non-monetary values, such as the positive emotions derived from living with wildlife and learning spiritual value of wildlife, can enhance tolerance, all of which can be cultivated through environmental education. These findings help explain why environmental education received relatively high effectiveness ratings in our study. The assessment of mitigation strategies revealed substantial variation in both perceived effectiveness and implementation rates. This variation may be attributed to regional and site-specific differences across PAs (Karanth and Kudalkar, 2017), as well as the species-specific nature of mitigation effectiveness (Pant et al., 2023).

Bringing these dimensions together provides actionable implications for future HWC mitigation. First, the spatial distribution of HWCs—especially their high intensity in central and southeastern China—suggests an urgent need to rebalance current management priorities. While biodiversity hotspots receive considerable policy and research attention, resource allocation should also focus on the underrepresented regions where rural communities disproportionately bear the economic and social costs of conflict. Second, the prominence of omnivore-related conflicts, involving wild boars, monkeys, and bears, highlights the need for omnivore-specific mitigation strategies. Given these species' dietary flexibility and high adaptability to human-modified environments, conventional deterrents may be insufficient. Third, our findings underscore the ecological importance of large carnivores in indirectly regulating conflict-causing omnivores and herbivores. The observed negative association between carnivore presence and perceived impacts on daily life and safety suggests that maintaining or restoring populations of top predators could contribute to conflict mitigation through ecological suppression effects. Integrating predator conservation into HWC policy frameworks could provide long-term ecosystem-based solutions. Fourth, spatial planning should be prioritized in PA design and management. The positive correlation between irregular PA boundary shapes and increased conflict risk indicates that more compact and regularly shaped PAs may help minimize edge effects and reduce human-wildlife encounters. Fifth, our results reaffirm the value of environmental education as a non-lethal, cost-effective, and highly impactful mitigation strategy. Education initiatives can foster positive attitudes, enhance local tolerance, and reduce retaliatory behaviours. Policymakers should therefore scale up support for environmental education campaigns, particularly in high-conflict regions.

While this study provides valuable insights into the patterns, drivers, and management of HWCs in Chinese PAs, several limitations should be acknowledged. First, the findings should be interpreted as national-scale patterns within the surveyed PA system rather than as precise prevalence estimates for all PAs in China. Although the stratified sampling design ensured coverage across major PA categories, response rates varied among PA types and some regions remained underrepresented.

Second, the reliance on ranger-reported data may introduce reporting bias, as conflict severity and frequency may be under- or overestimated depending on individual perceptions and local conditions. As professionals engaged in wildlife protection and PA management, rangers may also hold views on mitigation strategies—such as wildlife removal, compensation, and environmental education—that differ from those of local communities. Their field experience and direct involvement in conflict management provide valuable practical knowledge, but these professional perspectives may not fully capture local residents' concerns, needs, and priorities. The results on mitigation strategies should therefore be interpreted with caution, and future research should integrate community perspectives to provide a more balanced understanding of stakeholder views.

Third, while the analysis incorporated ecological and spatial predictors, it did not directly measure community-level sociocultural factors such as attitudes toward wildlife, local perceptions, or broader cultural context. These variables may also shape both the occurrence of HWCs and the effectiveness of mitigation strategies, but they are difficult to standardize in a national-scale PA survey. The results therefore reflect broad patterns and management tendencies across sampled PAs, and future research would benefit from combining PA-level assessments with household- or community-level surveys and additional socioeconomic and sociocultural variables to strengthen inference on resident experiences, conflict dynamics, and policy effectiveness.

5. Conclusion

This study provides a national-scale analysis of HWCs across Chinese PAs, based on primary data from rangers. Our findings reveal that HWCs are not confined to biodiversity hotspots but are widespread, particularly severe in central and southeastern regions where rural communities face the most significant economic and social burdens. The high prevalence of multi-species conflicts—especially those involving adaptable omnivores such as wild boars, macaques, and bears—underscores the need for mitigation strategies specific to omnivores. Among all potential drivers, the number of conflict-causing omnivorous families emerged as the strongest predictor of perceived impacts on agricultural production, daily life, and personal safety. In contrast, the presence of carnivores showed a mitigating effect, suggesting a potential ecological role in suppressing conflict-prone omnivore populations. Landscape features, particularly the shape complexity of PAs, also influenced conflict impacts, emphasizing the importance of spatial planning in PA design. Mitigation strategies varied widely in effectiveness and application. Environmental education stood out as the most effective and widely implemented non-lethal strategy, reinforcing its value in promoting coexistence. In contrast, commonly adopted approaches such as economic compensation and animal removal showed moderate to low effectiveness. Our findings underscore the need to extend HWC mitigation strategies beyond conventional biodiversity hotspots, with particular emphasis on managing omnivore populations and implementing preventive educational initiatives. The study yields practical policy recommendations for reconciling conservation objectives with socioeconomic needs in China's PAs, thereby contributing to international environmental governance frameworks.

Our findings suggest a need to rebalance conservation priorities to include high-conflict yet underrepresented regions. Future management efforts should prioritize integrated, ecosystem-based approaches that combine spatial planning, omnivore-specific interventions, and environmental education. These strategies are crucial for advancing equitable, effective, and locally adapted solutions to China's growing human-wildlife conflict challenges.

IRB Statement

Ethical review and approval were waived for this study, due to the fact that the survey content does not involve any sensitive or confidential information. Furthermore, all participants will be fully informed of the study objectives and data handling practices. Therefore, based on these considerations, it was deemed unnecessary to conduct ethical review and approval for this particular study.

CRediT authorship contribution statement

Marco Heurich: Writing – review & editing, Supervision, Resources. **Hannes König:** Writing – review & editing, Supervision. **Wanting Peng:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition. **Wang Yiifu:** Writing – review & editing, Validation, Supervision, Methodology. **Ye Htet Lwin:** Validation, Software. **Mengxi Kou:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to check grammar and to improve readability and language. After using this tool/service, we reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Declaration of Competing Interest

The authors declare no conflict of interest.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2026.e04194.

Data Availability

Data will be made available on request.

References

Acharya, K.P., Paudel, P.K., Jnawali, S.R., Neupane, P.R., Köhl, M., 2017. Can forest fragmentation and configuration work as indicators of human–wildlife conflict? evidences from human death and injury by wildlife attacks in Nepal. Ecol. Indic. 80, 74–83. https://doi.org/10.1016/j.ecolind.2017.04.037.

Bergman, J.N., Buxton, R.T., Lin, H.-Y., Lenda, M., Attinello, K., Hajdasz, A.C., Rivest, S.A., Tran Nguyen, T., Cooke, S.J., Bennett, J.R., Clements, J.C., 2022. Evaluating the benefits and risks of social media for wildlife conservation. Facets 7, 360–397. https://doi.org/10.1139/facets-2021-0112.

Bhardwaj, G.S., Kumar, A., 2019. The comparison of shape indices and perimeter interface of selected protected areas especially with reference to Sariska Tiger Reserve, India. Glob. Ecol. Conserv. 17. https://doi.org/10.1016/j.gecco.2018.e00504.

Boitani, L., Phillips, M. & Jhala, Y.V. 2023. *Canis lupus* (amended version of 2018 assessment). The IUCN Red List of Threatened Species 2023: e.T3746A247624660. https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T3746A247624660.en. Accessed on 07 May 2025.

Bombieri, G., Penteriani, V., Almasieh, K., Ambarli, H., Ashrafzadeh, M.R., Das, C.S., Dharaiya, N., Hoogesteijn, R., Hoogesteijn, A., Ikanda, D., Jedrzejewski, W., Kaboli, M., Kirilyuk, A., Jangid, A.K., Sharma, R.K., Kushnir, H., Lamichhane, B.R., Mohammadi, A., Monroy-Vilchis, O., Mukeka, J.M., Nikolaev, I., Ohrens, O., Packer, C., Pedrini, P., Ratnayeke, S., Seryodkin, I., Sharp, T., Palei, H.S., Smith, T., Subedi, A., Tortato, F., Yamazaki, K., Delgado, M.D.M., 2023. A worldwide perspective on large carnivore attacks on humans. PLoS Biol. 21, e3001946. https://doi.org/10.1371/journal.pbio.3001946.

Brooks, M.E., Kristensen, K., van Benthem, K.J., Magnusson, A., Berg, C.W., Nielsen, A., Skaug, H.J., Mächler, M., Bolker, B.M., 2017. Modeling zero-inflated count data with glmmTMB. BioRxiv, 132753. https://doi.org/10.1101/132753.

Buchholtz, E.K., Stronza, A., Songhurst, A., McCulloch, G., Fitzgerald, L.A., 2020. Using landscape connectivity to predict human-wildlife conflict. Biol. Conserv. 248, 108677. https://doi.org/10.1016/j.biocon.2020.108677.

Chartier, L., Zimmermann, A., Ladle, R.J., 2011. Habitat loss and human–elephant conflict in Assam, India: does a critical threshold exist? Oryx 45, 528–533. https://doi.org/10.1017/s0030605311000044.

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, e4922. https://doi.org/10.1002/ecs2.4922.

Dai, Y., Li, Y., Xue, Y., Hacker, C.E., Li, C., Zahoor, B., Liu, Y., Li, D., Li, D., 2022. Mitigation Strategies for Human-Tibetan Brown Bear (Ursus arctos pruinosus) Conflicts in the Hinterland of the Qinghai-Tibetan Plateau. Animals 12, 1422. https://doi.org/10.3390/ani12111422.

Davidson, A., Malkinson, D., Shanas, U., Cherry, M., 2022. Wild boar foraging and risk perception—variation among urban, natural, and agricultural areas. J. Mammal. 103, 945–955. https://doi.org/10.1093/jmammal/gyac014.

Dieser, O., Bogner, F.X., 2019. Intervention Impact on Young Students' Associations about Wolf and Lynx. Soc. & Anim. 27, 544–574. https://doi.org/10.1163/15685306-12341492.

Douma, J.C., Weedon, J.T., Warton, D., 2019. Analysing continuous proportions in ecology and evolution: A practical introduction to beta and Dirichlet regression. Methods Ecol. Evol. 10, 1412–1430. https://doi.org/10.1111/2041-210x.13234.

Farrington, J.D., Tsering, D., 2019. Human-snow leopard conflict in the Chang Tang region of Tibet, China. Biol. Conserv. 237, 504–513. https://doi.org/10.1016/j.biocon.2019.07.017.

Feng, L., Liao, W., Hu, J., 2019. Towards a More Sustainable Human–Animal Relationship: The Legal Protection of Wildlife in China. Sustainability 11, 3112. https://doi.org/10.3390/su11113112.

Ferraz, K.M.P.M.B., Marchini, S., Bogoni, J.A., Paolino, R.M., Landis, M., Fusco-Costa, R., Magioli, M., Munhoes, L.P., Saranholi, B.H., Ribeiro, Y.G.G., Domini, J.A, Magezi, G.S., Gebin, J.C.Z., Ermenegildo, H., Galetti Junior, P.M., Galetti, M., Zimmermann, A., Chiarello, A.G., 2022. Best of both worlds: Combining ecological and social research to inform conservation decisions in a Neotropical biodiversity hotspot. J. Nat. Conserv. 66, 126146. https://doi.org/10.1016/j.jnc.2022.126146.

Foley, J.A., Defries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E. A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyder, P.K., 2005. Global consequences of land use. Science 309, 570–574. https://doi.org/10.1126/science.1111772.

Freund, C.A., Achmad, M., Kanisius, P., Naruri, R., Tang, E., Knott, C.D., 2019. Conserving orangutans one classroom at a time: evaluating the effectiveness of a wildlife education program for school-aged children in Indonesia. Anim. Conserv. 23, 18–27. https://doi.org/10.1111/acv.12513.

Gao, J., Zou, C., Zhang, K., Xu, M., Wang, Y., 2020. The establishment of Chinese ecological conservation redline and insights into improving international protected areas. J. Environ. Manag. 264, 110505. https://doi.org/10.1016/j.jenvman.2020.110505.

Greer, C.E., Doughty, R.W., 1976. Wildlife utilization in China. Environ. Conserv. 3, 200–208.

Gubbi, S., Swaminath, M.H., Poornesha, H.C., Bhat, R., Raghunath, R., 2014. An elephantine challenge: human–elephant conflict distribution in the largest Asian elephant population, southern India. Biodivers. Conserv. 23, 633–647. https://doi.org/10.1007/s10531-014-0621-x.

Hartig, F., 2017. Package 'dharma'. R. Package 531, 435.

Hoeks, S., Huijbregts, M.A.J., Busana, M., Harfoot, M.B.J., Svenning, J.C., Santini, L., 2020. Mechanistic insights into the role of large carnivores for ecosystem structure and functioning. Ecography 43, 1752–1763. https://doi.org/10.1111/ecog.05191.

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. Glob. Ecol. Conserv. 22, e00947. https://doi.org/10.1016/j.gecco.2020.e00947.

IUCN, 2023. IUCN SSC guidelines on human-wildlife conflict and coexistence. Gland, Switzerland, IUCN. https://doi.org/10.2305/YGIK2927.

IUCN, 2024. The IUCN Red List of Threatened Species (version 2024.2). ⟨https://www.iucnredlist.org⟩.

Ji, Y., Wei, X., Liu, F., Li, D., Li, J., 2022. Spatial-temporal patterns of human-wildlife conflicts under coupled impact of natural and anthropogenic factors in Mt. Gaoligong, western Yunnan, China. Glob. Ecol. Conserv. 40, e02329. https://doi.org/10.1016/j.gecco.2022.e02329.

Jiang, H., 2020. Utilization and protection of wild animal resources in Sichuan and Shaanxi (1949-1962). J. Chin. Communist Part. Hist. Stud. 2, 104–117.

Jiang, Y., 2024. The study of current situation and residents' cognition of human-wildlife conflict caused by North China Leopard in Heshun County, Shanxi Province. Acad. J. Humanit. & Soc. Sci. 7, 144–149. https://doi.org/10.25236/ajhss.2024.071223.

Kansky, R., Kidd, M., Knight, A.T., 2016. A wildlife tolerance model and case study for understanding human wildlife conflicts. Biol. Conserv. 201, 137–145. https://doi.org/10.1016/j.biocon.2016.07.002.

Karanth, K.K., Kudalkar, S., 2017. History, location, and species matter: insights for human–wildlife conflict mitigation from India. Hum. Dimens. Wildl. 22, 331–346. ⟨https://doi-org.emedien.ub.uni-muenchen.de/10.1080/10871209.2017.1334106⟩.

Kautz, T.M., Fowler, N.L., Petroelje, T.R., Beyer, D.E., Svoboda, N.J., Belant, J.L., 2021. Large carnivore response to human road use suggests a landscape of coexistence. Glob. Ecol. Conserv. 30, e01772. https://doi.org/10.1016/j.gecco.2021.e01772.

König, H.J., Kiffner, C., Kramer-Schadt, S., Fürst, C., Keuling, O., Ford, A.T., 2020. Human–wildlife coexistence in a changing world. Conserv. Biol. 34, 786–794. https://doi.org/10.1111/cobi.13513.

Kuiper, T., Macdonald, D., Sibanda, L., Mathe, L.J., Mahdlamoto, D., Loveridge, A., 2024. The behaviours of different carnivore and livestock species shape spatial patterns of human–carnivore conflict. People Nat. 6, 1248–1261. https://doi.org/10.1002/pan3.10633.

Lamb, C.T., Mowat, G., McLellan, B.N., Nielsen, S.E., Boutin, S., 2017. Forbidden fruit: human settlement and abundant fruit create an ecological trap for an apex omnivore. J. Anim. Ecol. 86, 55–65. https://doi.org/10.1111/1365-2656.12589.

Li, B.V., Pimm, S.L., 2020. How China expanded its protected areas to conserve biodiversity. Curr. Biol. 30, R1334–R1340. https://doi.org/10.1016/j.cub.2020.09.025.

Li, W., Liu, P., Guo, X., Wang, L., Wang, Q., Yu, Y., Dai, Y., Li, L., Zhang, L., 2018. Human-elephant conflict in Xishuangbanna Prefecture, China: Distribution, diffusion, and mitigation. Glob. Ecol. Conserv. 16, e00462. https://doi.org/10.1016/j.gecco.2018.e00462.

Li, Y., Zhang, C., Gao, H., Lu, M., Nie, Y., 2024. Effects of expansion of protected areas and habitat transformation on spatiotemporal variation in human-wildlife conflict. Conserv. Biol. 39, e14393. https://doi.org/10.1111/cobi.14393.

Liu, J., Li, Y., Liu, K., Zhang, C., Gao, H., Lu, M., Nie, Y., 2024. The synergistic impact of socioeconomic and landscape factors on spatial patterns of human-wildlife conflicts. Biol. Conserv. 290, 110431. https://doi.org/10.1016/j.biocon.2023.110431.

Long, S., Li, S., 2025. The Status and Spatial Patterns of Poaching, Illegal Trade, and Human–Bear Conflict of Asiatic Black Bears in China, 2010–2020. Diversity 17, 93. https://doi.org/10.3390/d17020093.

Lou, Y., Cong, L., 2024. Temporal and spatial characteristics, mechanisms and patterns of Human-Wildlife Conflicts in China (in Chinese). Natl. Park 2, 433–446. https://doi.org/10.20152/j.np.202405020062.

Lu, C., Xie, G., Xiao, Y., 2012. Ecological Compensation and the Cost of Wildlife Conservation: Chang Tang Grasslands, Tibet. J. Resour. Ecol. 3, 20–25. https://doi.org/10.5814/j.issn.1674-764x.2012.01.004.

Lu, T., Huntsinger, L., 2023. Managing Human–Wildlife Conflict on the Tibetan Plateau. Ecosyst. Health Sustain. 9, 0023. https://doi.org/10.34133/ehs.0023.

Ma, B., Xie, Y., Zhang, T., Zeng, W., Xue, Y., 2021. Construction of a human-wildlife spatial interaction index in the Three-River Source Region, China. Ecol. Indic. 129, 107986. https://doi.org/10.1016/j.ecolind.2021.107986.

Ma, B., Cai, Z., Hou, Y., Wen, Y., 2023. Estimating the household costs of human–wildlife conflict in China's giant panda national park. J. Nat. Conserv. 73, 126400. https://doi.org/10.1016/j.jnc.2023.126400.

Ma, Z., Li, J., Chen, R., Wei, X., Chen, W., 2024. Estimating the impact of wildlife damage compensation policy on farmers' incomes. J. Nat. Conserv. 81, 126709. https://doi.org/10.1016/j.jnc.2024.126709.

Madden, F., 2004. Creating Coexistence between Humans and Wildlife: Global Perspectives on Local Efforts to Address Human–Wildlife Conflict. Hum. Dimens. Wildl. 9, 247–257. https://doi.org/10.1080/10871200490505675.

Mekonen, S., 2020. Coexistence between human and wildlife: the nature, causes and mitigations of human wildlife conflict around Bale Mountains National Park, Southeast Ethiopia. BMC Ecol. 20, 51. https://doi.org/10.1186/s12898-020-00319-1.

Mi, X., Feng, G., Hu, Y., Zhang, J., Chen, L., Corlett, R.T., Hughes, A.C., Pimm, S., Schmid, B., Shi, S., Svenning, J.C., Ma, K., 2021. The global significance of biodiversity science in China: an overview. Natl. Sci. Rev. 8, nwab032. https://doi.org/10.1093/nsr/nwab032.

Ministry of Natural Resources of the People's Republic of China. Terrestrial Ecological Foundation Zoning of China (Trial). 2023. ⟨https://m.mnr.gov.cn/⟩.

Moehl, J., Reith, A., McKee, J., Weber, E., Laverdiere, M., Swan, B., Yang, H., Hauser, T., Rose, A., Walters, S., Roddy, D., Pyle, J., O'Shell, M.A., Urban, M., 2023. Land. HD China v1, 0. ⟨https://landscan.ornl.gov⟩.

National Forestry and Administration Grassland. Public notice on the intergration and optimization adjustments of national protected areas 2024.https://www.forestry.gov.cn/lyj/1/gsgg/20241015/589055.html.

Nyhus, P.J., 2016. Human–Wildlife Conflict and Coexistence. Annu. Rev. Environ. Resour. 41, 143–171. https://doi.org/10.1146/annurev-environ-110615-085634.

Pant, B., Sharma, H.P., Dahal, B.R., Regmi, S., Belant, J.L., 2023. Spatio-temporal patterns of human-wildlife conflicts and effectiveness of mitigation in Shuklaphanta National Park, Nepal. PLoS One 18, e0282654. https://doi.org/10.1371/journal.pone.0282654.

Peng, Q., Yang, R., Cao, Y., Wang, F., Hou, S., Tseng, T.H., Wang, X., Wang, P., Zhao, Z., Yu, L., Locke, H., 2021. One-third of lands face high conflict risk between biodiversity conservation and human activities in China. J. Environ. Manag. 299, 113449. https://doi.org/10.1016/j.jenvman.2021.113449.

Pettigrew, M., Xie, Y., Kang, A., Rao, M., Goodrich, J., Liu, T., Berger, J., 2012. Human-carnivore conflict in China: a review of current approaches with recommendations for improved management. Integr. Zool. 7, 210–226. https://doi.org/10.1111/j.1749-4877.2012.00303.x.

Podgórski, T., Baś, G., Jędrzejewska, B., Sönnichsen, L., Śnieżko, S., Jędrzejewski, W., Okarma, H., 2013. Spatiotemporal behavioral plasticity of wild boar (*Sus scrofa*) under contrasting conditions of human pressure: primeval forest and metropolitan area. J. Mammal. 94, 109–119. https://doi.org/10.1644/12-mamm-a-038.1.

Pooley, S., Bhatia, S., Vasava, A., 2021. Rethinking the study of human-wildlife coexistence. Conserv. Biol. 35, 784–793. https://doi.org/10.1111/cobi.13653.

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. Conserv. Biol., e14428 https://doi.org/10.1111/cobi.14428.

R Core Team, R, 2024. R: A language and environment for statistical computing, In R Foundation for Statistical Computing. Vienna, Austria.

Ripple, W.J., Estes, J.A., Beschta, R.L., Wilmers, C.C., Ritchie, E.G., Hebblewhite, M., Berger, J., Elmhagen, B., Letnic, M., Nelson, M.P., Schmitz, O.J., Smith, D.W., Wallach, A.D., Wirsing, A.J., 2014. Status and ecological effects of the world's largest carnivores. Science 343, 1241484. https://doi.org/10.1126/science.1241484.

Salazar, G., Satheesh, N., Ramakrishna, I., Monroe, M.C., Mills, M., Karanth, K.K., 2024. Using environmental education to nurture positive human–wildlife interactions in India. Conserv. Sci. Pract. 6, e13096. https://doi.org/10.1111/csp2.13096.

Sharma, P., Chettri, N., Uddin, K., Wangchuk, K., Joshi, R., Tandin, T., Pandey, A., Gaira, K.S., Basnet, K., Wangdi, S., Dorji, T., Wangchuk, N., Chitale, V.S., Uprety, Y., Sharma, E., 2020. Mapping human-wildlife conflict hotspots in a transboundary landscape, Eastern Himalaya. Glob. Ecol. Conserv. 24, e01284. https://doi.org/10.1016/j.gecco.2020.e01284.

Sillero-Zubiri, C., Sukumar, R., Treves, A., 2007. Living with wildlife: the roots of conflict and the solutions. Key Top. Conserv. Biol. 266–272.

Stillfried, M., Gras, P., Börner, K., Göritz, F., Painer, J., Röllig, K., Wenzler, M., Hofer, H., Ortmann, S., Kramer-Schadt, S., 2017. Secrets of success in a landscape of fear: urban wild boar adjust risk perception and tolerate disturbance. Front. Ecol. Evol. 5, 157. https://doi.org/10.3389/fevo.2017.00157.

Su, K., Yang, J., Lin, L., Hou, Y., Wen, Y., 2021. Balancing human–bear coexistence with biodiversity conservation. Hum. Dimens. Wildl. 28, 155–169. https://doi.org/10.1080/10871209.2021.2013996.

Tang, L., Ke, X., Chen, Y., Wang, L., Zhou, Q., Zheng, W., Xiao, B., 2020. Which impacts more seriously on natural habitat loss and degradation? Cropland expansion or urban expansion? Land Degrad. & Dev. 32, 946–964. https://doi.org/10.1002/ldr.3768.

Teixeira, L., Tisovec-Dufner, K.C., Marin, G.L., Marchini, S., Dorresteijn, I., Pardini, R., 2021. Linking human and ecological components to understand human-wildlife conflicts across landscapes and species. Conserv Biol. 35, 285–296. https://doi.org/10.1111/cobi.13537.

Treves, A., 2009. The human dimensions of conflicts with wildlife around protected areas. Wildlife society science human dimensions 214–228.

Walwambe, D., Barakagira, A., 2024. The influence of conservation education on pro-wildlife sustainability behaviour at the eco-centric zone of budongo central forest reserve in Buliisa District, Uganda. J. Glob. Ecol. Environ. 20, 28–44. https://doi.org/10.56557/jogee/2024/v20i38832.

Wang, D., Li, Q., Hou, L., Su, X., Lian, X., 2024. Spatiotemporal overlap among snow leopard, bharal, and free-ranging livestock: Suggestions on mitigating human-snow leopard conflict. Glob. Ecol. Conserv. 53, e03029. https://doi.org/10.1016/j.gecco.2024.e03029.

Wang, W., Feng, C., Liu, F., Li, J., 2020. Biodiversity conservation in China: a review of recent studies and practices. Environ. Sci. Ecotechnol 2, 100025. https://doi.org/10.1016/j.ese.2020.100025.

Wang, Y., Yang, A., Yang, Q., Kong, X., Fan, H., 2023. Spatiotemporal patterns of human and wild boar conflicts in rural China and its implications for social-ecological systems coevolution. J. Geogr. Sci. 33, 1614–1630. https://doi.org/10.1007/s11442-023-2145-3.

Woodroffe, R., Thirgood, S., Rabinowitz, A., 2005. People and wildlife, conflict or co-existence? Cambridge University Press.

Xu, J., Wei, J., Liu, W., 2019. Escalating human-wildlife conflict in the Wolong Nature Reserve, China: A dynamic and paradoxical process. Ecol. Evol. 9, 7273–7283. https://doi.org/10.1002/ece3.5299.

Yang, J., Huang, X., 2021. The 30 m annual land cover dataset and its dynamics in China from 1990 to 2019. Earth Syst. Sci. Data 13, 3907–3925. https://doi.org/10.5194/essd-13-3907-2021.

Yovovich, V., Allen, M.L., Macaulay, L.T., Wilmers, C.C., 2020. Using spatial characteristics of apex carnivore communication and reproductive behaviors to predict responses to future human development. Biodivers. Conserv. 29, 2589–2603. https://doi.org/10.1007/s10531-020-01990-y.

Zang, Z., Guo, Z., Fan, X., Han, M., Du, A., Xu, W., Ouyang, Z., 2022. Assessing the performance of the pilot national parks in China. Ecol. Indic. 145, 109699. https://doi.org/10.1016/j.ecolind.2022.109699.

Zhang, K., Karim, F., Jin, Z., Xiao, H., Yao, Y., Ni, Q., Li, B., Pu-Cuo, W., Huang, Z., Xu, H., 2023. Diet and feeding behavior of a group of high-altitude rhesus macaques: high adaptation to food shortages and seasonal fluctuations. Curr. Zool. 69 304-314. https://doi.org/10.1093/cz/zoac047.

Zhang, W., Xie, M., Solomon, T., Li, M., Yin, X., Wang, C., 2024. Satisfaction of households in surrounding communities of protected areas with economic compensation for wildlife accidents: a case study of Xishuangbanna National Nature Reserve in China. For. Econ. Rev. 6, 22–38. https://doi.org/10.1108/fer-04-2024-0005.

Zhao, W., Zong, L., Wang, M., 2024. Spatial distribution of nature reserves in China. Acta Ecol. Sin. 44, 2786–2799.

Zheng, B., Lin, X., Qi, X., 2023. Identifying the risk regions of wild boar (*Sus scrofa*) Incidents in China. Animals 13, 3186. https://doi.org/10.3390/ani13203186.

Zimmermann, A., Johnson, P., de Barros, A.E., Inskip, C., Amit, R., Soto, E.C., Lopez-Gonzalez, C.A., Sillero-Zubiri, C., de Paula, R., Marchini, S., Soto-Shoender, J., Perovic, P.G., Earle, S., Quiroga-Pacheco, C.J., Macdonald, D.W., 2021. Every case is different: cautionary insights about generalisations in human-wildlife conflict from a range-wide study of people and jaguars. Biol. Conserv. 260, 109185. https://doi.org/10.1016/j.biocon.2021.109185.