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Human-Wildlife Conflict: Causes, Consequences and Mitigation Strategies Toward Coexistence

Azmat Ali
azmatalizoologist.edu@gmail.com
Department of Zoology, Government Post Graduate Jahanzeb College, Saidu Sharif Swat, Khyber Pakhtunkhwa, Pakistan
ORCID iD: 0009-0007-5385-3946

Corresponding Author: Azmat Ali azmatalizoologist.edu@gmail.com

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ABSTRACT

Human-wildlife conflict has become one of the most pressing challenges at the interface of biodiversity conservation and rural and urban livelihoods worldwide. As human populations expand into former wildlife habitat, encounters between people and animals, from large carnivores and elephants to raptors, primates and rodents, are growing more frequent and consequential. This narrative review provides a synthesis of recent and foundational research and literature on the ecological, socio-economic and behavioural drivers of HWC, impacts on human wellbeing, livelihoods, wildlife and the mitigation strategies that have been tested on different continents. Causes considered include habitat loss and fragmentation, resource scarcity, individual animal behaviour and habituation, and demographic and livelihood factors shaping exposure and vulnerability. Consequences include economic damages, physical harm and mortality, psychological distress and hardship, gendered burdens, and retaliatory killings that pose a risk to already endangered species. Mitigation strategies reviewed include physical barriers and emerging technologies, compensation and insurance schemes, community-based monitoring, connectivity-sensitive land-use planning, and a growing movement to reframe conflict management around coexistence rather than tolerance alone. The review concludes that there is need to develop context-specific, socially legitimate and multidisciplinary approaches that involve the lived experience of affected communities and include ecological knowledge in order to achieve durable solutions.

Keywords: *Human-Wildlife Conflict; Coexistence; Conservation; Wildlife management; Mitigation; Rural livelihoods*

INTRODUCTION

Human-wildlife conflict, commonly abbreviated as HWC, refers to interactions between people and wild animals that produce negative outcomes for either party, including crop and property damage, livestock loss, injury or death, and the killing or persecution of wildlife [1]. The phenomenon is not new, but its scale and visibility have grown as expanding human populations, agricultural intensification and infrastructure development bring people into closer, more frequent contact with wildlife across every inhabited continent [2]. Conflicts are recorded across a remarkable diversity of taxa, from large carnivores such as brown bears and grey wolves to megaherbivores such as elephants and hippopotamuses, raptors, primates and smaller opportunistic species such as rodents and wild boar [3]. Because conflicts arise from the interaction between ecological processes and human social systems, resolving them requires attention to the perceptions, values and livelihoods of the people who share landscapes with wildlife, not only to animal ecology [4].

Underlying most human-wildlife conflict is a parallel human-human conflict, in which stakeholders bring different explanatory frameworks, moral values and risk perceptions to the same situation, producing divergent goals for how wildlife should be managed [5]. Contemporary scholarship

increasingly favours the broader term human-wildlife interactions, which covers neutral and beneficial encounters alongside conflictual ones and frames the desired end state as coexistence rather than the mere absence of conflict [5]. This review draws on recent literature spanning South Asia, East and Southern Africa, Europe, East Asia, Latin America and North America to synthesise current understanding of the causes, consequences and mitigation of human-wildlife conflict, with a view to informing policy in regions such as Pakistan where communities continue to share landscapes with diverse wild fauna [6].

CAUSES OF HUMAN-WILDLIFE CONFLICT

Habitat loss, fragmentation and land-use change

The most frequently cited driver of human-wildlife conflict is the loss and fragmentation of natural habitat as agriculture, settlement and infrastructure expand into areas formerly occupied by wildlife [4]. When land sparing for conservation is not matched by wildlife-tolerant land sharing nearby, animals are squeezed into smaller patches and forced to cross human-dominated land in search of food, mates and shelter [4]. In the Kavango-Zambezi Transfrontier Conservation Area of Namibia, large mammal populations are recolonising areas from which they had once been largely eliminated, and this recovery, combined with a growing human population, has produced pronounced conflict that now threatens both local livelihoods and the long-term viability of the transfrontier conservation concept [7]. Fragmentation also determines where animals move: dispersing individuals seeking to maintain connectivity between habitat patches frequently pass through settled areas, creating identifiable connectivity-conflict interfaces that concentrate risk in predictable corridors [8]. Urban and peri-urban expansion introduces a distinctive variant of this dynamic, since green spaces designed for human recreation also provide food and refuge for wildlife, so that the size of urban parks is directly associated with pest-consultation frequency in cities such as Tokyo [2]. Similar patterns are apparent in Krakow, Poland, where red foxes, roe deer and wild boar are the species most frequently involved in vehicle collisions, property intrusion and other recorded damage along the urban-forest interface [3].

Resource overlap, food scarcity and attractants

Conflict frequently intensifies when natural food resources become scarce, pushing animals toward anthropogenic food sources or livestock [9]. Research on grizzly bears, *Ursus arctos horribilis*, in British Columbia found that conflict related mortality rose by roughly a fifth for every halving of annual salmon (*Oncorhynchus* spp.) biomass, and that most attacks on humans and conflict killings clustered around the onset of hyperphagia, supporting the view that limited natural food supply, rather than simply the presence of so-called problem individuals, drives much human-carnivore conflict [9]. Brown bears visiting human settlements in the Cantabrian population of Spain were disproportionately young individuals drawn by fruit trees within villages, particularly in summer when wild food is scarcer, indicating that attractant management could meaningfully reduce these encounters [10]. Around Daxueshan Nature Reserve in China, the spatial pattern of conflict with Asiatic black bears and other wildlife was closely tied to the proximity of croplands and apiaries to forest edges, again reflecting the influence of accessible food resources on conflict hotspots [11].

Individual behaviour, habituation and species biology

Not all conflict can be attributed to landscape-level drivers; the behaviour of individual animals also matters considerably [12]. Habituation to human presence, whereby animals lose their natural wariness, has been shown in brown bears of Shiretoko National Park, Japan, to elevate the risk of human-caused mortality in the offspring of habituated mothers, with more than 70% of young males born to highly habituated mothers near a remote protected area eventually killed by people, because these young bears appear to inherit their mothers' reduced avoidance of human activity [12]. Some elephants in Kenya learn that their tusks do not conduct electricity and specialise in breaking through electric fences, a behaviour that becomes entrenched and is disproportionately performed by bulls [13]. Comparative

work across three macaque species inhabiting temples and urban areas in Asia found that an individual's life stage, sex and social rank shape its propensity for risky interactions with humans, showing that conflict is not evenly distributed across a population but concentrated in particular demographic classes [14]. Cognitive flexibility also plays a role: species capable of rapid behavioural innovation and social learning, such as corvids and gulls, exploit novel human-derived resources more readily, a capacity that can escalate conflict in urban settings [15].

Socio-economic, demographic and livelihood factors

Exposure to and tolerance of wildlife are also shaped by socio-economic circumstances [1]. Households that rely heavily on livestock and poultry rearing report substantially higher rates of conflict and more negative attitudes toward predatory species such as the Andean condor, whereas socio-demographic variables including age, gender and occupation showed little independent association with conflict in the Southern Yungas of Argentina [1]. In central India, crop loss was reported by a large majority of surveyed households, with agricultural, demographic and environmental factors, together with existing mitigation measures, jointly determining the probability and scale of loss [16]. Poverty and dependence on natural resource-based livelihoods increase vulnerability to conflict because affected households often lack the financial buffers or alternative income sources needed to absorb crop or livestock losses, a pattern documented around Bale Mountains National Park in Ethiopia, where agricultural expansion, new human settlement, overgrazing, deforestation and illegal grass collection were together identified as the principal drivers of conflict with the park's wildlife [17]. Conflict linked to rodent outbreaks in Spanish farmland illustrates that even taxa not typically considered charismatic can generate intense and polarised conservation conflicts: farmers, hunters and conservationists hold markedly different views on how, and whether, rodent populations should be controlled [18]. A systematic review of 26 Ethiopian studies published between 2009 and 2021, covering 47 species of terrestrial vertebrate, identified land use change, proximity to protected areas and illegal resource exploitation as the drivers reported most consistently across this literature [19].

CONSEQUENCES OF HUMAN-WILDLIFE CONFLICT

Economic costs

Crop damage and livestock depredation remain the most commonly documented economic consequence of human-wildlife conflict [20]. In the Dhidhessa Wildlife Sanctuary of southwestern Ethiopia, conflict with the common hippopotamus, *Hippopotamus amphibius*, one of Africa's most threatened megaherbivores, imposed substantial costs on farming communities through crop destruction despite the species' conservation importance [20]. In communal areas adjacent to Mid Zambezi protected areas, goats, *Capra aegagrus hircus*, and cattle, *Bos taurus*, accounted for 47% and 38% of recorded livestock losses respectively, with lions, *Panthera leo*, and spotted hyenas, *Crocuta crocuta*, identified as the two wildlife species most often responsible [21]. Detailed household surveys in India show that, once all cost categories are compared directly, the monetary value of human injuries and deaths considerably exceeds that of crop and livestock losses for several species, so casualty-focused conflict resolution deserves at least as much attention as compensation aimed narrowly at material damage [22].

Human injury, mortality and safety

Human injury and death caused by wildlife carry consequences that extend well beyond their immediate toll [23]. In Nepal, elephants, tigers, leopards and rhinoceroses caused a substantial number of human fatalities and injuries over the study period, with particular demographic groups and locations disproportionately affected [23]. A systematic review of human-wildlife conflict research across the Hindu Kush Himalaya region found that fatal and non-fatal attacks were prominent themes across the 240 studies analysed, alongside crop and livestock loss, underscoring that physical safety concerns dominate local perceptions of conflict severity in mountain communities [6]. A six-year study in the

buffer zone of Shuklaphanta National Park, Nepal, found that wild boar caused most recorded human injuries, leopards were responsible for the majority of livestock deaths, mainly sheep and goats killed in summer, and Asian elephants caused most crop and the only reported structural damage to homes, although most respondents still judged existing mitigation measures to be reasonably effective [24]. Beyond the physical harm, injury and death from wildlife attacks frequently generate lasting resentment toward the species responsible, undermining public support for the conservation measures that protect them [23].

Psychological, social and gendered dimensions

Money is not the only thing at stake, since communities living with recurring wildlife encounters often carry a psychological and social burden that rarely shows up in a loss assessment [25]. Financial losses from predation are not a major concern in households but emotional losses from multiple interactions are more significant than financial losses [1]. One global review looked specifically at how these costs fall along gender lines, examining six areas, namely economic, physical, psychological and social costs, participation in conservation decisions, and exposure to wildlife crime, and found that women bore a disproportionate share of the psychological and caregiving burden while having comparatively little say in how conflicts were later managed [25]. Ethnographic fieldwork at the Kakum Conservation Area in Ghana also found that although the loss of food is the most obvious impact of elephant crop-raiding on the lives of farmers, the effects on their mental and physical health are also reported to have worsened beyond the loss of crops [26].

Consequences for wildlife populations and conservation

There are significant costs to the wildlife population from human-wildlife conflict, including retaliatory killing of species already of conservation concern [27]. The Andean condor, *Vultur gryphus*, listed as Vulnerable and included in CITES Appendix I, continues to face persecution linked to its perceived role as a livestock predator, with the greater threat arising from mass poisoning events rather than direct killing [1]. In the northern Andes of Ecuador and Colombia, at least sixty individuals of the Endangered Black-and-chestnut Eagle, *Spizaetus isidori*, were poached between 2000 and 2022 in apparent retaliation for poultry predation, even though forest cover around nests did not itself predict poultry consumption, pointing instead to husbandry practices and wild prey availability as more tractable targets for intervention [27]. Onagers, *Equus hemionus onager*, recovering within a protected area of southern Iran illustrate a similar dilemma: local tolerance rose with education and income but fell as conflict intensified, meaning that the species' long-term recovery depends on sustained public support as the population expands into farming and herding areas [28]. Elephant conflict management in Kenya has, in some cases, involved partial detusking of chronic fence-breaking bulls, a controversial but non-lethal alternative to destroying repeat offenders, and in one conservancy this reduced fence damage by the four worst offenders roughly six-fold [13].

Urban and peri-urban consequences

Cities are not exempt from this either, and if anything, urban wildlife management has become one of the more visible arenas for conflict in recent years [29]. American cities show how differently this plays out depending on the species: several municipalities now tolerate, even quietly welcome, resident coyotes, yet show almost no tolerance for rats, a gap owing more to cultural attitudes than to any real difference in risk [29]. Tokyo offers a longer-running example of the same idea: across twenty years of pest-consultation records for the city's districts, complaints about wasps and snakes climbed alongside the area of nearby green space, while complaints about rats and other indoor pests barely moved, suggesting that expanding urban greenery brings some species into closer contact with people without necessarily affecting others [2].

MITIGATION STRATEGIES

Physical barriers and emerging technologies

Physical exclusion remains a cornerstone of conflict mitigation, though its effectiveness depends on species-specific behaviour and maintenance [13]. Electric fencing has substantially reduced elephant incursions in parts of Africa, yet certain bulls learn that their tusks insulate them from shocks and become chronic fence-breakers, requiring supplementary measures such as detusking [13]. Aversive geofencing devices, designed to deliver a warning sound followed by a mild electric shock when a collared animal crosses a virtual boundary, are being proposed as a more flexible alternative to static fencing for Asian elephants, *Elephas maximus*, although the approach has mainly been tested in other species and still needs trials with captive elephants to confirm its safety before wider use [30]. Beyond fencing, a review of 105 studies on artificial intelligence applications in biodiversity hotspots found that tools such as camera trap image recognition, acoustic monitoring and predictive risk modelling have improved conflict monitoring, predictive accuracy and community engagement, although their uptake remains constrained by cost, infrastructure and local capacity in many of the regions where conflict is most severe [31]. Spatial risk modelling more broadly, including the mapping of connectivity-conflict interfaces, helps managers identify the specific corridors and habitat edges where mitigation investment will have the greatest effect, rather than applying uniform measures across a whole landscape [8].

Compensation, insurance and incentive schemes

Financial compensation and insurance schemes seek to redistribute the costs of conflict away from individual households and toward the wider society that benefits from conservation [11]. An insurance-based compensation scheme around Daxueshan Nature Reserve in China was found to be both administratively practical and potentially replicable at a broader scale, provided that loss assessment procedures are improved [11]. However, compensation programmes are frequently criticised for being poorly targeted, because the proportion of households in central India that both experienced loss and successfully received compensation is relatively low, and the amount received depends heavily on reporting behaviour and the species involved rather than solely on the scale of loss [16]. Given that human casualties represent the largest cost category in some contexts, compensation frameworks focused narrowly on crop and livestock loss risk neglecting the populations most burdened by conflict [22].

Community-based monitoring and participatory approaches

Local knowledge and community reporting networks have proven their worth here too [32]. In the Polish Carpathians, residents submitted more than 600 reports of wolf and bear sightings and encounters, and researchers used this crowd-sourced record to pinpoint, and even anticipate, conflict hotspots at a level of detail that conventional monitoring could not match, a fair demonstration of what rural communities can offer as active partners rather than passive subjects of top-down conservation programmes [32]. In addition, and sometimes ignored, is indigenous and traditional knowledge, as a long history of living with wildlife has created locally legitimate strategies for coexistence that have not been picked up by formal conservation science, and when combined with social science, indigenous knowledge leads to strategies that are more culturally informed and enduring [33]. Anthropologists working through multispecies ethnography bring yet another lens, paying close attention to how communities themselves talk about and make sense of their relationships with primates and other wild animals, and picking up nuances that a structured survey would likely miss [34]. And where the underlying dispute is really among people rather than with the wildlife itself, as with the debate over rodent control on Spanish farmland, bringing in trained, independent mediators has been suggested as a more honest way of addressing that human disagreement directly, rather than treating it purely as a technical wildlife problem [18].

Land-use planning, connectivity conservation and policy

Reconciling wildlife conservation with agricultural production over the long term requires land-use planning that considers land-sparing and land-sharing together rather than as alternatives, because coexistence depends on wildlife-tolerant practices within shared, working landscapes [4]. Within transfrontier conservation areas, effective conflict mitigation must be embedded in the broader governance framework linking neighbouring countries: fragmented or inconsistent policy across borders can undermine local efforts to manage recolonising large mammal populations [7]. Spatial ecology research emphasises that wildlife damage follows identifiable patterns at multiple scales, from the immediate vicinity of settlements to the wider landscape, information that can be used to prioritise where preventive resources such as fencing or deterrents will be most cost-effective [35]. Attractant management, including the removal of accessible fruit trees, rubbish and other unsecured food sources near settlements, is a comparatively low-cost intervention supported by evidence from brown bear visitation patterns in Spain [10].

Animal welfare considerations in lethal and non-lethal control

Any mitigation strategy that involves removing or killing problem animals raises welfare questions frequently overlooked in conflict management discussions [36]. Comparative analysis of predator control methods for terrestrial carnivores, such as wolves and lynx, and marine mammals, such as seals, in Europe found that welfare impacts vary considerably between lethal and non-lethal methods, and that formal welfare assessment is rarely built into the choice of control method [36]. This gap suggests that mitigation policy should evaluate not only the effectiveness of a given intervention in reducing conflict but also its consequences for the welfare of the individual animals involved [36].

Reframing conflict as coexistence

Part of the recent literature argues that the language used to frame conflict shapes how it is managed, and that shifting away from conflict-centred vocabulary toward coexistence encourages more holistic, less adversarial responses [5]. Coexistence has been defined as a dynamic state in which humans and wildlife coadapt to sharing landscapes under governance that keeps risk at a socially and ecologically tolerable level, a framing that also draws attention to the positive interactions a narrower focus on conflict can obscure [5]. Tolerance, long treated as the benchmark for successful coexistence, has been critiqued as an inherently anthropocentric concept that still positions wildlife as subordinate to human preferences, with hospitality proposed as an alternative that more actively welcomes wild animals into shared spaces [37]. Wildlife reintroduction programmes are likewise being reconceptualised as processes of renewed coexistence, in which the human dimensions of reintroduction are built into project design from the outset rather than added once ecological objectives are set [38]. Treating tolerance as a multidimensional construct has proved useful in carnivore conservation, as research among villagers living alongside tigers, *Panthera tigris*, in the Bangladesh Sundarbans found that tolerance was predicted by underlying beliefs about the species and perceptions of population trend and risk, with direct negative experiences shaping tolerance only indirectly, through those beliefs [39]. Recognition of animal cognition, including the capacity of some species to learn, remember and adapt their behaviour around humans, is likewise informing more behaviourally grounded approaches to deterrence and coexistence planning [15].

REGIONAL AND TAXONOMIC PATTERNS

Table 1. summarises representative causes, consequences and mitigation strategies documented across a range of taxa and regions, illustrating both the diversity of contexts in which human-wildlife conflict occurs and the recurring themes that connect them [19].

Table 1. Representative causes, consequences and mitigation strategies for selected taxa and regions

Region	Focal taxa	Principal causes	Principal consequences	Mitigation strategies reported
Southern Yungas, Argentina	Andean condor, raptors	Perceived livestock predation	Retaliatory persecution, poisoning	Community dialogue, attitude change [1]
Namibia (KAZA TFCA)	Elephants, large mammals	Species recolonisation, population growth	Livelihood impacts, threats to TFCA viability	Transboundary governance [7]
Central India	Tigers, elephants, ungulates	Habitat overlap, agricultural exposure	Crop and livestock loss	Compensation schemes [16]
Nepal	Elephants, tigers, leopards, rhinoceros	Protected area proximity	Human injury and death	Early warning, spatial mitigation [23,24]
Kenya	Elephants	Fence-breaking behaviour	Crop damage, fence costs	Detusking, electric fencing [13]
Ethiopia	Hippopotamus, mixed wildlife	Agricultural expansion, settlement	Crop loss, wellbeing decline	Community-based management [17,20]
Spain	Brown bear, grizzly bear	Food scarcity, attractants	Settlement visits, mortality	Attractant management [9,10]
Poland	Grey wolf, brown bear	Range expansion into settled land	Livestock depredation	Community-based monitoring [32]
Japan	Brown bear	Habituation	Elevated offspring mortality	Aversion training, habituation prevention [12]
Ecuador and Colombia	Black-and-chestnut Eagle	Poultry predation	Poaching of Endangered species	Habitat and poultry management [27]
Urban USA	Coyotes, rats	Urban food and shelter availability	Property and safety concerns	Differentiated tolerance policy [29]

CONCLUSION

There is no single face to human-wildlife conflict. It looks different depending on the species, the landscape and the community involved, and it is probably better understood as a tangle of ecological,

social and economic pressures than as one problem with one cause. Habitat loss, resource scarcity, the particular habits of individual animals, and the everyday economic pressures on rural households all play a part in where and how conflict shows up. Its costs go well beyond crop and livestock loss: people are injured or killed, households carry a psychological toll that rarely gets counted, and already threatened species lose ground as tolerance for them wears thin. No single tool fixes this. What seems to work is combining physical and technological deterrents with fair compensation, genuine community involvement, land-use planning that takes connectivity seriously, and real attention to animal welfare, rather than leaning on any one of these alone. Increasingly, the goal itself is shifting too, away from simply reducing conflict and toward coexistence, where sharing a landscape with wildlife is treated as normal rather than as a cost to be tolerated. In a country such as Pakistan, where people and wildlife continue to share the same ground day to day, this points toward locally grounded, participatory approaches that draw on more than one discipline, offering perhaps the best chance of protecting both livelihoods and the biodiversity they ultimately depend on.

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Conflict of interest

The author declares that he has no conflicts of interest.

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