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RESEARCH ARTICLE

HUMAN-WILDLIFE CONFLICT IN A CHANGING WORLD: PRECEDENTS, DRIVERS, AND TACTICS FOR SUSTAINABLE COEXISTENCE

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Abstract

Human-wildlife conflict (HWC) has appeared as one of the most persistent maintenance challenges worldwide, driven by quick habitat fragmentation, agricultural growth, and growing overlap between human settlements and wildlife ranges. This review combines key ecological and anthropogenic drivers motivating HWCs, concentrating on how land-use change, resource competition, and behavioural adaptation in wildlife deepen contacts with humans. Global patterns divulge region-specific disputes such as, elephant crop-raiding in Asia, carnivore-livestock predation in Africa, and primate invasions in urbanizing landscapes, stressing the socio-ecological dimensions of HWC. The ecological consequences spread beyond direct human and wildlife losses; they disturb trophic interactions, alter species dispersal, and endanger long-term ecosystem stability. Mitigation processes have grown from traditional deterrent-based approaches to more scientific, landscape-oriented strategies. Modern interventions include geofencing, early-warning systems, habitat restoration, and scientifically designed barriers, while traditional knowledge systems continue to provide context-specific solutions. Community-based preservation models and wildlife corridors have proven effective in reducing spatial clash by ensuring safe animal movement and improving human tolerance through inclusive decision-making. By integrating ecological understanding, local community participation, and adaptive management, this review emphasizes the need for holistic conflict mitigation.

Keywords: Anthropogenic Activities, Biodiversity, Crop Loss, Degradation, Habitat Fragmentation.

1. Introduction

Human-wildlife conflict (HWC) is scientifically defined as the negative interactions between human populations and wild animal species, leading to adverse consequences for social, cultural, or economic wellbeing, while simultaneously impacting wildlife populations and their habitats [1,2,3]. Such disputes emerge when humans and wildlife compete for limited and overlapping resources such as space, food, and water, especially in landscapes where natural areas are degraded due to agricultural expansion, industrial activity, urbanization, and infrastructural development [2,4]. Direct manifestations of HWC include crop raiding by herbivores, livestock predation by carnivores, damage to property and infrastructure, and, in severe instances, injury or loss of human life [3,5,6]. From the wildlife perspective, conflict situations often lead to vengeful killings, population decline, habitat disintegration, altered movement patterns, and disruption of natural behavior and genetic exchange [7,8]. Beyond immediate ecological impacts, HWC also erodes social tolerance toward wildlife, disproportionately affects rural and forest-dependent communities, exacerbates poverty, and threatens regional protection goals [5,9,10]. Thus, HWC represents not merely an ecological challenge, but a complex socio-ecological issue that demands integrated mitigation approaches involving ecological science, land-use planning, community participation, and supportive policy frameworks.

The frequency and severity of HWC are rapidly increasing worldwide, driven by expanding human populations (**Fig. 1**) [11,12]. As natural resources decline and anthropogenic pressures intensify, humans and wildlife are brought into closer and more frequent contact [13,14]. Climate change further alters territorial suitability and species movement patterns, creating new pressure points for confrontations [1,6,8]. In several regions, conservation efforts have also contributed to the recovery of certain wildlife populations, inadvertently increasing the likelihood of encounters in shared landscapes. Globally, HWC has emerged as a major barrier to biodiversity conservation and sustainable development, particularly in rural regions of Africa and Asia where high biodiversity intersects with dense agro-forestry-dependent human populations [15,16,17]. In these areas, the economic, nutritional, and emotional costs of conflict are profound, affecting food security, livelihoods, and human safety. Retaliatory responses often drive declines in threatened species, compound environmental degradation, and hinder long-term safeguarding outcomes [17].

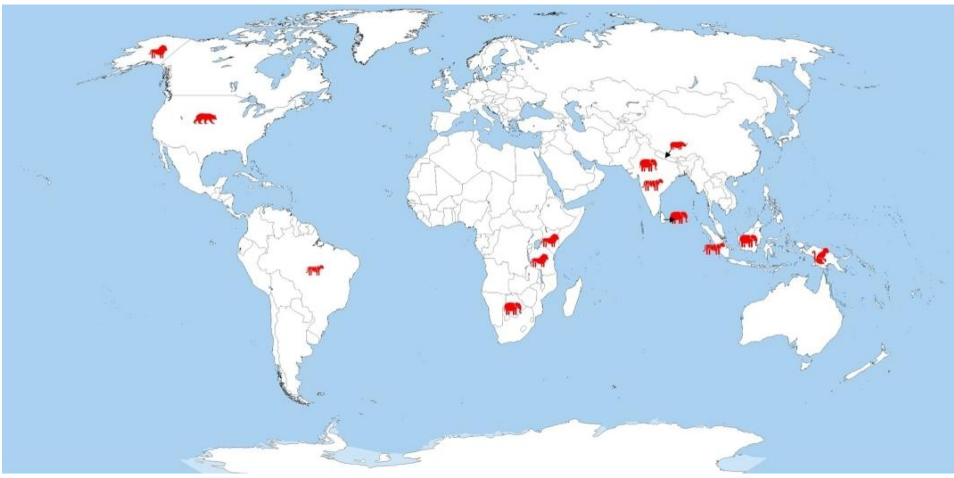

Fig. 1 Map depicting major HWC zones worldwide, highlighting species-specific conflict areas

In this context, the significance of mitigating HWC cannot be overstated. Contemporary conservation frameworks, including the Convention on Biological Diversity and the Sustainable Development Goals, prioritize coexistence-based approaches that balance ecological integrity with human wellbeing. Effective mitigation requires integrated, context-specific strategies such as landscape-level planning, early-warning systems, improved compensation mechanisms, and community-led rapid response teams. Strengthening local participation, promoting livelihood diversification, and implementing evidence-based policy frameworks are essential for fostering coexistence and enhancing both socio-economic and ecological resilience in human-dominated landscapes.

2. Key Ecological and Anthropogenic Drivers of HWCs

Major drivers of HWC are clearly illustrated by recent case studies that link specific land-use and climatic changes to documented incidents (**Fig. 2**). In Nepal, a landscape-scale analysis showed that deaths and injuries caused by tigers, leopards, rhinos, and elephants were concentrated in highly fragmented forest mosaics, where disaggregated patches and dense human settlements forced large mammals to move through villages and crop fields [18]. In eastern India's North Bengal, a two-year dataset of 380 crop-raiding events revealed that Asian elephants repeatedly targeted paddy and maize fields located along their traditional movement routes between forest blocks and tea estates, with risk increasing near forest edges and riverine corridors [19]. Across Assam, West Bengal, Odisha, and Chhattisgarh, news and conservation reports document annual cycles of elephant herds moving through tea gardens and paddy landscapes, causing extensive crop loss, house damage, and frequent human and elephant fatalities as migratory paths intersect expanding agriculture [20]. In the Western Ghats (Wayanad), compensation records and farmer interviews indicate that rising elephant numbers, fruiting jackfruit and mango in farm plots, and paddy cultivation near forest boundaries have shifted discord to peak seasons when elephants concentrate on these high-calorie crops, with over 90% of reported incidents involving crop depredation [21]. Climate-linked droughts and forest fires in India and East Africa are pushing elephants and large carnivores out of drying protected areas toward irrigated farms and village water sources, where tigers and elephants have been implicated in hundreds of human deaths and substantial crop losses over the past decade [22]. Beyond agriculture, a recent study from a coal-mining landscape in southern India showed that mining-induced land-cover change and associated monoculture plantations have altered rhesus macaque ranging, reducing crop damage but causing a shift toward frequent house-raiding in expanding built-up areas, directly tying extractive industry to new, highly localized conflict fronts [23].

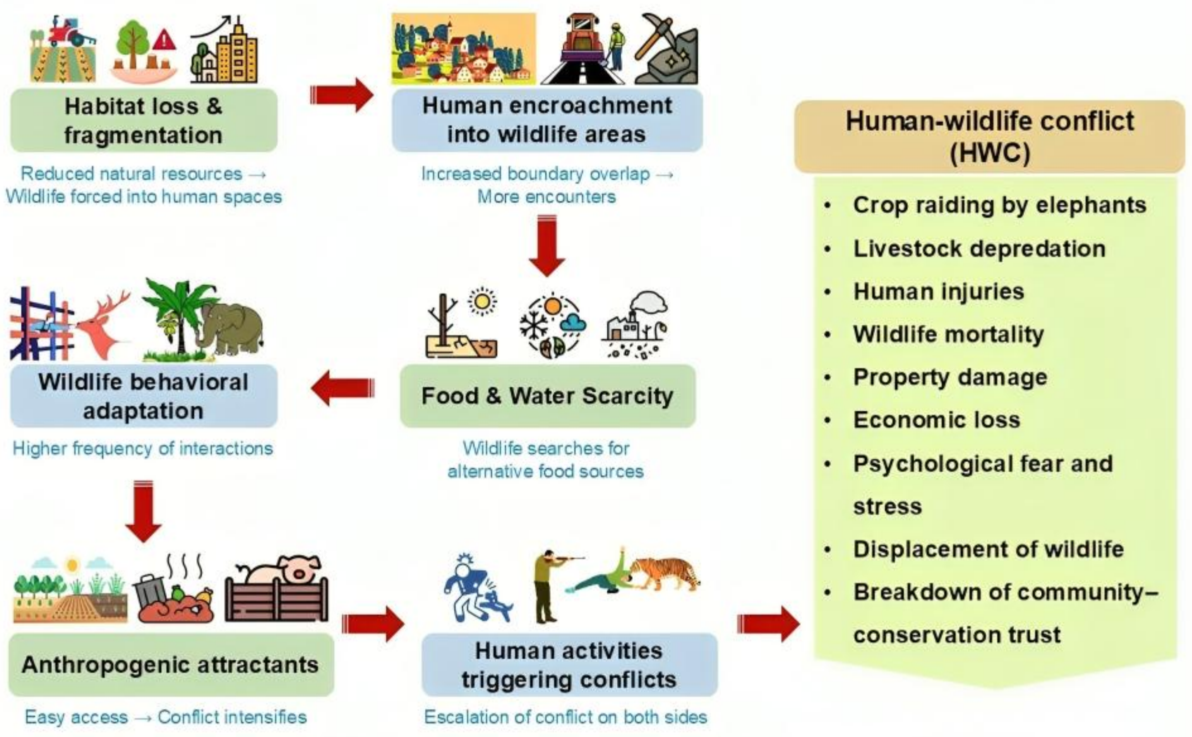

Fig. 2 Conceptual flowchart of the main drivers of HWC

3. Global patterns of major HWCs

HWCs varies globally with regionally distinct species driving most conflicts. These conflicts are often shaped by local ecological and socio-economic factors leading to diverse impact types such as livestock depredation, crop damage, or direct human injury. **Table 1** presents a concise overview of key species, associated issues, and geographic regions, illustrating how different continents face unique challenges and require tailored management approaches
.

Table 1 Overview of major HWC species, conflict types, and geographic distribution across global regions

Region/ Country	Key species	Dominant conflict issues
Kenya, Tanzania, Zimbabwe (Africa)	African lion, spotted hyena, African elephant	Livestock depredation, crop raiding, human injuries and deaths near protected areas [24,25,26]
Namibia, Botswana (Africa)	Hyena, elephant, leopard	Livestock kills, crop loss, retaliatory killings of predators [24,26]
India (Assam, West Bengal, Odisha, etc)	Asian elephant, tiger, leopard, wild boar	Crop raiding, livestock kills, human fatalities in forest fringe agriculture [27,28]
Sri Lanka	Asian elephant	Paddy and chena crop damage, high human-elephant mortality [29]
USA and Canada (North America)	Black bear, grizzly bear, gray wolf, coyote	Livestock depredation, bear encounters near urban areas, managed lethal control [30,31]
Australia (mainland and K'gari)	Kangaroo, dingo	Grazing competition, vehicle collisions, livestock predation, dingo attacks [32,33]
Brazil and Chile (South America)	Jaguar, puma, Andean bear	Livestock depredation, retaliation, habitat loss [34]
Indonesia and Malaysia (Southeast Asia)	Tigers, elephants, orangutans	Crop raiding, livestock loss, habitat encroachment [35]
Nepal	Tigers, rhinos, elephants	Livestock predation, crop damage, human injury and fatalities [19]

4. Ecological consequences

HWC can induce rapid behavioral shifts, with many species increasing nocturnality, shortening activity periods, and avoiding nearby settlements, which alters movement ecology and space use at population scales [4]. Reliance on anthropogenic food sources such as crops, garbage, or livestock carcasses restructures feeding niches and diet breadth in carnivores and omnivores, often increasing body condition for a subset of individuals while elevating disease risks and changing interspecific competition dynamics [6,36]. Fragmented landscapes and road networks create strong barriers to dispersal, reduce effective population size, and enhance inbreeding, with genetic studies showing reduced gene flow and emerging population structure in struggle-prone carnivores, elephants, and ungulates that must cross high-risk human-dominated matrices [4,37]. Because large carnivores and megaherbivores often act as keystone species, their local decline or extirpation through conflict-driven mortality can trigger trophic cascades, including mesopredator release, herbivore overabundance, vegetation degradation, and associated losses of ecosystem services such as carbon storage and natural pest control [36,38].

5. Mitigation strategies: Traditional and scientific approaches

Traditional HWC mitigation employs community-based strategies such as watch towers, fire torches, ditches, community patrols, and crop selection of non-palatable species, which leverage local knowledge and social structures to reduce wildlife incursions effectively at low cost [39,40]. Scientific and modern technological approaches have increasingly augmented these, including camera trapping and early warning systems that improve real-time monitoring of wildlife movement; innovative fencing techniques like solar electric, trench, and bio-fencing that create physical and psychological barriers; as well as acoustic and olfactory deterrents that exploit animal sensory sensitivities to prevent crop-raiding and livestock predation [41,42]. Drone-based monitoring and GIS remote sensing facilitate large-scale landscape analysis to identify hotspot areas and inform targeted interventions, while compensation schemes and insurance models offer economic incentives to communities, reducing retaliatory killings and fostering coexistence [43,44]. Central to all effective mitigation is the meaningful involvement of local communities and eco-development committees, which ensure culturally adapted, sustainable, and participatory struggle management strategies that align protection goals with human livelihoods (**Table 2**).

Table 2 Overview of major mitigation approaches for HWCs

Traditional/ community based approaches	Scientific/ Modern approaches
Watchtowers for crop monitoring	Solar-powered electric fencing
Drumming, shouting & fire torches to chase wildlife away	Early-warning systems (SMS alerts, sensor alarms)
Cowbells / noise-making devices	Camera trapping & GPS collaring for animal movement tracking
Living fences (agave, cactus, thorny hedges)	Drone-based monitoring of conflict-prone areas
Chili rope / chili smoke deterrents	Landscape planning & corridor restoration
Beehive fencing (effective against elephants)	Compensation schemes using verified digital evidence
Communal guarding of fields	Geofencing & virtual boundaries
Sacred groves and cultural restrictions limiting disturbance	Biological control of crop attractants
Use of guard animals (dogs, local cattle breeds)	Improved livestock enclosures (predator-proof sheds)
Traditional seasonal cropping to avoid peak movement periods	Waste management protocols to eliminate attractants

6. Community-based conservancy and corridor approaches

India's Wildlife Protection Act (1972) and its buffer zone policies form a cornerstone of the country's preservation framework by legally safeguarding wildlife and habitats through the creation of sanctuaries, national parks, and ecologically sensitive zones (buffer zones) that act as transitional spaces minimizing anthropogenic impacts on core protected areas [45,46]. However, enforcement challenges persist, including variable buffer zone notification and clearance processes that impact conservation efficacy. In Africa, conservancy models, community-led land stewardship programs integrating sustainable resource use and wildlife maintenance, have become prominent for addressing HWCs by empowering local communities and creating incentives for coexistence [47]. North American strategies emphasize the establishment and maintenance of wildlife corridors and landscape connectivity to facilitate safe animal movement across fragmented ecosystems, supported by legal protection under legislation such as the Endangered Species Act and State recovery plans, thus mitigating conflict arising from habitat encroachment [48]. At the international scale, frameworks such as the Convention on Biological Diversity (CBD) and IUCN guidelines integrate HWC mitigation into biodiversity conservation and sustainable development goals, promoting cross-border cooperation, policy harmonization, and the use of science-based management strategies globally [49]. Together, these policies establish a multilevel governance approach critical for balancing human needs with wildlife protection.

7. Conclusion

HWC represents a complex interplay of ecological pressures, human expansion, and shared resource use. This review highlights that effective mitigation cannot rely on isolated interventions but must integrate scientific tools, habitat connectivity, traditional knowledge, and active community participation. Strengthening coexistence requires long-term ecological planning, improved governance, and inclusive, locally adapted strategies. By promoting landscape-level conservation and empowering communities, sustainable solutions to HWCs can be achieved, ensuring both biodiversity protection and human well-being.

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