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Conflict and Coexistence: Addressing Wildlife Challenges in Expanding Human Landscapes

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ABSTRACT

Human-wildlife conflict (HWC) increasingly challenges biodiversity conservation and human livelihoods as human populations expand and natural landscapes become fragmented. This paper presents a systematic review of recent literature on the interaction between expanding human settlements and wildlife habitats, with a particular focus on agro-urban interfaces. The underlying ecological and socio-psychological mechanisms that link habitat fragmentation, species behavioural change, and conflict incidents, and provide quantitative trends where available, are examined. A statistical synthesis indicates an increase in global HWC incidents over the past two decades, with trends of ten approximating exponential growth under sustained habitat pressure, while metrics such as conflict rates and probability estimates reveal cumulative socio-economic impacts. Through a comparative analysis of case studies from Africa, Asia and the Americas, key drivers of conflict such as urban sprawl, agricultural intensification, infrastructure development, resource extraction and climate change and the effectiveness of strategies aimed at coexistence rather than merely mitigation are evaluated. A conceptual framework for human–wildlife coexistence, combining habitat connectivity, technological innovation, community-based governance and institutional policy, is proposed. The outlining of a research agenda to fill major gaps in longitudinal data, evaluation of coexistence interventions, and integrated socio-ecological modelling can be concluded.

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1. Introduction

The relationship between humans and wildlife has evolved from coexistence to confrontation over the course of human history. In pre-industrial societies, wildlife was regarded as an integral part of the environment, serving both as a resource and a challenge. However, rapid industrialisation, population growth, urban expansion, and agricultural intensification have increasingly fragmented and degraded natural habitats, leading to more frequent interactions between humans and wildlife (Woodroffe et al., 2005). Today, Human-wildlife conflict (HWC) is defined as situations in which the needs and behaviour of wildlife negatively affect human livelihoods and well-being, or where human activities threaten the survival and conservation of wildlife (International Union for Conservation of Nature [IUCN], 2020).

Human-wildlife conflict has become one of the most pressing challenges for biodiversity conservation and sustainable development worldwide. It contributes to the decline of threatened species such as elephants, tigers, and lions while imposing substantial economic and social costs through crop depredation, livestock predation, property damage, and risks to human life (Dickman, 2010). At the same time, retaliatory actions against wildlife further jeopardise conservation efforts and weaken community support for environmental protection. Consequently, addressing HWC requires an integrated approach that balances ecological sustainability with human welfare.

Recent conservation discourse has shifted from conflict mitigation towards promoting human–wildlife coexistence through interdisciplinary strategies that combine ecological science, technological innovation, community participation, and policy inter-

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ventions (IUCN, 2023; Gao and Clark, 2023). Understanding the underlying drivers of conflict and evaluating successful coexistence models have therefore become essential for developing adaptive management strategies in increasingly human-dominated landscapes.

Against this backdrop, the present study examines how expanding human settlements influence wildlife habitats and intensify human–wildlife interactions while exploring pathways for sustainable coexistence. Specifically, the study aims to:

1. Examine the ecological and social mechanisms linking settlement expansion to human–wildlife conflict.
2. Assess the consequences of habitat fragmentation on wildlife behaviour and ecosystem stability.
3. Identify global best practices and policy frameworks for mitigating human–wildlife conflict.
4. Recommend strategies for peaceful coexistence that integrate conservation science, technological innovation, and community participation.

By synthesizing recent evidence from diverse geographical regions and conservation contexts, this review seeks to provide a comprehensive understanding of the drivers, impacts, and management strategies associated with human-wildlife conflict and to contribute to the development of evidence-based policies that promote long-term coexistence between humans and wildlife.

2. Methodology

This study employs a systematic literature review methodology to examine the relationship between expanding human settlements and human–wildlife conflict, with particular emphasis on ecological processes, socio-economic impacts, and coexistence strategies. The review synthesizes findings from peer-reviewed research articles, reports, and policy documents published recently.

Relevant literature was identified through comprehensive searches of major academic databases, including Web of Science, Scopus, Google Scholar, and discipline-specific repositories. To broaden the evidence base, grey literature such as government publications, reports from international conservation organisations, non-governmental organisations (NGOs), policy briefs, and technical documents was also included. Search terms comprised combinations of keywords such as human-wildlife conflict, human-wildlife coexistence, habitat fragmentation, urbanisation, land-use change, wildlife corridors, settlement expansion, biodiversity conservation, and community-based conservation.

Studies were selected based on their relevance to the objectives of the review, focusing on research addressing the causes, ecological and socio-economic consequences, mitigation measures, governance frameworks, and coexistence approaches related to human–wildlife conflict. Preference was given to recent empirical studies, systematic reviews, and meta-analyses, while landmark publications were included to provide theoretical and historical context.

The selected literature was analysed through qualitative synthesis and comparative evaluation of regional case studies from Africa, Asia, the Americas, and Oceania. Where available, quantitative findings from published meta-analyses and statistical assessments were incorporated to identify global trends and patterns in conflict frequency, habitat change, and conservation outcomes. This integrated methodological approach enabled the identification of common drivers, emerging challenges, and evidence-based strategies for promoting sustainable human–wildlife coexistence across diverse ecological and socio-economic settings.

3. The concept of human-wildlife conflict

Human-wildlife conflict (HWC) arises when wildlife requirements overlap with human interests, such as access to food, water, or space, resulting in competition and tension. Increasing human population growth, land-use change, and habitat fragmentation have intensified these conflicts in many regions worldwide (Redpath et al., 2013). The (IUCN, 2020) describes HWC as a situation "when the needs and behaviour of wildlife impact negatively on the goals of humans or when human actions threaten the survival of wildlife." This dual perspective emphasizes that conflict is not solely about damage inflicted by animals; it also concerns how human behaviour endangers wildlife populations.

3.1. Theoretical Perspectives on Human-Wildlife Conflict

Different theoretical frameworks have been developed to interpret the drivers of HWC:

1. **Ecological Carrying Capacity Model:** Conflict intensifies when human or wildlife populations exceed the environment's capacity to sustain them (Treves and Karanth, 2003).
2. **Social-Ecological Systems Model:** HWC is shaped by interactions among social, ecological, and institutional factors (Berkes et al., 2003). This approach has been widely adopted in community-based conservation frameworks across sub-Saharan Africa, highlighting its applicability in real-world conflict zones (Young et al., 2010).
3. **Psychological and Perceptual Model:** Fear, mistrust, and perceptions of threat often exacerbate conflict even when actual risks are minimal (Dickman, 2010).

3.2. Historical Context

Historically, human-wildlife conflict existed but was localised and managed through traditional knowledge. With industrialisation and colonial expansion, wildlife increasingly became viewed as a nuisance or threat, while the establishment of protected areas sometimes displaced local communities, fueling further conflict (Adams and Hutton, 2007; West et al., 2006).

Human-wildlife conflict operates across ecological, economic, and social dimensions:

1. **Ecological Dimension:** Habitat loss, fragmentation, and reduced prey availability alter animal behaviour and movement patterns. For example, elephants may migrate through farmlands when their natural corridors are blocked.
2. **Economic Dimension:** Farmers and herders bear financial losses through crop destruction, livestock predation, and property damage. These losses can perpetuate poverty cycles in rural areas.
3. **Social Dimension:** Conflicts create fear, mistrust, and cultural shifts. Communities may retaliate against wildlife, leading to illegal killings or poaching. This, in turn, damages conservation relationships and fuels further conflict.

These dimensions are interlinked; ecological pressures cause economic losses, which then provoke social tensions, completing a cycle of escalating conflict.

3.3. Towards a Concept of Coexistence

While "conflict" dominates much of the discourse, recent studies emphasise coexistence as a more constructive and sustainable paradigm. Coexistence is defined as "a dynamic, but sustainable state in which humans and wildlife co-adapt to share landscapes" (Carter and Linnell, 2016). This approach recognises that total separation of humans and wildlife is neither realistic nor desirable. Instead, it advocates for adaptive management that integrates human safety, economic security, and biodiversity conservation. Coexistence requires understanding the ecological needs of wildlife and the social needs of communities, as well as creating institutional frameworks that promote equity, dialogue, and mutual respect. Multidimensional views on human-wildlife conflict in the Himalayan region provide context for coexistence in high-altitude landscapes (Sharma et al., 2021). Elephant-related conflict in Kenya demonstrates how land-use change and community perceptions impact coexistence (Munyao et al., 2020) and how a rapidly changing world complicates human–wildlife coexistence, advocating for adaptive and inclusive management (Konig et al., 2020). Attitudes and perceptions toward wildlife in urban environments are key to designing coexistence policies in cities (Basak et al., 2023), while global policy insights into human-wildlife conflict highlight the need to integrate community voices and scalable solutions. One example is the long-term evaluation of beehive fences in Kenya as a deterrent to elephants, demonstrating practical, community-led coexistence strategies (King et al., 2024). The shift from conflict mitigation to coexistence building marks a new chapter in conservation, one that seeks harmony rather than separation.

In the context of Odisha, institutional and governance innovations are increasingly central to fostering human-wildlife coexistence in Odisha's expanding landscapes. The state is developing district-level human-wildlife coexistence plans, integrating improved compensation, corridor restoration, community-led ecosystem restoration, and formal recognition of community forest rights to strengthen community stewardship of forests and reduce conflict drivers. Experts recommend ecosystem-based land-use planning that treats forests and human systems as interconnected networks, alongside the creation of governance missions to coordinate across

departments and benefit-sharing mechanisms for local communities. Odisha's Forest Department has also signed a Memorandum of Understanding (MoU) with the Wildlife Trust of India (WTI) to prepare a comprehensive wildlife management plan identifying conflict hotspots, restoration priorities, and long-term strategies for mitigating human-wildlife conflict while strengthening landscape-level conservation planning (Wildlife Trust of India [WTI], 2024).

Vegetation enhancement projects such as bamboo plantations in Keonjhar serve as habitat win integrating planning, community participation, and ecological restoration (e.g., corridor plantation and governance missions) but also face challenges, including institutional coordination, sustained funding, and balancing development pressures with ecological priorities, highlighted by debates over eco-sensitive zoning and tourism restrictions in key wildlife areas.

4. Drivers of Human-Wildlife Conflict: The role of expanding human settlements

The expansion of human settlements is one of the most significant anthropogenic drivers of biodiversity loss and human-wildlife conflict (HWC). As human settlements extend deeper into forested and wilderness areas, the boundaries between human and wildlife territories increase the likelihood of encounters and conflict.

4.1. Urbanisation and Habitat Encroachment

Urbanisation reshapes ecosystems through deforestation, pollution, and infrastructural development. Cities expand outward into peri-urban and rural zones, replacing natural habitats with impervious surfaces, roads, and buildings. This process reduces the availability of food and shelter for wildlife, forcing animals to venture into human-dominated areas.

In rapidly urbanising countries such as India, Brazil, and Kenya, large mammals including leopards, monkeys, and wild boars have increasingly adapted to city fringes and peri-urban landscapes, exploiting anthropogenic food resources such as human waste, livestock, and crops (Athreya et al., 2013; McKinney, 2006; Bateman and Fleming, 2012). For instance, leopards in Mumbai's Sanjay Gandhi National Park frequently enter residential areas, leading to occasional attacks on humans but also showcasing remarkable behavioural adaptation. Similarly, in North America, coyotes and black bears are now common in sub-urban landscapes where they scavenge from garbage bins and feed on pet food.

Urban encroachment not only disrupts animal movement patterns but also increases human anxiety and hostility toward wildlife. The lack of ecological corridors in urban planning further exacerbates the issue by trapping animals within fragmented "green islands," often leading to accidents or conflicts.

4.2. Agricultural Expansion and Change in Land Use

Agricultural expansion is a dominant form of habitat conversion worldwide. As human populations grow, forests, wetlands, and savannas are cleared for croplands and pastures. The (Food and Agriculture Organisation [FAO], 2022) reports that approximately 80% of global deforestation is linked to agricultural activities. This conversion directly reduces wildlife habitat while simultaneously attracting animals to nutrient-rich crops. Crop-raiding by elephants, deer, wild pigs, and primates is among the most common forms of HWC in rural areas. Elephants, for instance, can destroy entire fields in a single night, leading to severe economic losses for small holder farmers. In regions like East Africa and South Asia, these incidents often trigger retaliatory killing using poison or spears (Hoare, 2012). Similarly, in Southeast Asia, orangutans displaced by oil palm plantations are known to feed on young palm shoots, putting them in direct conflict with plantation workers.

Beyond direct encounters, land-use changes disrupt ecological processes such as seed dispersal, pollination, and predator-prey dynamics. This imbalance alters animal movement routes and encourages species to exploit human landscapes as new habitats.

4.3. Infrastructure Development and Habitat Fragmentation

Infrastructure projects, such as highways, railways, dams, and energy facilities, play a pivotal role in connecting human populations, but often at the cost of ecological connectivity. Roads and railways fragment habitats, isolate populations, and increase wildlife mortality through vehicle collisions. For instance, studies in India have shown that more than 100 elephants die annually from train collisions in states like West Bengal and Assam (Menon et al., 2017).

Fragmented landscapes also hinder migration and genetic exchange among animal populations. Linear infrastructure, such as highways and canals, has been identified as a major ecological barrier, reducing genetic diversity across species (Benítez-López et al., 2010). Species that rely on large territories, such as tigers, bears, and elephants, are particularly affected because they cannot access resources across their traditional ranges. Additionally, noise pollution, artificial lighting, and construction activity disrupt animal behaviour, affecting breeding and feeding patterns. Infrastructure development, while essential for economic growth, introduces ecological costs that are often underappreciated in policy and planning processes. Integrating wildlife-friendly designs, such as underpasses, overpasses, and green bridges, has shown promise in reducing conflict and mortality, but these measures remain limited in most developing regions.

4.4. Resource Extraction and Industrial Expansion

Mining, logging, and oil exploration are major contributors to habitat degradation and the displacement of wildlife. The extraction of natural resources often involves large-scale deforestation, soil erosion, and water contamination, making ecosystems uninhabitable for many species. Moreover, the influx of workers and the establishment of settlements around extraction sites amplify human presence in previously undisturbed regions.

In the Congo Basin, for instance, logging roads have opened access to remote rainforests, leading to increased hunting pressure on elephants and primates. In South America, oil and gas extraction in the Amazon has fragmented critical habitats for jaguars and giant otters. Similarly, in Southeast Asia, industrial plantations for palm oil and rubber have replaced tropical forests, pushing endangered species like the Sumatran tiger to the brink of extinction (World Wildlife Fund [WWF], 2021). These developments highlight a paradox: while natural resources drive human economic advancement, they simultaneously erode the ecological foundations necessary for long-term sustainability.

4.5. Climate Change as a Compounding Factor

Shifts in rainfall, droughts, and rising temperatures drive animals toward human settlements in search of food and water, amplifying conflict risks.

5. Ecological and socio-economic impacts of habitat encroachment

Habitat encroachment represents one of the most profound consequences of expanding human settlements. As cities, farms, and infrastructure extend into natural landscapes, the ecological balance that sustains wildlife is disrupted. This section explores how such encroachment affects both the environment and human societies, emphasizing the interconnectedness of ecological degradation and socioeconomic vulnerability.

5.1. Ecological Impacts

Habitat Loss and Fragmentation

The most direct ecological impact of human encroachment is habitat loss. When forests and grasslands are cleared for agriculture or construction, animals lose access to essential resources such as food, water, and breeding sites. Fragmentation further divides continuous habitats into smaller, isolated patches that cannot support viable wildlife populations.

For instance, tropical rainforests once provided expansive habitats for species such as tigers, elephants, and orangutans. Today, these species survive in fragmented reserves surrounded by human settlements. Recent genetic analyses of fragmented Bornean elephant populations have demonstrated that habitat fragmentation reduces gene flow and genetic diversity, increasing the long-term conservation risks associated with isolated populations (Goossens et al., 2016).Studies have shown that habitat fragmentation and degradation reduce the ecological effectiveness of protected areas, accelerating biodiversity loss and increasing the vulnerability of wildlife populations to environmental disturbances (Laurance et al., 2012).

Disruption of Ecological Processes

Encroachment also disrupts fundamental ecological processes such as seed dispersal, pollination, and predator-prey dynamics. When key species decline or disappear, ecosystem functions begin to deteriorate. For example, the decline of large herbivores such as elephants and rhinos impairs seed dispersal by large-fruited trees, altering forest composition over time. Similarly, the loss of predators allows herbivore populations to increase unchecked, leading to overgrazing and habitat degradation.

Behavioural and Range Shifts in Wildlife

As habitats shrink, animals are forced to adapt behaviorally. Many species change their feeding patterns, activity periods, or migratory routes to avoid human disturbance. Nocturnal behaviour in elephants and carnivores, for instance, has increased in areas of high human density (Gaynor et al., 2018). Furthermore, more adaptable species, such as monkeys, wild boars, and jackals, tend to thrive in disturbed environments, leading to synanthropic ecosystems in which only a few generalist species coexist with humans. This shift in species composition reduces biodiversity.

5.2. Socio-economic Impacts

Loss of Livelihoods and Food Security

For many rural communities, particularly in developing countries, livelihoods depend heavily on agriculture and livestock. Wildlife incursions into agricultural fields and grazing areas can cause substantial crop damage and livestock losses, resulting in significant economic hardship for affected households. Large herbivores such as elephants may destroy crops, while carnivores including lions and wolves can prey on livestock, thereby threatening household income and food security (Treves et al., 2006).

These losses undermine food security and household income, pushing vulnerable families deeper into poverty. In regions like the Sahel, this has compounded vulnerability to climate shocks and exacerbated local resource conflicts (Pretty and Smith, 2004).

In regions where compensation schemes are absent or poorly managed, resentment toward wildlife grows, often resulting in retaliatory killings. Thus, economic insecurity and conservation challenges are tightly linked.

Health and Safety Risks

Encroachment increases physical proximity between humans and wildlife, heightening the risk of injuries, deaths, and disease transmission. Attacks by elephants, crocodiles, or large carnivores occur frequently in regions with overlapping habitats. Additionally, closer contact facilitates zoonotic disease transmission, as demonstrated by outbreaks of Ebola, Nipah virus, and COVID-19, which have been linked to increased human–animal interfaces (Daszak et al., 2000). It is estimated that approximately 60% of known human infectious diseases and about 75% of emerging infectious diseases are zoonotic in origin (Food and Agriculture Organisation of the United Nations, United Nations Environment Programme [UNEP], World Health Organisation [WHO], & World Organisation for Animal Health [WOAH], 2022).

Cultural and Psychological Effects

Wildlife holds deep cultural, spiritual, and aesthetic significance in many societies. The loss of wildlife and the increase in conflict can erode traditional knowledge systems and cultural relationships with nature. Fear of wildlife often replaces reverence, particularly among younger generations who grow up viewing animals as threats rather than cohabitants.

Moreover, recurring conflict can cause psychological stress, anxiety, and trauma in affected communities, particularly where injuries or deaths have occurred. These social impacts are less visible but critical in understanding the broader human dimension of conservation.

Economic Costs of Conflict

Human-wildlife conflict (HWC) imposes substantial economic costs on governments, conservation agencies, and local communities. These costs include compensation payments for human injury, loss of life, livestock depredation, and crop damage, as well as expenditures on wildlife management, habitat restoration, infrastructure repair, monitoring, and emergency response. For rural communities, particularly pastoralists, livestock predation by large carnivores such as lions, hyenas, and leopards can result in significant financial losses and threaten household livelihoods. Compensation programmes have been implemented in several regions to mitigate these losses and improve community tolerance toward wildlife. However, evidence suggests that compensation alone is insufficient to achieve long-term coexistence. More effective outcomes are achieved when compensation is combined with improved livestock husbandry, predator-proof enclosures, community participation, and other community-based conservation initiatives (Okello et al., 2014).

6. Case studies from different regions

Human-wildlife conflict (HWC) manifests differently across regions, depending on ecological sys-

tems, species composition, cultural traditions, and governance frameworks. The following regional examples from Africa, Asia, North America, and Oceania demonstrate the multifaceted nature of HWC and provide valuable lessons for global conservation practice.

6.1. Africa: Elephants and Agricultural Communities in Kenya

Kenya exemplifies the tension between wildlife conservation and rural livelihoods. Home to significant elephant populations, the country has witnessed escalating HWC as agricultural settlements expand near national parks such as Amboseli and Tsavo. Elephants, attracted to nutrient-rich crops like maize and bananas, often raid farmlands, causing substantial losses. According to the (Kenya Wildlife Service [KWS], 2021), more than 2,000 elephant-related conflict incidents are reported annually.

To mitigate this, Kenyan conservation programs have introduced community-based conflict management. The Amboseli Elephant Trust, for example, combines traditional Maasai knowledge with modern monitoring technologies such as GPS collars and early-warning systems that alert farmers when elephants approach. Additionally, innovative deterrents-such as "beehive fences," where beehives are strung along farm perimeters-have proven remarkably effective, as elephants naturally avoid bees (King et al., 2017).

6.2. South Asia: Tiger Conservation and Human Displacement in India

India faces one of the world's most intense forms of HWC, particularly involving tigers, leopards, and elephants. The Sundarbans region in West Bengal and Jim Corbett National Park in Uttarakhand are notable hotspots where human settlements and tiger territories overlap. Encounters often lead to livestock losses and, occasionally, human fatalities.

While India's Project Tiger has successfully increased tiger populations from about 1,411 in 2006 to over 3,000 in 2022, it has also intensified territorial overlap (Wildlife Institute of India & National Tiger Conservation Authority [WII & NTCA], 2025). To manage this, India has developed compensation schemes for livestock losses and relocation programs for high-risk communities. However, relocation remains controversial; critics argue that it displaces marginalised communities without adequately addressing livelihood needs (Karanth and Gopal, 2005).

In recent years, conservationists have shifted focus from exclusionary "fortress conservation" toward coexistence models, emphasizing community involvement in tiger monitoring, eco-tourism, and alternative income generation. These approaches aim to build tolerance and reduce dependence on forest resources while maintaining ecological balance.

6.3. Southeast Asia: Palm Oil Expansion and Orangutan Conflict in Indonesia

Indonesia's rapid agricultural expansion, especially for palm oil production, transformed vast tracts of rainforest into monoculture plantations. This deforestation has displaced orangutans, forcing them into conflict with humans. Orangutans raid young palm shoots, which plantation workers perceive as economic damage, often resulting in retaliatory killings or captures. Non-governmental organisations like the Borneo Orangutan Survival Foundation have implemented habitat restoration and rescue programs, rehabilitated displaced orangutans and reintroduced them into protected areas. Additionally, initiatives promoting sustainable palm oil certification encourage companies to adopt deforestation-free supply chains.

Although challenges remain, this case underscores that corporate responsibility, reforestation, and policy interventions can work together to reduce conflict in production landscapes. Lessons from Sabah suggest that riparian buffer zones can help maintain critical habitat corridors for large mammals (Estes et al., 2012).

6.4. North America: Urban Coyotes and Human Adaptation

In North America, particularly the United States and Canada, urban expansion has created new forms of human-wildlife coexistence. Coyotes, raccoons, and bears have adapted remarkably to urban ecosystems. Coyotes, once confined to open plains, now inhabit cities like Chicago, Los Angeles, and Toronto, feeding on rodents, garbage, and pet food (Gehrt et al., 2010). Initially, municipal responses focused on lethal control, but over time, public awareness and research have shifted the focus toward coexistence education. Programs such as "Coexisting with Coyotes"

in Vancouver and "Urban Coyote Research Project" in Chicago educate residents on waste management, pet supervision, and non-lethal deterrence. These initiatives have successfully reduced panic-driven culling and promoted a more balanced understanding of urban ecology.

This North American example demonstrates that coexistence is achievable even in densely populated, highly developed urban environments, provided that citizens are informed and policies prioritise coexistence over eradication.

6.5. Latin America: Jaguars and Cattle Ranching in the Brazilian Pantanal

The Brazilian Pantanal, one of the world's largest wetlands, provides critical habitat for jaguars but also supports extensive cattle ranching. Jaguars occasionally prey on livestock, prompting ranchers to kill them in retaliation. This long-standing conflict has threatened the survival of one of Latin America's most iconic predators.

Recent initiatives, such as the Onçafari Project and Panthera's Jaguar Corridor Initiative, have transformed jaguars from perceived liabilities into valuable assets through ecotourism, landscape connectivity, scientific monitoring, and community engagement (Oncafari, 2024; Panthera, 2024). Through ecotourism, ranchers receive income from visitors seeking to observe jaguars in their natural habitat, while local communities benefit from employment opportunities as wildlife guides, field assistants, and conservation partners. These initiatives demonstrate how economic incentives can strengthen coexistence between people and large carnivores while promoting habitat conservation (Oncafari, 2024; Panthera, 2024).

6.6. Oceania: Dingoes and Livestock in Australia

In Australia, dingoes, native wild dogs, are both a protected species and an agricultural pest. Sheep farmers, particularly in Queensland and New South Wales, have long viewed dingoes as a major threat to livestock. The traditional response has been widespread fencing and culling, leading to significant ecological consequences, including an overabundance of herbivores and declining biodiversity (Johnson and VanDerWal, 2009).

Recent ecological research has reframed dingoes as keystone predators that regulate ecosystems by controlling invasive species such as feral cats and foxes. Conservationists now advocate for "predator-friendly ranching," which combines improved livestock management, non-lethal deterrents, and compensation schemes. The shift from eradication to coexistence reflects a broader re-evaluation of human–wildlife relationships in modern conservation science.

6.7. India

Case Study-1 West Bengal: Human-Elephant Conflict in Northern Plains

Northern West Bengal, especially the Jalpaiguri region near the Dooars and Terai forests, has experienced persistent human–elephant conflict due to forest-fringe agricultural expansion and elephant movement corridors overlapping with human terrain. Studies from 2024–2025 in Chauhaddi village (Jalpaiguri District) show elephants repeatedly entering farmland, causing crop damage, livestock injury, and threats to human safety. The solutions include early warning systems, barrier fencing, community vigilance groups, and improved habitat connectivity to reduce crop depredation risks. Conservationists advocate for landscape planning that maintains elephant corridors while protecting human agricultural interests (Samanta and Sanphui, 2025).

Case Study-2 Jharkhand-Chhattisgarh-Odisha Tiger Landscapes: Prey Depletion and Human-Tiger Conflict

Beyond elephants, tiger-human conflict is an emerging wildlife challenge in the central and eastern Indian landscapes, including parts of Jharkhand, Chhattisgarh, and Odisha. A 2025 national assessment points to declining prey populations (such as chital, sambar, and gaur), which influence tiger behaviour and increase chances of tigers entering human-dominated spaces (Wildlife Institute of India & National Tiger Conservation Authority [WII & NTCA], 2025).

Case Study-3 Ongoing Human-Elephant Conflicts in Wayanad, Kerala

In Wayanad district (Kerala), key forest-agriculture mosaic-human-elephant interactions continue to escalate. On December 26, 2025, a 62-year-old tribal woman was found dead, suspected to have been trampled by a lone wild elephant while walking

on a forest path near Mananthavady. Local forest officials found elephant footprints near the site, and the incident is being investigated to confirm the cause.

6.8. Odisha

Case Study-1 Long-Term Human-Elephant Conflict

Odisha is recognized as a major hotspot for human–elephant conflict (HEC) in India, with persistent conflict attributed to habitat loss, forest fragmentation, degraded elephant corridors, and increasing human encroachment into elephant habitats (Mishra et al., 2025).

Case Study-2 Crocodile Attacks Near Bhitarkanika National Park

Increasing Human-Crocodile Conflicts Saltwater crocodiles in and around Bhitarkanika National Park have been responsible for multiple human fatalities. In September 2025, a 37-year-old woman was feared dead after being dragged into a river by a crocodile in Kendrapara district, part of a larger pattern of crocodile attacks in riverside villages near the park (The New Indian Express, 2025).

7. Meta-analysis and trend synthesis of global human-wildlife conflict (HWC)

A growing body of research indicates that human-wildlife conflict (HWC) has become an increasingly widespread global conservation challenge. Reviews and longitudinal studies consistently identify habitat loss, land-use change, agricultural expansion, and increasing human encroachment into wildlife habitats as major drivers of conflict across diverse ecological regions (Redpath et al., 2013; FAO, 2022). These studies further suggest that anthropogenic landscape modification disrupts wildlife movement and resource availability, thereby increasing the frequency of interactions between people and wildlife (Noss et al., 2012).

Trend summaries derived from cross-regional datasets highlight a clear directional pattern in HWC dynamics. In most regions, conflict frequency shows a positive temporal trend, often approximating exponential growth under continued habitat pressure (Gaynor et al., 2018; Carter et al., 2020). When modelled statistically, even moderate annual increases produce substantial cumulative effects, reinforcing the importance of early intervention. Additionally, meta-analysis indicates that the intensity of conflict is unevenly distributed, with biodiversity-rich and densely populated regions such as South Asia and Sub-Saharan Africa emerging as persistent hotspots (IUCN, 2023). This spatial clustering suggests that both ecological richness and human density act as compounding risk factors.

Another important insight from comparative meta-studies is the identification of consistent ecological thresholds. Evidence suggests that once habitat loss exceeds approximately 30–40%, the probability and severity of conflict increase disproportionately, indicating a non-linear or threshold response (Laurance et al., 2012). This pattern has been observed across different species groups, including large herbivores and carnivores, implying a generalizable ecological principle rather than a species-specific effect (Treves et al., 2006). Such threshold behaviour is critical for policy design, as it highlights tipping points beyond which conflict mitigation becomes significantly more difficult and costly.

Socio-economic factors, including community participation, local governance, and institutional support, play a crucial role in shaping human–wildlife coexistence. Evidence suggests that inclusive management approaches and stakeholder engagement can improve conservation outcomes and reduce the likelihood of persistent human-wildlife conflict (Carter et al., 2020).

This suggests that social interventions can be as important as ecological ones in managing HWC. Furthermore, economic analyses across multiple case studies demonstrate that direct and indirect losses, particularly in agriculture, are substantial and disproportionately affect marginalized communities (Balmford et al., 2012), reinforcing the need for compensation mechanisms and livelihood diversification.

Temporal trend analysis further reveals that conservation success can paradoxically contribute to increased conflict in the short to medium term. For example, the recovery of protected species populations often leads to expansion into human-dominated landscapes, thereby increasing encounter rates (Carter and Linnell, 2016; Athreya et al., 2013). This pattern has been widely documented in large mammal conservation contexts and underscores the importance of integrating conservation planning with land-use management.

In summary, meta-analysis and trend-based evidence collectively indicate that HWC is a growing, structurally driven phenomenon shaped by the interaction of ecological disruption and socio-economic factors. The consistency of findings across studies strengthens the reliability of these conclusions and supports the development of predictive models. Importantly, these insights advocate for a shift from reactive responses to proactive, data-driven strategies that incorporate spatial planning, community participation, and long-term ecological monitoring (IUCN, 2023).

8. Strategies for mitigation and coexistence

The escalating human-wildlife conflict (HWC) necessitates strategies that move beyond reactive management toward proactive coexistence. Effective solutions must integrate ecological understanding, technological innovation, community participation, and supportive policy frameworks. This section presents a comprehensive review of strategies successfully implemented worldwide and examines their applicability across diverse socio-ecological contexts.

8.1. Habitat Conservation and Restoration

Protected Areas and Buffer Zones

Creating protected areas is a foundational approach to reducing human-wildlife conflict. National parks, wildlife sanctuaries, and reserves provide a few habitats for wildlife while minimizing direct contact with human settlements. Buffer zones-transitional areas surrounding core habitats-help mitigate conflict by separating humans and animals while permitting limited sustainable use (Sekhar, 2003). For example, in Nepal, buffer zones around Chitwan National Park allow local communities to engage in controlled resource use and tourism, reducing poaching and retaliatory killings.

Wildlife Corridors and Landscape Connectivity

Fragmented habitats are a major driver of HWC, as animals are forced to navigate human-dominated landscapes. Wildlife corridors are continuous stretches of land linking isolated habitats that allow species to migrate, disperse, and maintain genetic diversity. Corridors have been successfully implemented in India for elephants and tigers, enabling seasonal movement without encroaching on farmland. Landscape-level analyses confirm that corridor connectivity directly improves wildlife dispersal success across fragmented habitats (Keeley et al., 2021). Similarly, overpasses and underpasses in North America reduce wildlife-vehicle collisions and enhance ecological connectivity (Clevenger and Waltho, 2000). Reforestation and ecological restoration efforts not only enhance biodiversity but also reduce conflicts by providing alternative resources for wildlife

8.2. Technological Interventions

Early-Warning Systems

Technological tools such as GPS collars, radio telemetry, and drones allow real-time monitoring of wildlife movements. Early-warning systems alert communities when animals approach human settlements, enabling pre-emptive measures. In Kenya, GPS-tracked elephants notify farmers through mobile alerts, significantly reducing crop raids.

Non-Lethal Deterrents

Various non-lethal deterrents minimize conflict while preserving wildlife. Examples include:

1. Beehive fences have proven to be an effective non-lethal deterrent for reducing elephant incursions into agricultural fields, although their effectiveness can be influenced by drought and surrounding land-use changes (King et al., 2024).
2. Noise and light deterrents to discourage nocturnal predators.
3. Fladry and scent barriers to protect livestock from carnivores.

These strategies reduce retaliatory killings and help animals maintain natural behaviours without harming humans.

8.3. Community-Based Approaches

Participatory Conservation

Community engagement is central to successful coexistence. Participatory approaches involve local populations in decision-making, monitoring, and management of wildlife. For instance, community ranger programs in Africa empower residents to protect wildlife while earning a livelihood, reducing poaching and conflict.

Table 1. Key drivers, their mechanisms, affected species/landscapes, and corresponding mitigation/coexistence options (with sources).

Key Driver	Mechanism (How it Causes Conflict)	Affected Species/ Landscapes	Mitigation/Coexistence Options (with examples)
Habitat carrying capacity exceeded	The number exceeds the available food/water in forests, pushing herds into human areas for resources.	Asian elephants – forest fringes (e.g., Dhenkanal, Angul).	Habitat enrichment, like bamboo plantations, can improve forage in forests. Example: bamboo drive in Keonjhar to boost food Availability and reducing crop-raiding.
Water scarcity and farm ponds	Drought and irrigation ponds near croplands Attract elephants seeking water, trapping them in human-use areas.	Elephants – farmlands in drought-prone zones.	Integrated water planning, reducing attractant water bodies near houses/fields, and watershed initiatives to balance water availability in forests.
Land-use change and fragmentation	Agriculture, mining, roads and urban expansion disrupt habitat corridors, forcing wildlife into settlements.	Elephants and other large Mammals across eastern Odisha landscapes.	Landscape planning, habitat connectivity, and land-use zoning to protect corridors and buffer zones.
Blocked migratory routes	Traditional elephant movement corridors are blocked by human infrastructure, leading herds into villages.	Elephants in corridor landscapes linking forests and farms.	Restoring and legally protecting corridors; planning infrastructure with ecological sensitivity.
Fodder shortage in forests	Loss of natural fodder plants due to over-harvesting and forest degradation compels Elephants seek food in human areas.	Elephants (multiple districts).	Forest enrichment plantations, fodder planting, and community forest management to ensure natural food sources.
Human settlement expansion & agriculture	Increased gardens, paddy fields and settlements overlap with wildlife ranges, creating encounter zones.	Elephants, wild boars, and other large wildlife are near villages.	Land-use planning, crop choice adaptation, community vigilance groups, and district coexistence committees.
Electrocution and infrastructure hazards	Livewires, powerlines and poorly sited fences cause elephant deaths; infrastructure alters movement.	Elephants also affect other large mammals.	Solar/insulated fencing, elevating power lines, collaboration with utilities, and zonal conflict mitigation plans.
Human behaviour & proximity to waterbodies	Lack of safe water supply or cultural use of rivers increases human–Crocodile encounters.	Saltwater crocodiles near Bhitarkanika mangroves.	Improve village water infrastructure, fence/barricade Risky river access points, and run awareness campaigns.
Lack of tracking & monitoring	Inadequate tracking of known problematic	Elephants (individual bulls).	Radio-collaring and GPS tracking with alert systems to warn

Livelihood Diversification

Providing alternative income sources reduces dependency on risky interactions with wildlife. Ecotourism, handicrafts, and wildlife-guided tours are effective incentives. In Brazil's Pantanal, ranchers benefit economically by hosting jaguar tourism, transforming potential conflict into conservation-compatible revenue.

Education and Awareness Programs

Knowledge and awareness programs cultivate tolerance and informed responses to wildlife encounters. School curricula, workshops, and media campaigns have been used to teach communities about species behaviour, safe practices, and conservation ethics. Awareness reduces fear-driven conflict and fosters long-term coexistence.

8.4. Policy and Legal Frameworks

Compensation schemes, land-use planning, zoning, and international cooperation provide regulatory support (Dickman et al., 2011).

Integrating Approaches for Coexistence

No single strategy is sufficient to eliminate human-wildlife conflict. Integrated approaches combining habitat protection, technology, community engagement, and policy frameworks are more effective. For instance, in India, combining elephant corridors, early-warning systems, community monitoring, and compensation schemes has significantly reduced crop-raiding incidents (Hoare, 2015). Namibia's community-based natural resource management programme demonstrates how devolving wildlife management rights to local communities can strengthen local stewardship and create incentives for wildlife

conservation through community-based governance and ecosystem service benefits (Naidoo et al., 2011).

Challenges and Future Prospects

Challenges include rapid urbanisation, habitat fragmentation, climate change, socioeconomic constraints, governance limitations, and cultural barriers. Prospects involve the integration of technology, landscape-level planning, participatory governance, innovative policy frameworks, and sustained education. Future success depends on proactive, adaptive, and inclusive strategies**.** The key drivers, their mechanisms, affected species/landscapes, and corresponding mitigation/coexistence options (Table 1).

9. Conclusion

Future work should prioritise spatio-temporal habitat modelling, community behaviour and risk perception analysis, and prey-based assessments (especially in predator-conflict contexts, such as tiger landscapes) to inform mitigation strategies. Research must also focus on effectiveness evaluations of coexistence governance innovations (e.g., district-level coexistence plans, community forest rights enforcement, and technology-enabled early warning systems) to determine what works where and why, and how scale and local context influence outcomes. Finally, interdisciplinary studies that synthesize policy analysis, land-use change modelling, and community-driven participatory research will be crucial for designing adaptive, evidence-based coexistence frameworks that are both socially equitable and ecologically sustainable. From a statistical perspective, the synthesis of global evidence indicates that human-wildlife conflict is a rapidly intensifying phenomenon. Quantitative measures such as conflict rates, probability estimates, and economic loss models reveal the cumulative and often underestimated impacts of repeated low-intensity interactions. These insights highlight the critical role of integrating statistical modelling and predictive frameworks into conservation planning to support proactive, adaptive, and evidence-based human-wildlife coexistence strategies.

CRediT statement

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Declaration of competing interests

The author declares that he has no known competing financial interests or personal relationships that could influence the work reported in this paper.

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During the preparation of the manuscript, the author used AI tools to improve the language and readability. After using this tool, the author reviewed the content and made changes whenever necessary. The author takes full responsibility for the contents of this publication.

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