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Human–Leopard Coexistence Dynamics: An Ecological and Social Assessment of Jhalana Forest, Jaipur, India

Kumbhojkar Swapnil Vinayak
Research Scholar, Department of Zoology, Malwanchal University, Indore
Dr. Borane Vijay Ramdas
Supervisor, Department of Zoology, Malwanchal University, Indore

Abstract
Human–leopard coexistence in urban landscapes has emerged as a critical conservation concern, particularly in rapidly expanding Indian cities where wildlife habitats are increasingly fragmented. Jhalana Forest in Jaipur represents a unique case of a thriving leopard population living entirely within an urban matrix, offering valuable insights into predator adaptability and human tolerance. This study examines the ecological and social dimensions shaping coexistence in Jhalana by assessing leopard habitat use, prey availability, behavioural adaptations, and human–leopard interaction patterns. Using a mixed-methods approach that integrates ecological field observations with community surveys and stakeholder interviews, the research identifies key factors supporting coexistence, such as the availability of microhabitats, flexible dietary behaviour, and community attitudes influenced by conservation awareness and tourism. Findings reveal that while leopards exhibit behavioural modifications to avoid conflict, human perceptions vary depending on livelihood dependence, exposure to tourism, and previous interactions with wildlife. Management challenges include habitat fragmentation, encroachment, road disturbances, and unregulated tourist pressure. The study concludes that sustainable coexistence requires a holistic strategy combining scientific monitoring, community engagement, and urban-wildlife-sensitive policy frameworks. Jhalana serves as a model for urban carnivore conservation, demonstrating that harmonious coexistence is achievable when ecological needs and social dynamics are jointly addressed.

Keywords: Leopard ecology, human–wildlife conflict, urban biodiversity, Jhalana Forest, coexistence strategies

Introduction

Human–wildlife interactions have become a central concern in conservation science, especially in rapidly urbanizing regions where natural habitats overlap with dense human settlements. Among India's large carnivores, the leopard (*Panthera pardus fusca*) has demonstrated remarkable ecological adaptability, enabling it to survive in fragmented landscapes and peri-urban environments. Jhalana Forest in Jaipur, Rajasthan, stands as a unique example of such

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coexistence—an isolated, 24-sq km protected forest patch surrounded entirely by a bustling metropolis, yet supporting a stable leopard population. This paradoxical coexistence presents an invaluable opportunity to study how a top predator persists amidst intense anthropogenic pressures. Understanding these dynamics is crucial not only for conservation management but also for reducing human–wildlife conflict, promoting ecological balance, and preserving the long-term viability of leopard populations in urban and semi-urban ecosystems. The ecological peculiarities of Jhalana—semi-arid vegetation, limited prey base, artificial waterholes, and proximity to residential areas—make it an important case study for analyzing habitat use, movement patterns, prey selection, and behavioral adaptations of leopards living in close association with humans. Existing studies across India have highlighted that when adequate prey and habitat structure exist, leopards can coexist with people with minimal conflict; however, each landscape has its own social, cultural, and ecological intricacies that shape these interactions.

Equally significant to understanding leopard ecology is examining the human dimension of coexistence. Communities around Jhalana Forest have varying levels of awareness, attitudes, and perceptions toward leopards, shaped by local experiences, socio-economic conditions, and interactions with the expanding wildlife tourism sector in the area. The establishment of Jhalana Leopard Safari has further influenced public engagement, conservation awareness, and economic opportunities, while also reshaping human expectations and tolerance levels. As urban growth continues to intensify pressure on the forest, understanding community perspectives becomes essential for designing effective conservation strategies. Issues such as livestock depredation, occasional sightings near human habitation, fear of attacks, and dependence on forest resources influence coexistence patterns. At the same time, positive interactions—ecotourism benefits, pride associated with living near a leopard habitat, and conservation-led livelihood opportunities—can enhance coexistence. Therefore, a holistic evaluation of both ecological and social dimensions is necessary to build sustainable conservation frameworks. This study aims to bridge these perspectives by assessing habitat conditions, leopard behavior, human attitudes, and ongoing management interventions, ultimately offering insights into how urban forests like Jhalana can serve as models for human–leopard coexistence in India and beyond.

Overview of Human–Wildlife Interactions in India

Human–wildlife interactions in India have evolved through centuries of shared landscapes, cultural reverence, and ecological interdependence. India, home to some of the world's richest biodiversity, supports an extraordinary range of species—from apex predators like tigers, leopards, and elephants to smaller mammals, reptiles, and birds—that often inhabit areas adjacent to or overlapping with human settlements. This coexistence is deeply rooted in India's cultural and religious traditions, where wildlife is often regarded as sacred and symbolic of

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natural harmony. However, rapid population growth, agricultural expansion, infrastructure development, and urbanization have intensified human encroachment into wildlife habitats, transforming many interactions into conflicts. Instances of crop raiding by elephants, livestock depredation by leopards and tigers, and attacks on humans have increased, reflecting the growing competition for space and resources. Despite these challenges, India has demonstrated remarkable resilience and adaptability through its policy frameworks, protected area networks, and community-based conservation initiatives.

The Wildlife (Protection) Act of 1972 and Project Tiger were landmark steps toward safeguarding species and ecosystems, yet the interface between humans and wildlife extends far beyond reserve boundaries. Rural communities living around forest fringes continue to face economic losses and safety risks, while urban areas like Mumbai and Jaipur now witness leopards adapting to city environments. In many regions, traditional tolerance and local ecological knowledge have mitigated conflict and promoted coexistence. Non-governmental organizations, forest departments, and researchers are increasingly focusing on participatory conservation, integrating scientific monitoring with socio-economic interventions. Technological tools such as GPS tracking, camera traps, and GIS mapping have enhanced understanding of animal behavior and movement, allowing for proactive conflict management. However, media portrayal and public perception often exaggerate fear, overshadowing positive coexistence narratives. India's challenge, therefore, lies in maintaining a delicate balance between

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development and biodiversity conservation—ensuring that coexistence remains viable in the face of modernization. Human–wildlife interactions in India thus represent a complex blend of conflict, coexistence, and cultural continuity, reflecting both the pressures of the Anthropocene and the enduring capacity of people and wildlife to adapt and share space in a densely populated nation.

Literature Review

Kumbhojkar et al. (2019) explore the dynamics of coexistence between humans and Indian leopards (*Panthera pardus fusca*) in the Jhalana Forest Reserve, Jaipur, India. The study emphasizes that Jhalana represents a unique urban-wild interface where leopards inhabit a relatively small protected area surrounded by dense human settlements. Through camera-trap data and interviews, the authors highlight that leopards primarily utilize nocturnal activity patterns to minimize encounters with humans. The coexistence model observed here is underpinned by leopards' adaptability in diet and behavior, coupled with local communities' cultural tolerance toward the species. However, the research also underscores the fragility of this balance, as urban expansion, habitat fragmentation, and potential increases in human-leopard encounters could disrupt the equilibrium. The authors suggest proactive conflict mitigation, awareness programs, and integrating conservation priorities into urban planning.

In their 2021 *Oryx* publication, Kumbhojkar et al. assess the dietary dependence of Jaipur's leopards on domestic animals. Using scat analysis and camera-trap evidence, they reveal that livestock—particularly goats and dogs—form a substantial part of the leopard's diet. This reliance raises significant conservation and socio-economic concerns, as predation on livestock can heighten human-wildlife conflict. The authors argue that the high prevalence of domestic prey reflects both a scarcity of wild prey within the fragmented habitat and the ease of hunting unguarded domestic animals in surrounding villages. The study advocates for improved livestock management, compensation schemes, and habitat restoration to reduce conflict and encourage a shift back to wild prey reliance.

The 2020 study by Kumbhojkar et al. in *Animals* applies camera-trap data and spatial analysis to investigate leopard home ranges within Jaipur's urban-proximate habitat. The findings indicate that individual leopards maintain relatively small, overlapping home ranges compared to those in more extensive wild habitats. This spatial compression is linked to abundant domestic prey and the absence of larger carnivore competitors. The study suggests that home-range overlap may increase the risk of intra-specific encounters and territorial disputes, but also points to the leopards' adaptability to anthropogenic pressures. The authors recommend ongoing monitoring and spatial planning to maintain safe wildlife corridors and avoid habitat bottlenecks.

Chauhan, Srivathsa, and Athreya (2021) provide a complementary perspective by analyzing media reports on human-leopard interactions in northwestern India. Their content analysis

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reveals seasonal peaks in sightings, often coinciding with agricultural cycles or festival periods when human outdoor activity increases. The study notes that most interactions are non-lethal and that media narratives often sensationalize leopard presence, potentially influencing public perception and policy responses. The authors stress the need for balanced reporting, community education, and transparent incident reporting mechanisms to build trust between stakeholders and foster evidence-based conflict mitigation strategies.

Yosef, Dabi, and Kumbhojkar (2021) contribute an ethological dimension by documenting thanatological behavior—a female leopard's prolonged interaction with her deceased cub. Such observations, rare in wild felids, suggest complex social and emotional responses in leopards. While not directly related to conflict, this behavioral insight adds depth to our understanding of leopard ecology and cognition, with implications for their welfare in conservation contexts. The authors propose that ethological knowledge can inform conservation messaging by humanizing wildlife and fostering empathy, which may indirectly aid in conflict reduction.

Doubleday's (2018) doctoral research examines the socio-political dimensions of apex predator reintroduction in Rajasthan, using leopards as a focal species. The thesis reveals that rewilding efforts are not purely ecological undertakings but are deeply embedded in local histories, power dynamics, and land-use politics. While conservationists often frame rewilding as a restoration of "natural" systems, local communities perceive it through lenses of livelihood security and historical human-animal relationships. The work underscores the necessity of integrating social anthropology into conservation planning to avoid imposing top-down models that overlook community priorities.

Leopards (*Panthera pardus fusca*), the most adaptable of India's large felids, inhabit an ecological spectrum ranging from dense forests to urban peripheries. Rajasthan, particularly the Jaipur district and the semi-arid Aravalli range, offers a unique case study in leopard conservation, where these predators persist in proximity to expanding cities. The literature on this subject reflects a multi-dimensional approach—spanning ecological surveys, conflict assessments, ethological observations, and socio-economic analyses—to understand coexistence and conflict dynamics. This body of research underscores that leopard survival in human-dominated landscapes depends not solely on biological adaptability, but equally on socio-cultural tolerance, urban planning, and strategic conflict mitigation.

The reviewed works collectively identify patterns of leopard distribution, habitat use, prey preference, seasonal behavior, conflict incidents, and human perceptions. They also explore the effects of urban expansion, tourism, and conservation efforts beyond protected areas. While the focus is largely on Rajasthan, insights from studies in Maharashtra and the Himalayan region provide comparative perspectives on human–carnivore coexistence in India.

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Chauhan, Srivathsa, and Athreya (2021) employ media content analysis to investigate spatio-temporal patterns of human–leopard interactions in northwestern India. Their dataset, drawn from regional news outlets, reveals seasonal peaks in sightings and encounters—often coinciding with agricultural harvesting or festivals, when human outdoor activity increases. Geospatial mapping of incidents demonstrates clustering near habitat edges and along wildlife movement corridors, suggesting that land-use patterns directly shape conflict hotspots. A significant finding is the media's role in framing leopards either as dangerous intruders or as charismatic wildlife, influencing public sentiment and conservation discourse. The authors advocate for balanced reporting and the integration of media data into official wildlife monitoring systems.

Naha, Sathyakumar, and Rawat (2018) provide a complementary view from the Indian Himalayan region, identifying key drivers of human–leopard conflict such as livestock depredation, proximity of human settlements to forest edges, and seasonal resource availability. Their survey-based approach reveals that while many locals acknowledge the leopard's ecological role, perceptions are shaped by economic losses and fear of attacks. Importantly, their work shows that mitigation strategies must address both tangible losses (e.g., livestock compensation) and intangible concerns (e.g., perceived safety), reinforcing the need for socio-ecological solutions in Rajasthan as well.

Sharma and Dutta (2017) document leopard presence in human-dominated landscapes in Rajasthan, demonstrating that leopards can persist outside protected areas if basic habitat features—such as cover vegetation and water sources—are available. Their study highlights how nocturnal movement patterns and cryptic behavior enable leopards to avoid human detection, facilitating coexistence despite habitat modification.

Singh and Pandey (2019) focus specifically on Jaipur's rapid urban growth and its encroachment into leopard habitats. Using GIS-based land-use change analysis, they reveal significant habitat fragmentation and reduction in natural corridors. The consequences include increased leopard sightings in residential areas, heightened livestock depredation, and road mortality incidents. The authors call for urban planning that incorporates ecological corridors to sustain leopard populations while reducing conflict.

Meena and Chauhan (2016) map leopard distribution across Rajasthan's semi-arid zones, finding that these landscapes—although marginal for many wildlife species—still support stable leopard populations. They attribute this resilience to the species' dietary flexibility and use of rocky outcrops for denning. However, they caution that the absence of large wild prey forces leopards toward livestock dependence, setting the stage for chronic conflict.

Athreya et al. (2016) provide an important comparative perspective from Maharashtra, where leopards exhibit a strong preference for domestic dogs as prey. This behavior parallels findings in Rajasthan where leopards also target goats, dogs, and calves, particularly near urban fringes.

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The study underscores how prey choice is shaped by prey availability, human density, and predator risk perception

Singh and Kumbhojkar (2020) examine seasonal variation in leopard sightings at Jhalana Leopard Reserve, Jaipur. Their findings reveal peak activity in the cooler months (October–February), coinciding with increased tourist footfall and agricultural harvests in surrounding areas. Reduced sightings during hotter months may result from decreased movement to avoid heat stress, or a shift to less accessible parts of the reserve. Such seasonal patterns are crucial for scheduling conflict-prevention measures and tourism activities.

Kumar and Bhatnagar (2017) assess large carnivore presence in peri-urban landscapes, including leopards, and argue that such areas function as critical buffer habitats. Their study emphasizes that peri-urban zones are not ecological wastelands but dynamic interfaces where wildlife adapts to anthropogenic pressures. The implications for Rajasthan are clear: conservation strategies must not neglect these transitional zones, especially in districts like Jaipur where urban sprawl is accelerating.

Joshi and Singh (2016) synthesize lessons from leopard conservation efforts outside protected areas in Rajasthan. They argue that community-led initiatives, traditional ecological knowledge, and locally adapted livestock management practices are essential for sustaining leopard populations. Their work challenges the notion that conservation success is confined to national parks and reserves, instead presenting a decentralized, participatory model for human–wildlife coexistence.

Yosef and Kumbhojkar (2021) report an unusual case of thanatological behavior in a female leopard at Jhalana Leopard Reserve, who remained with her deceased cub for several hours. While rare in wild felids, such behavior suggests complex emotional capacities and has potential implications for conservation messaging. Presenting leopards as sentient beings can foster empathy and public support for conservation initiatives.

Sharma and Sharma (2018) evaluate the role of wildlife tourism at Jhalana Leopard Safari Park. They find that regulated tourism can generate revenue for conservation, raise awareness, and provide economic benefits to local communities. However, they caution against over-commercialization, which may disturb leopard behavior and exacerbate human–wildlife tensions if visitor management is inadequate. Their recommendations include strict visitor limits, guide training, and reinvestment of tourism revenues into habitat management and community development.

Overview of Jhalana Forest, Jaipur

Jhalana Forest, located in the eastern part of Jaipur city in Rajasthan, India, is a compact yet ecologically rich protected area spanning approximately 24 square kilometers. Despite its relatively small size, it holds national and global significance for its successful conservation of

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leopards in an entirely urbanised landscape. Surrounded on all sides by dense residential colonies, commercial complexes, road networks, and industrial areas, Jhalana stands as an ecological island that has managed to sustain a stable leopard population for decades. The forest consists primarily of dry deciduous and scrub vegetation typical of the Aravalli hill system, including species such as *Acacia catechu*, *Prosopis juliflora*, *Boswellia serrata*, and *Zizyphus mauritiana*. Its semi-arid climate, with hot summers and mild winters, shapes the distribution and movement behaviour of wildlife.

Water availability in Jhalana is managed through natural depressions and artificially maintained waterholes, which become crucial during the summer months. The prey base consists mainly of herbivores such as nilgai, spotted deer (introduced), feral dogs, langurs, peafowl, and small mammals, which collectively support the leopard population. Interestingly, the forest's leopards have adapted exceptionally well to limited prey and fragmented habitat, often shifting their activity patterns to avoid human interference.

In recent years, Jhalana has gained national attention due to the establishment of the Jhalana Leopard Safari, which transformed the forest into a major urban ecotourism destination. This initiative increased public awareness, improved monitoring systems, and generated livelihood opportunities for local communities while reinforcing conservation-oriented behaviour. The presence of leopards living in such close proximity to human settlements makes Jhalana a rare ecological phenomenon, offering a live laboratory to study coexistence dynamics, wildlife behaviour, and adaptation to urban pressures. Despite its success story, challenges remain, including habitat shrinkage, encroachment, vehicular disturbance, and increasing tourist pressure.

significance of Studying Urban Leopard Populations

Studying urban leopard populations carries immense ecological, social, and conservation significance, particularly in rapidly urbanising regions such as India. As cities expand, natural habitats become fragmented, forcing wildlife—especially adaptable predators like leopards—to navigate human-dominated landscapes. Understanding how leopards survive, behave, and interact within these environments is crucial for developing effective coexistence strategies that prioritise both human safety and wildlife conservation. Urban leopards provide a unique natural experiment to examine how large carnivores adjust their movement patterns, hunting strategies, and diel rhythms in response to anthropogenic pressures such as roads, lights, noise, and human activity.

From an ecological perspective, leopards are apex predators and play a vital role in regulating prey populations, controlling feral dog numbers, and maintaining ecological balance even in semi-urban ecosystems. Their persistence inside city limits demonstrates ecological resilience, raising important questions about habitat requirements, diet flexibility, territoriality, and genetic

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health in isolated populations. Studying these aspects helps in understanding the minimum ecological conditions required for the long-term survival of large carnivores in urban landscapes. From a social standpoint, human–leopard interactions often evoke mixed emotions, ranging from awe and admiration to fear and conflict. Areas like Jhalana show that human communities can coexist with predators when awareness, tolerance, and well-developed management strategies are in place. Research on urban leopard populations helps identify factors that shape local attitudes, conflict drivers such as livestock depredation or sudden sightings, and the socio-economic impacts associated with living near leopards. These insights contribute to designing education programs, mitigation strategies, and community participation models that reduce conflict while promoting coexistence.

Policy-wise, studying urban leopards provides valuable evidence for city-level planning, wildlife corridor design, and protected area management within expanding metropolitan regions. As India sees increasing cases of leopards entering towns and cities, insights from sites like Jhalana can guide national conservation frameworks. Ultimately, research on urban leopard populations is essential for fostering sustainable, science-based approaches to conserving large carnivores in the Anthropocene.

Research Problem

Human–leopard coexistence in rapidly urbanising landscapes presents a complex conservation challenge, particularly in ecologically sensitive yet densely populated regions such as Jhalana Forest in Jaipur, India. Although Jhalana is widely celebrated as an example of successful urban leopard conservation, scientific understanding of the ecological and social factors underpinning this coexistence remains limited. The primary research problem lies in the fragmented knowledge regarding how leopards adapt their behaviour, habitat use, and movement patterns within a small, isolated forest patch surrounded entirely by urban infrastructure, and how these adaptations influence the frequency and nature of human–leopard interactions. Simultaneously, there is insufficient assessment of community perceptions, levels of tolerance, awareness about leopard behaviour, and the socio-economic implications of living in proximity to a large carnivore. Tourism-driven interventions, such as the Jhalana Leopard Safari, add another layer of complexity by influencing human attitudes while potentially altering wildlife behaviour. Existing studies often treat ecological and social dimensions separately, resulting in a knowledge gap that hinders the development of integrated conservation strategies suitable for urban ecosystems. Therefore, the research problem centers on understanding the interplay between ecological dynamics and human attitudes, identifying potential conflict triggers, mapping coexistence zones, and evaluating current management practices. Addressing this gap is essential for designing sustainable, community-inclusive, and evidence-based strategies that ensure the long-term survival of leopards in urban India while safeguarding human livelihoods and security.

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Conclusion

The study of human–leopard coexistence in Jhalana Forest highlights the remarkable resilience of wildlife within heavily urbanised settings and underscores the importance of integrative conservation frameworks that address ecological realities and social dynamics simultaneously. The findings demonstrate that despite habitat fragmentation, limited prey availability, and expanding city infrastructure, leopards in Jhalana have successfully adapted by modifying their movement patterns, utilising microhabitats, and synchronising activity to avoid peak human disturbance. Equally crucial is the role of human communities, whose perceptions, tolerance levels, and daily experiences form the foundation of coexistence. The influence of ecotourism, particularly the Jhalana Leopard Safari, has generated both benefits and challenges, enhancing conservation awareness while demanding stricter guidelines to prevent ecological disruption. The research shows that effective coexistence requires not only scientific monitoring of leopard ecology but also sustained community engagement, transparent communication from forest authorities, and the establishment of conflict mitigation mechanisms tailored to local needs. Urban wildlife conservation can no longer rely solely on traditional models designed for remote forests; instead, it must incorporate urban planning, behaviour science, socio-economic considerations, and participatory governance. Jhalana serves as a living laboratory demonstrating that large carnivores and humans can share landscapes when supported by informed policies, ecosystem-sensitive tourism, and strong institutional management. Moving forward, long-term monitoring, habitat restoration, buffer zone development, and education-based initiatives will be essential for ensuring the stability of leopard populations. Thus, the study concludes that Jhalana's model of coexistence offers valuable insights for other Indian cities facing increasing human–wildlife interface challenges, reaffirming the possibility of harmonious coexistence when ecology, society, and governance work in alignment.

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