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Going with, or going to the dogs: City Serenade of Multispecies Survival

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Abstract

1. As tropical cities rapidly urbanise, multispecies coexistence faces unprecedented challenges. Ground-dwelling (dogs), arboreal (macaques), and aerial (black kites) urban commensals navigate complex social-ecological systems shaped by anthropogenic resource provisioning, cultural practices, and architectural constraints. Despite escalating human-animal conflicts—20 million annual dog bites in India alone, macaque territorial instability, and aviation safety concerns from avian aggregations—management interventions remain reactive and species-specific, failing to address underlying social-ecological drivers. A critical gap persists in understanding how ritual feeding practices, urban waste systems, and socioeconomic inequalities structure coexistence dynamics across taxonomic guilds in South Asian megacities.

2. We investigated multispecies urban ecology across Delhi's socioeconomically diverse neighborhoods (2012-2024), integrating quantitative population assessments with ethnographic insights. For free-ranging dogs, we conducted photographic capture-recapture surveys across 14 stratified sampling units (2.95 km²), quantifying density, pack structure, and food subsidy availability. For rhesus macaques, we documented displacement intervention outcomes at Dr. B R Ambedkar University Delhi (2023-24), tracking recolonisation dynamics following removal of 50 individuals. Semi-structured interviews with 65 stakeholders—including security guards, residents, and administrators—illuminated human dimensions of coexistence. We contextualised findings within long-term black kite research demonstrating synchronisation between population dynamics and human cultural practices.

3. Delhi harbours an estimated 795,313 free-ranging dogs (530±89 dogs/km²) supported by 327,069 feeding stations and 85,109 garbage points—infrastructure with combined carrying capacity approaching 1.6 million dogs. Pack density correlated strongly with feeding infrastructure ($r=0.856$, $p<0.001$) rather than incidental waste, while high-density areas exhibited male-biased sex ratios ($r=-0.589$, $p=0.027$). Macaque populations achieved full numerical recovery within a month post-displacement despite 31% removal, demonstrating futility of translocation without addressing religious provisioning and architectural accessibility. Ethnographic data revealed socioeconomic gradients in conflict vulnerability: outdoor workers bore disproportionate costs while possessing minimal management agency. Cultural ambivalence toward ritual feeding—simultaneously expressing spiritual obligation and conflict concern—defied simplistic intervention prescriptions.

4. Multispecies coexistence emerges through dynamic negotiation across biological, spatial, and temporal scales rather than fixed states amenable to technical solutions. Effective management requires modifying human practices—feeding systems, waste infrastructure, architectural design—rather than controlling animal populations directly, cantering environmental justice alongside ecological understanding in tropical urban planning.

Key words: Urban ecology; Human-wildlife conflict; Anthropogenic subsidies; Environmental justice; Social-ecological systems; Commensalism; South Asia; Behavioural adaptation; Animal welfare; One Health

1. A fictional take on the multispecies coexistence crisis

Hello Reader! *I write to you from the streets of Delhi in 2030, where the multispecies coexistence crisis we ignored by the turn of the century has reached a breaking point. What were once shared urban spaces for human and non-human denizens have become battlegrounds. For instance, citizens, street dogs, animal advocates, and bite victims are trapped in escalating cycles of violence—poisoning campaigns met with vigilante protection, culling drives sparking counter-protests, fear breeding hatred breeding more fear. The "solution" has become the problem, and the issue has become existential. This is not fiction but a trajectory.*

Despite our rich tropical biodiversity, we never truly understood the complex dynamics between humans and animals in rapidly changing urban landscapes. By 2030, these bustling cities teeter on the edge of social-ecological collapse. This collapse does not simply mean outright failure, but progressive truncation of who all—human as well as nonhuman—could call tropical cities home. What was once a delicate dance of coexistence has devolved into chaos—dogs attacking vulnerable children and the elderly, macaques trapped in makeshift urban sanctuaries, communities divided between protectors and exterminator.

If you are reading this in 2025-26, this dystopia is still preventable, against the backdrop of escalating human-animal conflicts in changing landscapes. But the warning signs were already there: misplaced cultural practices, eroding eco-literacy, and the abandonment of traditional knowledge that once balanced (some) aspects of human-animal relationships and underlaid mutual tolerance. Our cities are anything but "smart" when it comes to multispecies living, something that urban administrators and planners will soon realise (see Fig. 1). The folk biological practices that sustained coexistence in social-ecological systems for centuries crumble under rapid urbanisation and technological gentrification.

Yet hope persists in transdisciplinary approaches—if you acted, now. Imagine researchers building a true "Science of Tropical Cities," developing innovative methodologies tailored to our unique challenges. Research guided by the One Health approach could illuminate the connections between animal behaviour, disease pathways, and public health. We could rediscover and adapt the cultural practices that once celebrated care for our non-human companions.

But coexistence is not just a scientific problem. These ethical imperative warrants insights to prevent the severing of people-nature connections due to urbanisation. Here, technological applications can integrate scientific knowledge with biocultural narratives and folklore, promoting a new-age eco-literacy. The false race to meet global urban benchmarks in tropical cities affects humans and nonhumans alike, requiring us to understand coexistence across species lines. Breaking cycles of violence requires real-time assessments of the behavioural profiles of social/breeding units of animals. The latter warrants respecting the (ecosystem) web that binds all urban life, which transgresses biological and sociological silos. In our timeline, it shall be a future where the following poetry of coexistence gives way to fragmented prose of conflicts:

In the heart of many tropical cities, where the concrete meets the sky,
Quadrupeds (ground-dwelling) meet bipeds (humans) in a dance to comply.
A constant cognitive mutualism, familiar and yet new,
With barks, whines, and tail wags, their signals are true.

Negotiating streets, amidst the urban beat,
A dance of coexistence, where different life worlds meet.
For what dogs or coyotes consider safe, humans may not agree,
Yet they continue to negotiate, in the city, as we see.

‘Tailed Simians’ in their realm, brachiate with grace,
From branch to branch, they find their (limited) urban space.
Meeting humans in the streets, when safety/food is assured,
Yet the dynamic streets often bring discord.

And then there are the avian scavengers, soaring high and free,
Over unfamiliar turf, as far as their eye can see.
Hostilities arise, but only for a time so brief,
When parent-birds are tied to nests, intrusion brings grief.

Birds negotiate with winds in the tropical city’s core,
Finding conducive spaces, forever exploring more.
This is the code of coexistence, a lesson to be learned,
In the heart of the city, where many ‘lifetables’ are turned.

From ground dwellers to arboreal, to aerial lifestyles wide,
The spectrum of human-animal negotiations, side by side.
It is a dance of life, a symphony bitter yet sweet,
In the urban jungle, where different life worlds meet.

Yet, in this dance, there is a tropical rhythm, a beat,
Shaped by Eastern religions, cultures, and the streets.
Known to prevent indiscriminate culling, retaliation’s tide,
When some animals become threats to urban pride.

This cultural essence of coexistence, this cognitive dissonance,
Potentially allows Indians to protect their biodiversity with such resonance.
It is not always about wisdom, not always about scientific discourse,
But about living together, coexistence, and staying the course.

But there is a modern prevalence, a non-traditional patronising tone,
Towards non-human city dwellers, opportunistic ones full-grown.
Ritually fed by people, a practice spread wide,
Might not be justified—it is a dangerous ride.

Subalterns in humans and animals both bear the heaviest cost,
When the web of interdependence is lost.
Because of fear of conflicts and diseases animals spread,
which affects the subalterns, more exposed to such dread.
Thus, warranting scientific evaluations, a need to reassess,
Traditional practices that once ensured the coexistence’s success and progress.

Fig. 1. Urban Imaginaries: A 7-year-old kid's vision of a tropical city from Oxfordshire in the year 2025 reveals the fundamental tension between sanitised human-centred development (left) and the messy, vibrant reality of multispecies coexistence (right). In this child's urban ecology, orange-winged creatures, insects, bats, spiders, climbing vines, snakes and interspecies encounters populate the spaces that planning discourse renders invisible - suggesting that even young minds intuitively understand what urban design systematically overlooks: cities are always already multispecies assemblages. (Oxford Sparks, 2025)

2. Introduction

As human habits and habitats transform in the 21st century (Anonymous, 2016), our relationships with urban-adapted species—from ground-dwelling commensals (dogs) to arboreal exploiters (macaques) to aerial opportunists (bird scavengers)—face unprecedented challenges (Nyhus, 2016). This crisis of multispecies coexistence, depicted in our opening fictional narrative from 2030, reflects current trajectories in tropical cities that demand immediate scientific attention. With approximately 65% of humanity now urbanised within less than 4% of Earth's land area (United Nations Population Division, 2018), cities have become the primary stage for reshaping human-animal coexistence (Soga & Gaston, 2020). These challenges intensify in developing tropical regions like South Asia, where rapid urbanisation, increasing resource pressures, and shifting cultural practices converge to destabilise traditional management approaches (Kumar et al., 2019c).

a) Ground-dwelling commensals: Dogs (*Canis lupus familiaris*), arguably the first domesticated species, are the most widespread carnivores globally, with populations estimated at approximately one billion individuals. In urban contexts, ecologists classify dogs into overlapping categories—pet, street, free-ranging, and feral—based on their behavioural relationships with humans and their dependence on human provisioning (Vanak & Gompper, 2009). Approximately 80% of dogs worldwide remain free ranging, exhibiting varying levels of adherence to the human niche and displaying diverse interdependencies with urban communities.

The scale of the challenge is staggering. The Indian subcontinent harbours the majority of the world's free-ranging dogs (Vanak, 2017), yet we have not explored relational patterns between human densities, dog densities, and conflict ecology. In tropical cities like Delhi, free-ranging dog (FRD) populations create a complex mosaic of social and breeding units that operate across human settlements, generating multilayered challenges: conflict with vulnerable human populations (children, elderly, waste workers), disease transmission risks (particularly rabies), and ethical dilemmas regarding population management (Sharma, 2023). Current estimates suggest 20 million annual dog bites globally—one every two seconds—with India experiencing approximately 40% of global rabies deaths. These conflicts exact substantial costs: 40 million human working days in recovery and £21 million in prophylactic treatment annually across India alone (Vanak, 2017). Critically, these figures capture only bite incidents, excluding the broader spectrum of disturbances—barking and chasing behaviours, livestock conflicts and losses, and inter-species tensions with other urban commensals and wildlife (Gompper & Gompper, 2013). This data gap extends beyond incidence reporting: we poorly understand how anthropogenic food subsidies translate into dogs' numerical responses (abundance and distribution) across different urban contexts.

Traditional interventions—culling, mass sterilisation, or translocation—have generated cycles of retaliation and counter-protection, creating what researchers term the "intervention paradox," wherein management solutions escalate rather than resolve underlying tensions. The behavioural heterogeneity within FRD populations, coupled with their capacity for rapid learning and adaptation to urban niches, demands quantitative assessment of population dynamics, conflict patterns, and the efficacy of evidence-based management strategies. Delhi's recent experience with dog management interventions illustrates how underestimating rapid recolonisation potential contributes to management failure (India Legal, 2022; Reporter, 2021; Shukla, 2025).

b) Arboreal urban exploiters: Rhesus macaques (*Macaca mulatta*) exemplify a fundamentally different mode of urban adaptation compared to ground-dwelling commensals. Unlike dogs, macaques do not generally form dyadic bonds with humans but instead exploit urban resources—particularly refuse and ritually provisioned foods—through their three-dimensional mobility. This arboreal advantage enables them to raid human settlements and retreat to trees, woodlots, or rocky/building outcrops beyond human reach, rendering traditional ground-based management ineffective. Their opportunistic intelligence, combined with rapid learning and cultural transmission within social groups, allows macaque troops to identify and exploit new resource patches.

We lack comprehensive knowledge of how arboreal species like macaques respond to urban food sources and territorial pressures. Urban infrastructure development, increasing waste generation, and shifting cultural norms regarding wildlife tolerance occur against a backdrop of macaque behavioural profiles, sentient of these changes. Yet these complexities remain poorly understood and inadequately addressed by traditional management approaches (Barua et al., 2013; Braczkowski et al., 2023; Dickman, 2010a; Nyhus, 2016; Torres et al., 2018). Interventions documented across Delhi and other megacities—removal of problematic individuals or entire troops—have shown limited long-term success and often generate unintended consequences, including establishment of new problem troops in neighbouring areas. Cases of rhesus macaques exemplify how ritual feeding and high human footfall contributed to macaque territorial instability, making conflict resolution through displacement ineffective (Deol, 2023; Govindrajan, 2015; Rittem et al., 2024). A critical gap exists in quantitative understanding of macaque population dynamics in urban settings, conflict escalation pathways, and the spatial and temporal factors that determine management outcomes. Such understanding is essential for developing targeted, evidence-based interventions that balance conservation concerns with legitimate human safety and welfare priorities (Ganguly et al., 2018; Priston & McLennan, 2013; Radhakrishna et al., 2012; Ross et al., 1993; Wu et al., 2022).

c) Aerial opportunists: Black kites (*Milvus migrans*), studied through long-term research in Delhi by Gupta & Kumar (2024), exemplify how aerial scavengers navigate complex urban landscapes while generating novel forms of human-animal conflict (Kumar et al., 2019). Unlike terrestrial or arboreal species, aerial commensals present distinct challenges including aviation safety hazards when large congregations (Kumar et al., 2020) create airspace conflicts (Arrondo et al., 2021; Baxter et al., 2003; Sodhi, 2002). The seasonal influx of migratory black-eared kites (*Milvus migrans lineatus*) generates massive communal foraging roosts in and around landfills, with aggregations numbering in the thousands at single sites (Kumar et al., 2020).

Recent studies have identified how avian scavengers adjust their foraging and nesting behaviours in response to human activity patterns and cultural beliefs (Gupta & Kumar, 2024; Kumar et al., 2018a; 2019a,b). These large avian assemblages create significant nuisance issues for surrounding communities—including noise, waste dispersal, and nesting conflicts—while simultaneously raising largely unexplored concerns about disease transmission (particularly through scavenging of diseased animal carcasses) and toxicant bioaccumulation in urban food webs (Kumar et al., 2019c; Xu et al., 2016). Researchers have largely overlooked the ecological impacts of waste-based biomass availability, despite cursory evidence showing significant effects on urban-adapted birds and mammals at garbage points and landfills (Katlam et al., 2018). The role of aerial scavengers in maintaining ecosystem services (carrion removal, nutrient cycling) versus their ecological and health liabilities remains inadequately quantified, particularly in tropical urban contexts where sanitation infrastructure and wildlife management intersect.

The Role of Cultural Practices and Urban Waste Systems in cross-scale processes

A distinguishing feature of tropical urban ecosystems is the interplay between regional cultural practices and ecological relationships (Gupta & Kumar, 2024; Kumar et al., 2019b). Ritualistic feeding of urban commensals—dogs, kites, macaques, and livestock—represents a prominent aspect of Indian religious traditions (Pinault, 2008). While these practices reflect deep cultural values of coexistence (Kumar et al., 2019c), their health and ecological implications remain underexplored. Intersections of spiritual obligation and urban ecology create feedback loops for population and behavioural ecology: feeding practices alter natural foraging behaviours (Kumar et al., 2014), increase population densities (Kumar et al., 2019b), and modify species-specific movement patterns in response to built environments (Evans & Gawlik, 2020). These cultural dimensions distinguish tropical urban ecosystems from their Western counterparts, where such practices are largely absent (Evans & Gawlik, 2020; Oro et al., 2013).

Urban waste systems further complicate these dynamics (Kumar et al., 2019c). Heterogeneously developed urban pockets in tropical megacities form mosaics of varying habitat suitability, creating human-animal interfaces simultaneously driven by biophysical and biocultural factors. Interactions between top-down state interventions and bottom-up community waste management or ritual practices shape the continuum of coexistence, which frequently involve agonistic human-animal encounters (Kumar et al., 2019a; 2018b).

A critical knowledge gap persists: *How do cultural feeding practices interact with urban waste systems to shape the ecology and behaviour variably for ground-dwelling, arboreal, and aerial urban commensals?* Understanding these interactions is essential because they represent controllable variables in urban ecosystem management. Unlike infrastructure or population density, feeding practices and waste management systems can be modified relatively quickly through regional policy and community engagement—but only if we understand their ecological consequences across the full spectrum of urban-adapted species (Luniak, 2004; Santini et al., 2019). The convergence of ritual feeding, waste availability, and species-specific resource utilisation patterns creates unique urban ecological dynamics that require integrated management, backed by social-ecological research (Fall & Jackson, 2002; Gil-Fernández et al., 2020; Kokko & Sutherland, 2001; Wong & Candolin, 2015).

Recent advances in human-animal behavioural research provide foundations for addressing these policy and ecological gaps. Studies have significantly advanced our understanding of interspecies communication, social cognition, and cooperation, particularly how street dogs interpret human gestures and form social bonds. Research by Bhadra and colleagues (Bhattacharjee et al., 2018; Bhattacharjee & Bhadra, 2022) demonstrates that FRDs treat individual humans as discrete resource units, preferring direct food provisioning while adapting their behaviour based on human social cues. However, these behavioural insights remain disconnected from proximate ecological drivers—environmental and infrastructural factors that shape human-animal relationships across scales. Bridging this scale gap is essential for translating individual-level behavioural understanding into landscape-level management frameworks capable of addressing the systemic dimensions of the coexistence crisis (Wong & Candolin, 2015).

Research Gap and Study Rationale

These three urban commensalism models—ground-dwelling, arboreal, and aerial—highlight a critical scientific and management question: *How can we effectively integrate Western urban infrastructure with regional mindsets of coexistence in tropical urban environments?* The answer requires moving from reactive to predictive management. Studies recommend that management should incorporate behaviourally informed approaches that acknowledge the complex social structures of urban-adapted species. Despite infrastructure and anthropogenic changes affecting human-animal relationships (Kumar et al., 2018a, b), the fundamental ecological niches of urban-adapted species remain mostly consistent. For instance, FRDs continue as opportunistic scavengers, creating geographies of coexistence based on access to human food subsidies—a pattern echoed across ground-dwelling, arboreal, and aerial urban commensals(Gámez & Harris, 2022; Hussain & Baumann, 2024; Pocheville, 2015; Regos et al., 2021).

However, our understanding of these relationships remains surprisingly limited. Studying the ecology of these urban commensals is important for several reasons. ***First***, comparative quantitative assessment of their population dynamics, conflict profiles, and management efficacy remains scarce (Ganguly et al., 2018; Priston & McLennan, 2013), particularly across multiple tropical urban contexts and in relation to human density gradients, socioeconomic variation, and cultural practices (Dickman, 2010b; Franklin, 1999; Sueur & Huffman, 2024). ***Second***, behavioural heterogeneity within populations—evident in dogs, macaques, and scavenging birds—demands species-specific yet integrated frameworks for understanding coexistence (Beckmann & Berger, 2003; Gordo et al., 2021; Jones & Thomas, 1999). ***Third***, the interconnections between human and animal wellbeing, disease ecology, and social justice have been inadequately synthesised, limiting our ability to develop management strategies that address the multifaceted dimensions of the coexistence crisis (Dhee et al., 2019; Hassell et al., 2017). ***Fourth***, the distinctive role of cultural feeding practices and waste systems in shaping urban animal ecology remains largely unstudied (Kumar et al., 2019c), despite representing tractable intervention points for policy and community engagement. ***Finally***, individual-level behavioural understanding must be integrated with landscape-scale ecological data (Kumar et al., 2014, 2018a; 2019a,b) to develop robust management frameworks that account for environmental heterogeneity and social inequities.

3. Methodology

Study Design

To bridge aforementioned gaps, our study investigated multispecies urban ecology across various human niches in Delhi, extending long-term species-centred investigations to a systems approach. This manuscript presents the first comprehensive quantitative data on dog population estimates—including density, pack structure, demographics, phenology, and diet—along urban gradients, which relate to patterns in the dispersion of food subsidies across neighbourhoods of varying socioeconomic status and infrastructure quality. Through semi-structured interviews involving diverse communities (methodological details in Gupta & Kumar, (2024)), we examined how different human groups perceive and interact with urban-adapted species, capturing the cultural specificity and contextual variation that shapes coexistence outcomes. For macaques, we analysed the ecological and social consequences of displacement-based conflict resolution at Dr. B. R. Ambedkar University Delhi in 2023-24, assessing whether traditional interventions mitigate or exacerbate conflicts.

Fieldwork and data analysis

This study is part of a long-term research initiative launched in 2012, aimed at unravelling the ecology and ethno-zoology of urban commensal scavengers in Delhi. Our approach has been methodical, involving systematic monitoring surveys across 32 sampling plots, each approximately 1 km^2 in size, selected through a stratified-random design. These plots represent a diverse array of urban environments, ranging from semi-natural areas to densely populated regions, reflecting the city's varied socio-cultural and ecological fabric. The design included all three sanitary landfills (for details, see (Kumar et al., 2019b). This field research approach has facilitated interactions with an average of 27.03 ± 2.31 new observers daily within each sampling unit, providing a rich source of qualitative data on human-animal coexistence in the context of urban ecosystem(s) of Delhi that are emblematic of tropical, South Asian urbanism. For details, see (Gupta & Kumar, 2024).

Since many areas of the city were private properties not accessible to the public, it was not possible to design a large, continuous study area. Additionally, since FRDs in our area can attain extremely high densities, small plots distributed over a wide area were better suited for sampling all available conditions than a single, necessarily limited, continuous plot. Therefore, we designed a network of 14 sample plots, randomly chosen from each stratum within the original 32-plot study system (Kumar et al., 2019b). Average size of each dog-sampled plot measured ~0.2 km^2 of homogenous accessibility. We ensured they were distributed throughout the city, covering all types of potential FRD habitats. The selection of sampling plot size was contingent upon the largest FRD pack area in Delhi, which closely corresponded to the dimensions of municipal waste management in respective residential blocks. However, a standardised shape or a standardised surface of 0.2 km^2 could not be attained for all plots because of constraints imposed by private properties and logistical difficulties of access. Private properties had similar landscape features to the surrounding areas of the city, and we are confident that their exclusion did not bias our density estimates. However, because of the above, dog territories that were located at the periphery of each sample plot were carefully examined while generating density estimates.

We conducted repeated surveys of each quadrant every few weeks, between April - August 2023. We walked slowly and carefully, inspecting all potential areas where FRDs dwell, including parks, roads, buildings, under vehicles and other hideouts, and open areas. We also occasionally used dog bark playbacks to flush out the hidden FRDs. To classify public or private areas as active canine territories, the same set of individuals within a pack was repeatedly observed based on the regularity of space usage. Once found, FRD territories were regularly inspected using still camera records to observe their survival. FRD territories were checked approximately every eight days. During each visit, we collected data on potential foraging locations, such as garbage units, feeding trays, or platforms, within each dog territory. We estimated macaque troops' sizes at Dr. B. R. Ambedkar University Delhi across the translocation event in September - October 2023. For this, we employed double observer sampling; n = 5 (Nichols at al., 2000).

Aforementioned covariates were collected to model the relationship between plot-wise FRD densities and human food subsidies. Density was calculated as the number of individuals as well as territorial packs per unit area and expressed as the number of individuals and packs in every square kilometre area. We also conducted a preliminary assessment of the time activity budget of the dogs sampled. When necessary, variables were logarithmically, or arc-sine square root transformed to achieve a normal distribution. Throughout, means are given ±1 standard error, tests are two-tailed, and statistical significance was set at an α level of 0.05.

We used thematic analyses based on the interview transcripts. These transcripts were anonymised to ensure confidentiality in keeping with human subjects' ethics permits held at AUD. This process involved coding responses to identify patterns and themes within the data, which were then interpreted for links in people-places and animals. Qualitative data gathered through semi-structured interviews elicited comprehensive and insightful responses from the participants. Interviews were either audio-recorded with the consent of the participants to ensure accuracy and reliability or summarised on paper as soon as the interview was finished. The recorded data were then transcribed verbatim to facilitate a thorough analysis. Qualitative data were analysed using a systematic approach described in Gupta & Kumar, (2024). The transcribed data were read multiple times to gain an understanding of the participants' perspectives. Then, the data were coded into themes and sub-themes, a process that involved identifying and categorizing patterns in the data. This process employed a Delphi-like ethnographic approach described in detail in Gupta & Kumar, (2024); Mukherjee et al., (2015) to understand the range of stakeholders and their interactions with human-commensal companionship, waste, and ritually motivated feeding by people from multiple communities.

4. Results

Ecological assessment of human-dog coexistence

Cumulatively, we censused 1484 dog individuals using photographic capture-recapture, within a total of 2.95 km^2 area monitored across 14 sampling units. The mean density of FRDs within the city of Delhi was 530 ± 89 dogs/km^2. This value, when extrapolated over the 1500 km^2 of the National Capital Territory of Delhi, yields an estimated population of 7,95,313 street/feral dogs in the capital (range: 6,61,423 to 9,29,203). The average number of packs was 106 ± 14 /km^2, with an estimated 5 ± 1 dogs per pack. The mean male-to-female sex ratio was 1.06 ± 0.06, indicating that there were slightly more males than females in the sampled population (Table 1).

Table 1: Free-ranging dog population characteristics and anthropogenic resource availability across 14 sampling sites in Delhi, India (April-August 2023). The limited size of Site 5 is attributed to the entire area of the top of *Ghazipur* landfill.

Site ID	Sampled Area (km^2)	Photo captured dogs	# of packs	Mean pack size	Density (dogs/km^2)	Pack density (packs/km^2)	Sex Ratio Adult (♂ : ♀)	#Feeding trays/km^2	#Garbage heaps/km^2
1 (Central)	0.38	335	59	5.68	881.58	155.20	1.05	552.63	10.53
2 (Central)	0.43	177	44	4.02	411.63	102.30	0.86	300.00	4.65
3 (Central)	0.28	174	46	3.78	621.43	164.20	0.85	410.71	28.57
4 (East)	0.20	56	6	9.33	280.00	30.00	1.16	15.00	25.00
5 (East	0.05	70	6	11.67	1400.00	120.00	1.00	0.00	400.00
6 (East)	0.14	85	12	7.08	607.14	85.70	1.30	0.00	142.86
7 (West)	0.20	56	20	2.80	280.00	100.00	1.25	350.00	20.00
8 (North)	0.17	119	32	3.72	700.00	188.20	0.99	429.41	5.88
9 (North)	0.19	23	4	5.75	121.05	21.05	1.10	284.21	21.05
10 (Northwest)	0.19	18	4	4.50	94.74	21.05	1.59	42.11	31.58
11 (Northwest)	0.16	66	16	4.13	412.50	100.00	0.83	25.00	18.75
12 (South)	0.15	72	22	3.27	480.00	146.67	0.95	313.33	46.67
13 (North)	0.21	135	29	4.66	642.86	138.09	0.99	195.24	23.81
14 (North)	0.20	98	21	4.67	490.00	105.00	0.82	135.00	15.00

Systematic surveys of food subsidies available to FRDs across stratified sampling sites in Delhi revealed consistent patterns in anthropogenic resource provisioning. Across these diverse neighbourhoods, each square kilometre of urban area where FRDs reside contained, on average, 57 ± 16 garbage accumulation points (refuse piles, landfill sections, or concentrated waste zones) and 218 ± 51 feeding stations (including feeding trays, bowls, platforms, or regularly provisioned locations established by residents).

Wealthier areas with better sanitation infrastructure tended to have fewer garbage points but potentially more formalised feeding practices, while it was vice-versa for lower-income areas. Extrapolating from sampling site data to Delhi's total urban area, these density estimates yield city-wide totals of approximately **85,109 garbage points** and **327,069 feeding stations** distributed across the metropolitan area. These represent the primary anthropogenic food sources sustaining FRD populations throughout Delhi.

Estimating Resource Distribution Among Dogs: During surveys at feeding stations, we consistently documented the presence of **2-3 dogs**. At garbage accumulation points, we observed **7-10 dogs** actively scavenging or resting in proximity. To understand how current dog populations relate to available food resources, we employed a resource-allocation approach. We began with estimates of FRD populations in Delhi (~795,313 individuals), then calculated the implied dog-to-resource ratio by dividing total dog numbers by the number of available food sources: these calculated ratios, thus, align well with our direct field observations.

Dogs per feeding station = **2.4 dogs/feeding platform**, assuming all were provisioned
Dogs per garbage point = **9.3 dogs/garbage site**, assuming all scavenged

Estimating Carrying Capacity: Using the validated resource-support ratios derived from our field observations, we can estimate the maximum carrying capacity of Delhi's anthropogenic food subsidy infrastructure:

Carrying capacity from feeding stations: 327,069 × 2.4 dogs/tray = **~785,000 dogs**
Carrying capacity from garbage points: 85,109 × 9.3 dogs/garbage = **~791,000 dogs**
Combined carrying capacity: ~1,576,000 dogs (~1,050 dogs/km² of urban area)

Garbage availability demonstrated significant positive correlations with both individual pack size ($r = 0.563$, $p = 0.036$) and overall dog density ($r = 0.601$, $p = 0.023$), indicating that neighbourhoods with greater waste availability supported both larger packs and higher densities of FRDs. This pattern aligns with resource-based predictions of animal population dynamics: where anthropogenic food subsidies are more abundant, dogs can maintain larger social units and achieve higher population densities. Feeding infrastructure showed a particularly strong positive correlation with pack density ($r = 0.856$, $p < 0.001$), indicating that areas with concentrated, regularised human feeding practices harboured significantly more packs per unit area. This relationship was substantially stronger than the garbage availability correlation, suggesting that the predictability and spatial concentration of intentional human provisioning—rather than incidental waste availability—is the primary driver of pack density across Delhi's urban gradient. Where communities engaged in ritual or regular feeding practices, FRD packs achieved their highest densities, compressing their territorial requirements in response to reliable, concentrated food sources. This relationship suggests that where communities engaged in regular, spatially concentrated feeding practices, FRD packs compressed their territorial requirements and increased their density—a mechanism consistent with optimal foraging theory predictions.

Notably, pack density demonstrated a significant negative correlation with adult sex ratio ($r = -0.589$, $p = 0.027$), indicating that areas with the highest pack densities, consequently supported by enormous food subsidies, exhibited male-biased sex ratios among adult dogs. Given the modest sample size ($n=14$ sampling units), these correlations should be interpreted as preliminary findings requiring validation in larger, independently sampled datasets. Time-activity budget observations revealed that vehicular and pedestrian traffic intensity significantly constrained FRD activity and spatial use. In high-traffic areas, dogs exhibited avoidance behaviour, selectively occupying refugia including spaces beneath/atop parked vehicles, building alcoves, and sheltered nooks that minimised exposure to traffic and human interference. Dogs in these high human and vehicular-traffic zones remained predominantly inactive during peak traffic periods, with activity increasing only during off-peak hours (11 pm - 07 am) or in sheltered locations where human and vehicular disturbance was minimal (Fig. 2). This pattern suggests that urban infrastructure and traffic dynamics function as significant ecological stressors, substantially limiting the behavioural repertoire and spatial accessibility of FRD populations.

In marked contrast, FRDs inhabiting areas with reliable human provisioning and minimal traffic disturbance exhibited substantially higher activity. A case study from *Moti Nagar* exemplifies this pattern: a residential block backyard (~800 m²) that received regular ritual feeding harboured three distinct dog packs totalling 19 individuals. Dogs within this feeding-provisioned area displayed active foraging, social interaction, and territorial patrol behaviours throughout 24-hr diel cycles. Such dogs exclusively dependent on ritual feeding in specific localities with low traffic exhibited notably heightened territorial aggression in response to stranger entry, displaying aggressive vocalisations and approach behaviours toward unfamiliar humans regardless of time of day.

Rather than simply affecting FRD abundance, ritual and opportunistic feeding by residents appears to fundamentally reorganise pack social structure and spatial distribution. From a management perspective, this finding indicates that interventions targeting feeding infrastructure—whether through formalised feeding programmes, restrictions on public feeding, or integration of feeding with sterilisation campaigns—may represent tractable levers for modulating pack density and territorial stability in ways that species-specific interventions (e.g., targeted removal) alone cannot achieve (Fig. 2). Below, we pair the correlations with qualitative data from semi-structured interviews to strengthen the interpretation beyond descriptive statistics.

Ethnographic insights from the co-existence of humans and dogs

(i) *Recognition, Familiarity, and Differential Treatment*

All interviewees who engaged in regular dog feeding (n=35, excluding targeted ethnographic participants) reported that provisioned dogs recognised them reliably—either by visual appearance, distinctive vocalisations, or movement patterns. This recognition created differentiated spatial and social geographies within ostensibly shared urban spaces. Notably, others frequenting these same localities—including ragpickers, delivery personnel, and transient workers—expressed marked disdain toward provisioned dogs, attributing greater aggression to regularly fed animals. This perception, whether empirically accurate or not, fundamentally shaped how different urban residents navigated shared spaces and interpreted dog behaviour.

> *They guard this area because she feeds them. Dogs from the other lane also come here to eat, though I do not feel much attachment to them. They do not let random people enter the street. But we have to make rotis for them, before we cook for ourselves.*

> *At our temple, when kirtan used to happen, one dog would come and sit with us for the entire kirtan. We would give him prasad and then he would leave. Every being has sense* - A young female explaining how another girl feeds dogs on a daily basis and dogs from the lane and other lanes recognise her and come for food.

A priest from the temple at *Shastri nagar* pointed out how dogs are familiar with religious gatherings and sit until it is over to request *parasad* (food). These differential perceptions created what we term a geography of recognition and alienation: spaces transformed by consistent provisioning became socially and affectively loaded for some residents (feeders) while remaining sites of anxiety and avoidance for others (non-feeders). People who visited different parts of the city as part of daily routines—commuting to workplaces, collecting waste, making deliveries—encountered unfamiliar dogs in unfamiliar territories. Without the recognition relationship established through consistent feeding, these transient visitors experienced dog encounters as unpredictable and potentially threatening, generating uncertainty about appropriate behavioural responses when dogs approached. This created what anthropologists term "interactional friction": the inability to establish mutual recognition and appropriate social scripts for encounter, against the backdrop of prevalent urban conundrums in tropical cities that are socio-cultural agglomerates.

(ii) *Behavioural Adaptation and Perceived Risk*

Interviewees revealed individual strategies for managing perceived dog-related conflict risk. Residents expressing fear of dogs employed two primary coping mechanisms: **spatial avoidance** (selecting routes and times that minimised dog encounters) and **carrying defensive implements** (sticks, stones, or other objects for protection). Older adults were particularly affected, reporting that perceived dog-conflict risk in their neighbourhoods significantly restricted their daily mobility and social activities, contributing to feelings of isolation and constraint.

> *I do not go to the south side of 56 bigha-park anymore because of the dogs near the exit corner (middle aged female), or I now leave the house only in the morning when the dogs are sleeping for my morning walk (an aged male)*

People with prior negative dog encounters—bites, chasing, or threatening approaches—demonstrated escalated defensive responses toward dogs more broadly, suggesting that individual negative experiences generalised into category-level avoidance or hostility. Over time, such interactions created feedback loops: prior negative encounters increased human aggression or avoidance toward dogs, which in turn intensified dog defensive or aggressive responses. This dynamic, though documented through self-report rather than direct behavioural observation, illustrates how human-dog conflict generates self-reinforcing cycles rather than discrete incidents (Fig. 2).

(iii) *The Failure of Population Control Approaches*

Current anti-birth control (ABC) programmes in Delhi—which primarily focus on sterilisation and neutering to reduce population growth—substantially underestimate the complexity of human-dog coexistence. These programmes operate under a simplified model: population size drives conflict, therefore reducing population size reduces conflict. However, our ethnographic data reveal a fundamentally different ecological and social reality: **the dynamics of human-dog interaction are constantly negotiated and renegotiated, making generic, one-size-fits-all interventions ineffective**. Interview data revealed substantial and widespread resident opposition to ABC practices. This opposition stemmed from three distinct, though sometimes overlapping, concerns:

A. **Cultural and Spiritual Concerns:** Some interviewees perceived street dogs as integral to the urban landscape, describing them in terms of familiarity, protection, and even spiritual significance consistent with certain Hindu philosophical traditions emphasising care for all sentient beings. Sterilisation was experienced as interference with the natural order or even as cruelty.
   We live with and depend on them. They can sense evil spirits before anyone else.

   We feed these dogs as our moral and spiritual duty. God is watching. These voiceless beings have no one else. Their presence helps keep us safe and creates a positive environment.

   Every being has senses. They still carry memories from their past lives. Humans are the ones with corruption in their nature. Dogs live according to the laws of nature.

B. **Logistical and Practical Concerns:** Residents raised valid concerns about the feasibility of large-scale sterilisation implementation in densely populated Delhi: inconsistent capture and handling procedures, inadequate post-operative care and monitoring infrastructure, and the practical difficulties of identifying and tracking individual dogs across mobile, interconnected populations. The complexity of managing street dog populations in urban areas with constrained municipal resources made systematic ABC programmes appear unrealistic.
C. **Ethical and Welfare Concerns:** Interviewees engaged in sophisticated ethical debates about human responsibility and animal welfare, questioning whether large-scale surgical intervention—however well-intentioned—represented an appropriate response to urban coexistence challenges.

These discussions often foregrounded the agency and welfare of the dogs themselves, rather than framing them purely as problems to be managed. These objections collectively highlighted the intersection of human values, urban ecology, and animal welfare—a reality that standardised population control programmes systematically overlook.

Here, they do dog surgery and leave the dogs in a poor state. Who gives them right to take away dogs' reproductive rights? Most of them become abandoned like this, and this dog came here and started living around.

(iv) *Complex Lifeworlds: The Rohini Case*
A particularly illuminating case emerged from interviews with residents in the outskirts of Rohini, a northwestern Delhi suburb, revealing the complexity of simultaneous human attachments to and conflicts with dogs. One family described maintaining a deep emotional bond with their neighbourhood street dogs, caring for and provisioning them as integral members of their extended household. Paradoxically, these same residents experienced genuine predation threat: feral dogs, distinct from their familiar provisioned companions, occasionally preyed upon the calves and goats the family raised in their backyard.

We love our dogs that live with us (see, they have straps). They are like our children, and we lock them with our high breed livestock inside the shanty. But the wild ones that come at night and attack our animals—those are different. We do not know them. These feral ones kill our livestock, as well as our dogs.

Our interviews and field observations revealed striking temporal and behavioural differentiation between street dogs and feral dogs at this location. During nighttime hours, when darkness provided cover from human scrutiny and intervention, street dogs and feral dogs converged in overlapping spatial and social domains. Feral dogs appeared to integrate, however temporarily, into the communal social dynamics established by street dogs—participating in collective foraging and social interactions. However, during daylight hours, behavioural divergence became pronounced: feral dogs retreated to the fringes of human habitation, scavenging from garbage piles while notably abstaining from the affiliative interactions (tail-wagging, approach, vocalisation) typical of socialised street dogs. This temporal and behavioural differentiation suggests that feral and street dog populations, despite their genetic proximity, occupy fundamentally different ecological and social niches within the same urban space.

At night, you cannot tell our dogs and the wild dogs apart. They often mix looking for food. But in the morning, the wild ones run away while our dogs stay.

This case exemplifies a critical insight: human-dog coexistence in tropical cities is not a binary of "conflict" versus "coexistence," but rather a **complex, multiplex set of simultaneous relationships** ranging from deep affection and care to predation threat and economic loss. Individual humans maintain differentiated relationships with distinct dog populations (street vs. feral, known vs. unknown), and their responses to urban dog presence reflect these distinctions. Generic management approaches that homogenise all FRDs as "problem animals" requiring control fundamentally misrepresent the lived complexity of these urban worlds (Fig. 2).

The divergence continuum in behavioural repertoire of street and feral dogs showcases how ecological, physical and social boundaries mediate coexistence. While both shared the urban periphery environment, their interactions were fundamentally tempered by feral dogs' reduced dependence on human affiliation. As night fell, feral dogs retreated into darkness, establishing resting sites 200-300 meters from artificial light sources—a spatial choice reflecting their fundamentally different relationship to human niche. Feral dogs sought solace in darkness and distance, while street dogs remained proximate to human settlements and artificial illumination. The contrasting behavioural and ecological patterns of street and feral dogs underscore the negotiation of space, resources, and relationships, variably shaped from Delhi's core to its urban periphery.

(v) Toward Dynamic, Contextually Sensitive Understanding

These ethnographic findings collectively demonstrate that effective human-dog conflict mitigation requires abandoning simplistic, population-centric models in favour of approaches that centre the **dynamic ecology of daily human-dog interaction**. Understanding conflict requires attention to: (a) how recognition and familiarity mediate human responses to dogs; (b) how individual experiences generate behavioural feedback loops; (c) how cultural values shape acceptance of human intervention; (d) how spatial and temporal heterogeneity creates multiple, coexisting human-dog relationships; and (e) how marginalised communities bear disproportionate conflict costs while having minimal voice in management decisions. Only by honouring this complexity can urban planning and dog management move beyond reactive, often counterproductive interventions toward genuinely coexistent futures.

(vi) Urban Architecture as Ecological Constraint: The Unique Case of South Asian megacities

Delhi's dense, contiguous urban fabric creates a distinctive ecological matrix fundamentally shaping FRD behaviour and human-dog encounters. Unlike sprawling cities with fragmented development, or rural-urban peripheries with interspersed farmland and natural habitat, Delhi's architectural configuration—characterised by minimal/no gaps between residential structures and high building density—necessitates that street dogs rely almost exclusively on established roadways as primary nodes of movement, resource access, and shelter. Roads and streets function not merely as conduits but as **veritable territories and survival corridors**, shaping not only dog mobility patterns but determining access to critical resources: food derived from human interaction and urban refuse, suitable reproductive partners, and viable shelter zones. This reliance on road networks and constructed spaces invariably increases encounter frequency between urban canines and human pedestrians. The spatial coalescence of dogs and humans on Delhi's thoroughfares meets constant change in resource quality, quantity, predictability, and spatial distribution—becoming a crucible of selective pressures that likely shape dog behavioural responses (Fig. 2).

> *These three dogs stay here, near the Moti Nagar market dairy. They get food from there because people feed them things like paneer, and otherwise I also give them food.*

We learnt that some dogs approach and engage with pedestrians seeking food, while few chase and snatch food; others maintain distance or display defensive behaviours; still others appear largely indifferent to human passage. This behavioural heterogeneity reflects differential histories of positive, neutral, and negative encounters with humans—histories that are spatially structured by consistent feeding patterns, traffic intensity, and community attitudes.

(vi) The Architectural Choreography of Urban Coexistence

The unique structural configuration of Delhi's urban matrix fosters a multitude of distinctive scenarios in which **architecture, resources, and interspecies interaction sculpt the behavioural landscape** of FRD populations. The city's street dogs are simultaneously moulded by and actively mould this urban choreography: they navigate the constraints and possibilities imposed by Delhi's physical form while their movement patterns, territorial choices, and resource use reshape the social and ecological character of specific streets and neighbourhoods. The daily pursuit of survival, reproduction, and territoriality unfolds against the backdrop of continuous negotiation with human populations. This architectural-ecological coupling reveals that street dog behaviour cannot be understood through population-level metrics (density, pack size, sex ratio) alone (Fig. 2). Rather, these population patterns emerge from daily spatial negotiations within Delhi's specific urban form.

In *Moti Nagar* market street with shops, FRDs were visible after 10 pm, very aggressively defending their spots frequently associated with feeding trays. But the residential lanes with no shops had fewer dogs and they seemed calmer. In the absence of architectural features that disallowed FRDs to seek refuge, dogs sat atop cars. This social-ecological and architectural perspective reframes the "dog problem" from a question of animal behaviour or population control to a question of urban design, social-ethics and planning: *How do we design cities that facilitate multispecies coexistence rather than conflict*? *How can we reshape infrastructure, traffic patterns, cultural expressions and food systems to enable safer, more equitable encounters between humans and the canine populations that co-inhabit urban spaces*?

Fig. 2. Spatial and temporal dimensions of human-dog coexistence in Delhi. ***(Left)*** Free-ranging dogs provisioned near shops chase a scooter rider, demonstrating territorial aggression in feeding-concentrated zones. ***(Centre)*** A homeless person and street dog share pavement space, illustrating intimate cohabitation. ***(Right)*** Free-ranging dogs occupy road corridors during night hours when human/vehicular traffic subsides, creating navigation hazards for nocturnal commuters. These scenes reveal how coexistence is negotiated across spatial (commercial areas, pavements, roads), temporal (day/night), and socioeconomic gradients—demonstrating that human-dog relationships are dynamic, context-dependent interactions rather than fixed arrangements. Photos: Thinkpaws field research, Delhi 2023-2024.

Human-Macaque Coexistence case at Dr B R Ambedkar University Delhi

(i) *Ecological Context and Displacement Intervention*

AUD campus is situated within a landscape of long-term macaque occupancy, embedded in the historically macaque-saturated areas surrounding Kashmere Gate and Old Delhi Railway Station. This region, characterised by age-old markets, medieval architecture, dense commercial spaces, and numerous religious sites, has sustained rhesus macaque populations for decades or potentially centuries, providing consistent ecological and infrastructural resources. Prior to intervention, 148 ± 6 macaques (based on n = 5 independent counts using a double observer sampling method) occupied the AUD campus and immediately adjacent areas, utilising institutional buildings, green spaces, and a historic *Hanuman* temple where predictable religious provisioning occurred, including a feeding peak on Tuesdays and Saturdays (auspicious *Hanuman* days) (Fig. 3). In response to escalating human-macaque conflicts, approximately 50 individuals were captured using baited cage traps and translocated in eastern Delhi. Despite this substantial removal, macaque numbers returned to pre-intervention levels within one month, demonstrating rapid recolonisation driven by the campus's position within a broader, saturated macaque habitat matrix. The following ethnographic insights, derived from semi-structured interviews with 30 campus stakeholders (22 security guards, 5 faculty members, 3 administrative staff) conducted between September 2023 and December 2024, illuminate the human dimensions of this displacement intervention and the complex social negotiations underlying human-macaque coexistence (Fig. 3).

Fig. 3. Macaque foraging strategies and conflict contexts at Dr B R Ambedkar University Delhi. Rhesus macaques exploit dual food sources: direct human provisioning (centre-left) and waste accumulation (centre-right), with refuse providing persistent foraging opportunities reflecting inadequate sanitation infrastructure. Individuals forage on paved surfaces and building perimeters (left, right), demonstrating habituation to institutional architecture and high human-traffic zones. This resource predictability and architectural accessibility embolden macaques toward close human proximity, generating conflict scenarios particularly affecting spatially constrained outdoor workers. Photos: AUD campus, 2023-2024.

Differential Vulnerability: (Security Guards as Primary Conflict Victims) Security guards—occupying lower-wage, outdoor positions with limited autonomy over work location and timing—emerged as the stakeholder group experiencing the most frequent and severe negative encounters with macaques. Guards reported that macaque aggression was not random but rather **strategically targeted**. Macaques appeared to recognise and selectively approach guards when the latter were positioned in spatially constrained locations—narrow corridors between buildings, dead-end staircases, or isolated guard posts with limited escape routes/without sticks or catapult for self defense. In these contexts, guards described feeling cornered and vulnerable due to threat behaviours (open-mouth threats, lunging, vocalizations), and in some instances physical contact (grabbing, biting).

> *When I am alone at the back gate and the monkeys come, I have nowhere to go. They know this. The alpha male always comes when I am checking the narrow entrance. He knows I can't run from there.*

Faculty members, who spent most time in enclosed offices and had greater control over movement timing and routes, reported typically being attacked at specific locations. This differential vulnerability underscores how **occupational position and socioeconomic status mediate conflict risk**: those with least workplace autonomy and highest exposure to outdoor spaces bear disproportionate costs of macaque presence.

> *I see the monkeys from my office window, but they rarely bother me inside the buildings. When I need to leave, I just wait until they move away, or I call the guards for help.*

(ii). *Temporary Relief and Return to Baseline Conflict*
Interviewees consistently reported that the displacement intervention provided only **short-term, illusory relief** from human-macaque conflict. During the first 7-10 days following macaque removal, campus stakeholders noted a marked reduction in macaque presence and encounters. However, this relief proved ephemeral. Within 2-3 weeks, macaque numbers and encounter frequencies returned to pre-intervention levels. More troublingly, several respondents perceived that **macaque aggression either returned to baseline levels or intensified** following recolonisation. The perception of increased post-displacement aggression, whether objectively accurate or not, suggests a potential unintended consequence of displacement interventions. Recolonising macaques—potentially dispersers from neighbouring troops unfamiliar with campus human populations and resources—may exhibit different behavioural profiles than the displaced resident population. Alternatively, the disruption of established human-macaque recognition relationships through population turnover may have increased uncertainty on both sides, generating more frequent agonistic encounters as new macaques and resident humans renegotiated behavioural scripts for coexistence (Fig. 3).

(iii) *The Loss of Langurs and the Invention of "Monkey Chasers"*
Administrative staff interviews revealed a remarkable history of management approaches reflecting changing ecological realities and regulatory environments. Prior to 2012, AUD and surrounding institutions employed **live *Hanuman* langurs (*Semnopithecus* spp.)** as biological deterrents to macaque presence. Common langurs and rhesus macaques are sympatric species with complex competitive relationships: langurs, being larger-bodied and socially cohesive, can displace macaque troops through territorial defense and interspecific aggression. The practice of employing captive langurs to "chase" macaques from human spaces capitalised on this natural interspecific competitive dynamic.

> *In the early years at AUD, we had a langur with its keeper on campus. The macaques would disappear immediately when they heard/saw the langur. But it was discontinued in 2012.*

However, following legislative intervention by animal welfare organizations (notably PETA) around 2012, the use of captive langurs for macaque control was discontinued on ethical and welfare grounds. This regulatory change created a management vacuum: langurs had been effective deterrents, but their use was now legally or ethically untenable. In response, the Municipal Corporation of Delhi (MCD) developed an innovative, if somewhat absurd, alternative: trained "monkey chasers"—human workers trained to imitate *langur* physical appearance and/or vocalisations. This practice has been documented in a Bollywood movie, *Eb, Alley, Oo*, produced by Anurag Kashyap. These monkey chasers wore black costumes or carried props to simulate langur presence and produced vocal mimicry of langur alarm calls, attempting to trigger macaques' evolved competitive avoidance responses (Fig. 4).

Fig. 4. From sympatric competition to failed mimicry: The evolution of macaque management in Delhi. ***(Left)*** Common langur chasing rhesus macaque, illustrating natural interspecific competition that historically coexisted with macaque populations. Prior to 2012, institutions employed captive langurs as biological deterrents. ***(Right)*** Following ethical prohibition of langur use (PETA intervention, 2012), Municipal Corporation of Delhi introduced "monkey chasers"—trained workers imitating langur calls and appearance while pursuing macaques. This substitution fails because macaques distinguish genuine threats from human mimicry, quickly habituating to artificial deterrents. Delhi's regional langur extinction severed the ecological relationship management now attempts to replicate symbolically, demonstrating that effective coexistence requires actual ecological processes, not superficial imitation. *Photos: representative sympatric interaction; and MCD monkey chaser generated by ChatGPT, Delhi 2023.*

(iii) *Multispecies Coexistence, Ecological Memory, and Social Practice*

The langur-to-monkey-chaser transition exemplifies how **multispecies coexistence is negotiated through the intersection of ecology, regulation, ethics, and social practice**. The original langur-based deterrent relied on sympatric species interactions shaped by extended eco-evolutionary coexistence. When legal and ethical norms shifted to prohibit exploitation of captive langurs, urban management authorities attempted to replicate the ecological function (interspecific competition) through social performance (human mimicry). The effectiveness of this substitution has been questionable, which is beyond the scope of this manuscript. More broadly, this case illustrates the concept of **ecological memory** (Fig. 4): Delhi's urban landscape once supported both langurs and macaques in complex competitive coexistence. Langurs' regional extinction from wild habitats within Delhi (due to habitat loss, persecution, or other anthropogenic pressures) eliminated the ecological relationship that human management practices attempted to exploit. The fact that humans turned to imitating an absent species reflects both the historical effectiveness of interspecific competition as a natural macaque deterrent and the profound ecological disruption that has severed Delhi's current urban fauna from its historical species assemblages (Fig. 4).

5. Discussion: *Negotiating Multispecies Coexistence Across Scales*

From Static Management to Dynamic Negotiation

Integrated analysis of ground-dwelling (dogs) and arboreal (macaques), and prior work of Kumar et al. (2019 and 2025) for aerial (black kites) urban commensals reveals that multispecies coexistence in tropical cities is not a fixed state but an **ongoing, multiscale negotiation** constantly recalibrated across biological, social, spatial, and temporal dimensions. Our findings fundamentally challenge conventional urban wildlife management (Fall & Jackson, 2002; Fehlmann et al., 2021a), which treats human-animal conflicts as discrete problems amenable to species-specific technical solutions—culling, displacement, or deterrence (Allen et al., 2023; Reese, 2005; Srinivasan, 2013). Instead, our results demonstrate that coexistence emerges from the dynamic interplay between anthropogenic resource provisioning, cultural practices, architectural form, and the remarkable adaptive capacities of urban-adapted species.

The quantitative and ethnographic data we presented converge on a critical insight: **urban animals are not passive recipients of human-imposed environments but active participants reshaping urban social-ecological systems—***the relational aspect of people and nature* (Derham & Mathews, 2020; Dhee et al., 2019). FRDs compressed territorial requirements in response to concentrated feeding infrastructure, reorganising pack structure and spatial distribution around predictable human provisioning rather than incidental waste (Jackson et al., 2017; Wilcox et al., 2021). Macaques recolonised AUD within one month following displacement, demonstrating that removal interventions fail when underlying ecological attractants—religious provisioning, architectural accessibility of institutional buildings—remain unchanged (Evans & Gawlik, 2020; Oro et al., 2013; Tella et al., 2020; West & Jones, 2022). This case profoundly illustrates the current confusion over FRD management, following the Indian Supreme Court directives in August 2025 (Supreme Court of India, 2025). Black kites, as documented in long-term research in Delhi (Kumar et al., 2019c; Gupta & Kumar, 2024), similarly calibrate nesting and foraging behaviours to ritual feeding patterns and landfill resource pulses, achieving densities inextricably tied to human cultural practices. Kumar et al., in association with the Indian Air Force and the Department of Forest and Wildlife, Government of NCT of Delhi incorporated the longitudinal research insights for mitigating birdstrike threats posed by black kite flocks on the ceremonial path on which aircraft fly to salute the chief guest on India's Republic Day (26^{th} January, every year) (Republic Day, 2024)

Cultural Practices as Ecological Infrastructure

A distinguishing feature of tropical South Asian urbanism is the entanglement of religious and cultural practices with urban ecology (Gupta & Kumar, 2024; Kumar et al., 2019). Our findings demonstrate that **ritual feeding functions not merely as resource provisioning but as ecological infrastructure** shaping population dynamics, spatial distributions, and behavioural repertoires across taxonomic guilds. Each square kilometre of Delhi contained 218 ± 51 feeding stations alongside 57 ± 16 garbage points, creating a dual-subsidy system with combined carrying capacity approaching 1.6 million dogs—double the current estimated population of ~795,000. This substantial surplus capacity suggests that dog populations could increase further if not constrained by ABC, density-dependent, social, and disease-mediated factors under existing access to food-subsidies. For instance, over the last 25 years, Delhi has seen a simultaneous increase—in tune of 200-300%—to its built-space, people, FRD and vehicular densities, and its per-capita income and solid waste production (Government of India, 2024; Kumar et al., 2017; Livestock Census of India, 2019; Paul & Nagendra, 2015; Shukla, 2025; UNO, 2018). The escalating FRD population, coupled with the saturation of urban environments by both biotic and abiotic factors, subjects dogs to numerous selective pressures, frequently creating tension between their behavioural and population dynamics in the wake of changing urban social profiles (Anderies et al., 2007; Doebeli et al., 2021; Ross et al., 1993; Wong & Candolin, 2015).

Similarly, the macaque population in around AUD, and black kite aggregations at ritual feeding (mosques) and waste sites (Kumar et al., 2019b) demonstrate temporal synchronisation with religious provisioning schedules. Macaques concentrated activity at *Hanuman* temple and other ritual feeding sites, tracking heightened provisioning during Tuesday/Saturday worship, while black kites modulated foraging around predictable refuse availability and cultural tolerance for avian scavengers on hours and periods of Muslim worship (Gupta & Kumar, 2024). These patterns reveal that **cultural practices create temporal and spatial resource pulses that animals exploit through learned, socially-transmitted behaviours**—a form of co-cultural niche construction operating bidirectionally across species boundaries, and in tandem with human agencies (Broekhuis et al., 2021; Holt, 2008; Sueur & Huffman, 2024).

Our ethnographic data reveal ambivalence and internal contradiction within communities regarding these practices. Interviewees simultaneously expressed spiritual obligation to feed animals, concerns about population increases and conflict risks, and ethical discomfort with interventions like sterilisation, translocation and mass relocation. This cultural complexity defies simplistic management prescriptions and underscores that **coexistence is negotiated not only between humans and animals but within human communities holding divergent values and interests** (Almada, 2011; Baker et al., 2014; Beumer & Martens, 2015; Cavé, 2014).

Socioeconomic Gradients and Environmental Justice

Our research illuminates how multispecies coexistence is mediated by socioeconomic position and infrastructural inequality (Jordan et al., 2020). Wealthier neighbourhoods with efficient waste management concentrated feeding infrastructure while minimising garbage, whereas lower-income areas exhibited inverse patterns—high garbage availability but fewer organised feeding structures (Cavé, 2014; Kumar et al., 2019c; Kumar et al., 2017). This spatial heterogeneity means that **marginalised communities bear disproportionate conflict costs**: lower-income residents, outdoor workers (security guards), waste collectors, and children experience higher exposure to human-animal conflicts while possessing minimal political agency to shape management interventions.

The AUD case exemplifies this dynamic: security guards—occupying precarious, low-wage positions with limited workplace autonomy—reported targeted macaque aggression in spatially constrained locations (narrow corridors, isolated guard posts), while faculty members with greater mobility and indoor workspaces experienced substantially fewer negative encounters. Similarly, elderly residents avoiding dog-occupied spaces due to perceived bite risk, and ragpickers navigating unfamiliar street dog territories during waste collection, illustrate how **occupational position and mobility constraints structure vulnerability to human-animal conflict** (Braczkowski et al., 2023; John et al., 2021; Thangaraj et al., 2025).

These patterns converge with policy frameworks that systematically exclude multispecies considerations. Delhi Development Authority slum rehabilitation schemes plan to relocate 376 slum (*jhuggi-jhopri*) clusters without provisions for dependent/connected animal populations—dogs with established territories, macaques utilising human-modified habitats, aerial scavengers dependent on refuse piles (Dupont & Gowda, 2020; Gowda, 2021; Gupta & Gupta, 2017). Such policy blindness generates cascading ecological disruptions: abandoned animals likely face(d) territorial displacement, potentially increasing aggression and conflict in receiving areas, while relocated human communities and host neighbourhoods both experience elevated human-animal tensions (Galbreath et al., 2014; Silk et al., 2019). **Environmental justice in urban contexts thus requires recognising animals as constituents whose well-being and spatial claims must inform planning processes**, rather than treating them as externalities to be managed reactively (Amin, 2013; Angel et al., 2011; Barua, 2014).

The Cognitive Sophistication of Urban-Adapted Species

Our macaque deterrent vignettes and dog behavioural observations reveal the remarkable **cognitive flexibility enabling animals to navigate complex urban environments** (Albuquerque et al., 2016; Benítez et al., 2022). Macaques mostly ignored langur visual cutouts placed at strategic locations in G20 meetings during the month of September 2023—demonstrating semantic learning for context-dependent threat assessment that distinguishes genuine dangers from artificial deterrents (Santini et al., 2019). Similarly, FRDs demonstrated strategic space use: they occupied refugia beneath vehicles and in building alcoves to avoid high-traffic zones, selectively activated territorial aggression in feeding-provisioned areas while exhibiting evasion behaviours elsewhere and maintained differentiated relationships with familiar provisioners versus unfamiliar transient humans. The temporal and behavioural partitioning between street dogs (human-focused, daytime active, affiliative) and feral dogs (garbage-focused, nocturnal, avoidant yet convergent with street dogs at night) further illustrates **niche differentiation emerging from learned behavioural repertoires** rather than fixed species-typical patterns (Bhattacharjee et al., 2018, 2018; Bhattacharjee & Bhadra, 2022; Majumder et al., 2014; Majumder et al., 2014).

Likewise, black kites have been studied for exhibiting analogous sophistication, adjusting nesting site selection and foraging schedules in response to human activity patterns and cultural beliefs (Kumar et al., 2018a; Gupta & Kumar, 2024), even defending offspring against perceived human threats near ritual feeding sites (Kumar et al., 2018b). This behavioural flexibility across taxonomic groups—mammals and birds, terrestrial and aerial—suggests that **cognitive adaptability, in association with specific morphological or physiological traits, may be the primary prerequisite for thriving in urban environments** (Francis & Chadwick, 2012; Sciences et al., 2011). This has profound implications: if urban animals are learning, adjusting, and culturally transmitting novel behaviours, then static management interventions will consistently fail as populations adapt and habituate (Bhattacharjee & Bhadra, 2020; Chimento & Farine, 2024; D’Aniello et al., 2018).

Architectural Form as Ecological Constraint and Possibility

Delhi's dense, contiguous urban fabric—characterised by minimal gaps between structures and high building density—creates distinctive ecological constraints fundamentally shaping animal behaviour and human-animal encounters (DDA, 2017; Dupont & Gowda, 2020). For FRDs, roads function as veritable territories and survival corridors, concentrating movement and resource access in ways that increase encounter frequency with humans. For macaques, institutional buildings provide three-dimensional habitat—rooftops for refuge, ledges for thermoregulation, interior spaces for foraging—replicating the vertical structure of natural forest habitats. For black kites, trees, building architecture and pylons offer nesting/roosting sites proximate to landfill and other foraging zones, enabling high breeding densities despite limited natural nesting habitat (Kumar et al., 2018a; Nagendra et al., 2014; Paul & Nagendra, 2015).

This architectural-ecological coupling reveals that **urban form is not a neutral backdrop but an active participant in structuring multispecies assemblages**. The medieval and colonial-era architecture around Kashmere Gate and Old Delhi—featuring two or three-story structures, accessible roofs, and interconnected building complexes—has sustained macaque populations for decades or centuries precisely because it provides functional habitat analogues. Modern institutional buildings at AUD, despite contemporary design, are linked with conserved aspects of key architectural features and thus proved immediately suitable for macaque occupation (Baviskar, 2020; Ganguly et al., 2018; Gupta, 1981).

Our findings thus reframe urban planning questions: rather than *how do we exclude animals from human spaces?* the relevant question becomes *how can we design urban forms that enable safer, more equitable multispecies coexistence?* This might involve: architectural features reducing dangerous human-animal encounters (e.g., enclosed corridors minimising dogs and macaques cornering of vulnerable people); waste management infrastructure preventing resource concentration that draws high animal densities into vulnerable human communities; and green space design facilitating movement corridors that reduce reliance on roads as primary territories (Amin, 2013; Angel et al., 2011; Barua, 2023; Bobiec et al., 2021; Dupont & Gowda, 2020; Hinchliffe et al., 2005; Lim & Sodhi, 2004; Narayanan, 2017; Philo, 1995).

The Failure of Reactive, and Isolated Species-Specific Interventions

The rapid macaque recolonisation at AUD (full recovery within one month despite 31% population removal), the persistence of dog populations at ~50% of food subsidy carrying capacity despite ABC programmes, and the ineffectiveness of acoustic deterrents against habituated macaques collectively demonstrate that **reactive, species-focused management interventions fail because they address symptoms rather than underlying social-ecological drivers** (Dickman, 2010b; Ganguly et al., 2018; Priston & McLennan, 2013). For instance, based on the field observations, we suggest that human-canine conflicts can be easily assessed by examining the time budget of dogs in the area, concerning the human and vehicular traffic on the streets and the extent of direct feeding to, and by, specific individuals (Cunha Silva et al., 2025).

Displacement removes individual animals but not the ecological attractants—food provisioning, architectural accessibility, territorial vacuums—that drew them initially (Reese, 2005). Sterilisation reduces reproductive potential but not the immigration pressure from surrounding saturated populations or the anthropogenic resource base sustaining high densities. Acoustic/visual deterrents attempt to trigger evolved anti-predator responses in contexts where animals have learned such threats are absent (Pérez-Espinosa et al., 2018). Each intervention operates under a flawed premise: that animal populations can be controlled through direct manipulation while leaving the human practices and infrastructural conditions generating conflicts unchanged (Fehlmann et al., 2021b; Hunold & Mazuchowski, 2020; Nyhus, 2016).

Our data suggest alternative intervention logic: **modify the social-ecological conditions structuring human-animal interfaces** rather than attempting to control animal populations directly (Aiyedun & Olugasa, 2012; Gompper & Gompper, 2013). For FRDs, this means regulating feeding practices and waste management systems (the primary drivers of pack density and territorial compression) rather than focusing exclusively on sterilisation. For macaques, this requires restricting religious provisioning at temples or redesigning architectural accessibility rather than repeated costly displacement efforts (Ganguly et al., 2018). For black kites, this involves managing landfill operations and co-opting/controlling ritual feeding that determine population densities rather than tolerating nuisance until crisis interventions become necessary (Kumar, 2023; Republic Day, 2024).

Overall, such approaches require acknowledging that **human behaviour and cultural practices are the modifiable variables, which eventually mediate animal behaviour** (Kumar et al., 2018a; 2019a). Animals respond adaptively and predictably to resource availability, habitat structure, and human actions. Lasting coexistence requires humans adjusting practices, infrastructure, and spatial arrangements to reduce conflict-generating conditions—a fundamentally different intervention philosophy than attempting to modify animal populations to fit existing human practices (Barua, 2023; Bhalla et al., 2021; Hinchliffe & Whatmore, 2006).

Limitations and Future Directions

Our study has important limitations. The modest sample size (n=14 dog sampling units, single macaque displacement case) requires cautious interpretation and validation through independent replication. The correlation-based findings for dogs, while paired with qualitative ethnography, cannot establish causation. The macaque population monitoring documented recolonisation but did not track individual animals to assess translocation outcomes for displaced individuals—an ethical concern requiring attention (Ganguly et al., 2018). Our focus on Delhi limits generalisability; comparative research across tropical cities with different cultural, infrastructural, and ecological contexts would strengthen understanding of how specific local conditions shape coexistence dynamics (Barua, 2023; Gupta & Kumar, 2024).

Future research should, therefore: *(1)* employ longitudinal monitoring to assess whether dog populations approach the estimated 1.6 million carrying capacity or remain regulated by non-food factors that regulate access to resources (Carricondo-Sanchez et al., 2019); *(2)* conduct experimental manipulations of feeding infrastructure and waste management to test causal relationships (Kumar et al., 2019b); *(3)* track individual macaque fates post-displacement to assess welfare outcomes and dispersal patterns (Govindrajan, 2015); *(4)* investigate disease ecology at human-animal interfaces, particularly zoonotic pathogen transmission in high-density contact zones (Bradley & Altizer, 2007); *(5)* develop participatory action research engaging marginalised communities (security guards, waste workers, blue collared workers, slum residents) as co-researchers and decision-makers in designing equitable coexistence interventions (Anonymous, 2023; Dupont & Gowda, 2020; Gowda, 2021); and *(6)* extend analysis to other urban-adapted taxa (rats, mongooses, pigs, cattle, pigeons, crows) to assess whether patterns documented here generalise across mammalian and avian commensals (Barua, 2023; Doron, 2021).

Toward Predictive, Culturally Informed Urban Ecology

The convergent findings across dogs, macaques, and black kites illuminate pathways toward **predictive, culturally informed management frameworks** capable of anticipating rather than reacting to human-animal conflicts. By understanding: *(1)* how anthropogenic resource subsidies (feeding practices, waste systems) structure population dynamics, *(2)* how architectural form constrains or enables animal space use, *(3)* how cultural practices create temporal resource pulses, and *(4)* how socioeconomic inequality mediates conflict vulnerability, urban planners and wildlife managers can identify intervention points likely to generate lasting coexistence improvements.

This requires moving beyond the disciplinary silos fragmenting current approaches—wildlife biology treating animals as behavioural problems, urban planning treating animals as externalities, public health treating animals as disease vectors, and cultural studies treating animals as symbols (Allen et al., 2017). **Multispecies coexistence demands integrated social-ecological frameworks** recognising that urban ecosystems are co-produced by human practices, animal behaviours, infrastructural forms, and cultural meanings operating across multiple scales (Alberti, 2008; Lin et al., 2021).

The alternative—continuing reactive, species-specific interventions—leads toward the dystopian 2030 scenario depicted in our opening narrative: escalating cycles of conflict, poisoning, culling, and counter-protection that serve neither human welfare nor animal wellbeing. Our research demonstrates that this trajectory is not inevitable. By cantering dynamic negotiation, cultural specificity, environmental justice, and architectural-ecological coupling in urban planning, tropical cities can move toward the "poetry of coexistence" rather than the "fragmented prose of conflicts"—fostering thriving multispecies metropolises that honour the legitimate claims and needs of all urban residents, human and non-human alike.

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Ethical Statement

The ethical approval for dog counting was via permit number 2023/ER/Canine Conumdrms/01, validity: 29.094.2023 to 31.12.2027. Since this counting was non-invasive and free-ranging dogs are not under the Wildlife Protection Act, no specific permission from the Department of Forest and Wildlife, Government of NCT of Delhi was required. The non-invasive observation and counting of macaques were under the ethical approval to execute the research funded by Dr B R Ambedkar University Delhi (SMGFR-IV), benefitting from the translocation drive conducted by the Municipal Corporation of Delhi in September 2023.

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