Urban Waste and the Human–Animal Interface in Delhi

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It is well-documented that urban waste contributes to the economy by creating livelihoods. Less is known, however, about the role of urban waste in producing human–animal ecologies involving livestock and wild birds. Here, four aspects of human–animal relationships in two urban subsystems involving waste as raw material for both stall-fed livestock (focusing on cows) and foragers (focusing on kites) are discussed. These are the roles of waste as feed, complex spatial relationships between animals, humans and their wastes, high densities of animals and humans leading to conflict over waste, and emerging threats of diseases spilling across social and physical barriers between animals and humans mediated by waste, with implications for the health of urbanised living beings.

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In developing tropical countries, rapid urbanisation, often involving in-migration, has created megacities marked by social and economic heterogeneity (UN 2018). Despite the rapid expansion in research on tropical megacities (reviewed in Niemelä et al 2011), four aspects of urban waste have received limited attention.

First, that waste feeds animals. Urban economic expansion is associated with a rise in the per capita consumption of animal products, especially meat and milk (Pica-Ciamarra 2005; Speedy 2003). Demand for milk has transformed India from a state of acute shortage to being the world's leading milk producer (FAO 2009, 2019). This dietary transition has generated livelihoods for livestock owners in cities, many of whom use urban food waste from domestic and commercial sources as animal feed for their backyard cows and other urban livestock (Narayanan 2019). This is a valuable subsidy to dairy owners in cities and towns. In the process, they also ensure the relatively safe disposal of some urban food waste (Salemdeeb et al 2017). Edible waste in roadside garbage dumps provides food for urban livestock, primarily cows, and other urban animals (Kumar et al 2018a).

Second, the production of edible waste and the distribution of urban animals interact in complex ways in the urban space. Waste gatherers living in informal settlements collect, segregate, and recycle the contents of urban garbage piles containing consumption waste from humans mixed with waste from animals (da Silva et al 2005; Harriss-White 2019; Hayami et al 2006). Gatherers routinely work alongside cows, dogs, and pigs, as well as crows and kites. How can these relationships be characterised? The question whether the responses of human and animal scavengers working simultaneously on garbage piles create systematic trans-species relationships—known as guilds—is work in progress (O'Connor 2000). The forms and functions of guilds developing over urban feed and foraging resources affect cultural constructions of animal co-inhabitants among citizens as well as fine-grained behavioural adaptations by animals to the heterogeneous social environments of cities (Kumar et al 2018b).

Third, rapid changes in urban physical structure, modes of garbage creation and disposal, and the scope and range of urban domestic animal rearing have been accompanied by conflicts. Increasing numbers of undomesticated species have adapted to changing urban environments. Termed as opportunistic species in zoology, a subset has seized opportunities, such as nesting and feeding sites, in response to the patronage practices of people who also contribute edible waste. As a direct and indirect result, kites, dogs, rhesus macaques, rats, and some cattle have proliferated to become "social nuisances" threatening the livelihoods and well-being of urban people, particularly waste gatherers and residents of informal settlements (Baviskar 2011; Kennedy et al 2018).

High population densities of animals and humans lead to conflicting interactions. Waste figures in these cross-species and multispecies conflicts because it supplies food for animals that compete for territory and themselves contribute to waste. The spatial mosaic of human activity in city streets, along with cultural practices of ritual feeding of animals by humans, and the varied standards of management of human and animal waste combine to surface in

aggressive and fearful cross-species encounters (Kumar et al 2018a, 2018b, 2019b)

Fourth, progressively tighter human–animal encounters lead to the spillage of diseases across species (called zoonosis) caused by generalist pathogens shared between multiple hosts and sometimes mediated through the impact of waste around which humans and domestic and feral animals meet, for example, rabies, tuberculosis, leishmaniasis, leptospirosis, echinococcosis, and cysticercosis (WHO 2019). India is thought to have the highest burden of zoonotic threats, concentrated in urban villages and unauthorised settlements where human and animal waste is noticeably accumulated and where livestock is reared in damp, cramped environments (Delia Grace et al 2012). However, this role of waste in zoonosis has not yet been much researched for its health effects on tropical urban humans or animals.

Using evidence for Black Kites, researched and monitored since 2012, together with research carried out between 2017 and 2019 on urban cows and commensal animal species in informal human settlements comprised of *jhuggi-jhopdi* and squatter colonies in Delhi, we contribute to the four research gaps by (i) evaluating the role of waste as livestock-feed, (ii) exploring the relationships of humans and animals to complex and differentiated built and social environments, (iii) assessing human–animal conflicts over waste, and (iv) outlining the importance of zoonotic relations mediated through waste.

Methodology

In the last census, the National Capital Territory of Delhi (NCT) had more than 16 million inhabitants and the region was associated with highest per capita production of solid waste in India (CoI 2011). The national capital's growth has engulfed surrounding villages, incorporated informal settlements of immigrants, and extended to satellite towns, creating a continuous urban sprawl, which came under the purview of the NCT in 1992. Delhi also has the largest city-based animal population (GoI 2017), including (i) at least 60,000 cows mostly reared in urban villages and informal settlements, (ii) semi-domestic or feral animals such as stray dogs (estimated at over 1,90,000), and (iii) wild creatures such as Black Kites (about 28,000 resident breeding pairs and 10,000 birds of the migratory *lineatus* race at the Ghazipur landfill alone) and a substantial population of Rhesus Macaques (whose population census is currently being conducted by the Wildlife Institute of India) (Joshi 2019a, 2019b).

From the original insight that sets of cities form systems in terms of interconnected relations of population, economy, and space (Berry 1964), the concept of system has also been found useful to trace complex material and social relations within cities (Fistola and La Rocca 2013; Petit-Boix et al 2017). These intra-city relations have been framed as subsystems by geographers (Rose 1970; Simmons 1981). And, just as ecosystems in cities are now recognised for

their unique configurations, so are ecological subsystems, of which urban waste and decomposition form one open component of a larger urban complex. Waste subsystems and their human–animal relations can be explored in Delhi.

Three aspects of Delhi have significant implications for its waste subsystems. First, systems of solid waste disposal in the city create informal livelihoods in manual garbage segregation (closely interacting with opportunistic urban animals) while leaving edible organic refuse available for semi-stallfed cows and feral animal scavengers. Delhi's network of garbage piles of various sizes and contents, its informal human settlements of precariously poor people, and its great range of animal communities are thought to give the capital a representative character in terms of Indian urbanisation. As in the rest of the country, cows have recently become the objects of resurgent religiously and politically motivated veneration. This is adding to material and social pressures at the tight human–animal interface that we discuss below.

Second, human consumption generates subsystems of animal waste. Despite its relatively small size, the NCT ranks among the top regions of the country for the consumption of animal products, reflecting the city's per capita income, which is three times the national average (GoI 2017; MoF 2018). Over and above the supplies from suburban and rural sites and organised milk cooperatives (MoI 2012), in recent decades, the long-established practice of rearing cows in sheds and backyards has expanded in Delhi. Over 90% of the city's livestock is housed in former villages, now included in the NCT, to such an extent that these suburbs have the highest livestock density in the country, and thus a high level of livestock waste (MoI 2012).

Third, even as volumes of general unsegregated waste, animal remains, and excreta have increased, waste spaces are constrained and the lack of suitable new places for garbage disposal generates conflicts of management. Considering the likelihood of further disruptions to animal communities and ecosystem functions, permission for new landfill sites has been denied in ecologically sensitive zones such as the floodplains of the Yamuna and sites in protected urban sanctuaries and green belts (SCS Engineers and Abt Associates 2017). In waste management, civic bodies of the capital also experience conflicts of interest and jurisdiction: the Delhi Development Authority, which makes the city's Master Plan every 20 years including spaces for waste; municipal corporations, which are responsible for garbage collection as well as spaces for dumping (Talyan et al 2008); the forest department of the Government of NCT, which is constantly addressing encroachment by unauthorised dumpers of waste, and animal welfare organisations defending the rights of animals. Litigation by animal welfare activists has resulted in court judgments forcing cattle-rearing to shift to villages on the urban periphery and the decommissioning of abattoirs and dairies on the grounds of animal cruelty.

However, the failure to find new sites has meant that all three of Delhi's landfills continue to function more than a decade after court orders for their decommissioning were passed.

Our arguments are based on two Delhi research initiatives on Black Kites, a prominent avian scavenger, opportunistically responding to the food afforded by unsegregated garbage in the city (Kumar et al 2014, 2018a, 2018b, 2019a). In Delhi, such foraging opportunities support a density of Black Kites that is the highest concentration of a raptor recorded in the world. Over the period 2013–19, kite behaviour has been monitored comprehensively at 30 sampling plots of approximately 1 km^2 representing conditions ranging from semi-natural to extremely built-up (Kumar et al 2014). Modelling individual-level breeding habitat preferences, and testing for their extrapolation to population-level effects, this research has investigated the effects on bird behaviour of urban landscape structure, human population density, and human practices, including those of waste management (Kumar et al 2018b). Then, from 2017 to 2019, preliminary studies were carried out at the same 30 sampling units on the processing of waste, combining economic, sociological, and ecological perspectives. This has generated insights about the ways in which waste supplies food for feral, opportunistic, and domesticated animals, particularly cattle.

Edible Waste in the Feed Subsystem

In Delhi, in the high-density areas we sampled, residents deposit their household or commercial waste directly on roadsides. This attracts rodents and pigeons that are potential prey for animal predators (Kumar et al 2014). Semi-structured interviews with 10 randomly selected local residents in the sample sites (Kumar et al 2018a) about garbage collection from local dumps by the municipal corporations confirmed our direct observations that the types, numbers, and guild structure of commensals foraging on accumulated garbage are systematically and spatially patterned. Older and newer settlements in Delhi differ considerably in their human and animal densities, their waste-generation practices, and their public sanitation and hygiene. At a micro-level, edible refuse consumed by birds is found to be associated with the width of streets, their human traffic, and the density of overhead electric wires that can prevent them from landing on garbage piles (Kumar et al 2018b). Spatial subsystems in which dumped edible waste is gathered for animal rearing or left in situ for foraging are illustrated here, first for cows and second for kites.

In Delhi, a substantial part of livestock keeping is not registered or regulated by the state. Most cows maintained in backyards are of robust, disease-resistant, native stock with lower daily milk yields and shorter and fewer lactation cycles than the high-yielding cross-breeds characteristic of intensive dairying. Their stock is replenished from the surrounding National Capital Region. The

slaughter of cattle for meat creates carcass waste that forms a major component of meat currently offered to kites. Whereas in villages and small towns, dung from milch cattle is used as fuel or manure, in Delhi, it is either left dispersed in the streets or swept into open drains, adding to Delhi's waste. Decomposing dung is a source of harmful pathogens, greenhouse gases, and noxious odour (Chaudhuri 2015; FAO 2009; Sorathiya et al 2014).

Well-established suburban colonies, for example, slums and the older Muslim-dominated neighbourhoods in east Delhi, may have poor sanitation (Dubochet 2019). After waste collectors have retrieved recyclable material that they can sell from the neighbourhood garbage dumps, waste goes to one of Delhi's three landfills. Municipal officials at the landfill offices explained in interviews that each of the three landfills daily receive about 500 five-tonne truckloads of mixed garbage, much of it potentially edible to animals. The largest is at Ghazipur and covers an area of 70 acres, standing 65 metres high, just 7 metres shy of the heights of the Taj Mahal and Qutub Minar. Commissioned in 1984, this landfill is adjacent to Ghazipur Dairy, Delhi's largest cattle abattoir, and to markets for fish and chicken, and fruit and vegetables (Talyan et al 2008). The migratory populations of Black Kites from Central Asia circle and feed around this complex of the landfill, slaughterhouses, and markets.

Despite the abundance of edible waste, trail cameras fixed on nests revealed that ~90% of the diet of breeding kites consisted of ritual offerings (Kumar et al 2019a). Meat thrown to kites, typically outside local mosques to request blessings, comes from cattle viscera or other slaughterhouse offal supplied by meat shops (of which there are relatively high concentrations in Muslim-dominated neighbourhoods) and informal markets. Such expressions of respect and love for animals mediate physical flows and livelihoods not just in offal for kites, but also in waste meat, fruits, and grains for cows, dogs, macaques, and other animals (Gupta 2016).

Waste, Coexistence and Conflicts between Species

In Delhi, many birds, mammals and insects co-produce and co-consume garbage systems in which the usefulness of edible waste varies by composition and site. Places generating food waste most suitable for animal feed are often separated from the urban villages where animals are reared. Meanwhile, roadside garbage tips and municipal garbage sites are common sites for foraging cows owned—but not stall-fed—by urban producers. In fact, the consumption of edible waste by cattle reduces the costs of milk and meat production, since edible waste compensates for the nutrient deficiencies of the low-quality fodder poor urban cattle-keepers can afford (FAO 2019). Many other animals forage. According to one estimate (Kumar et al 2019b), Delhi's kites annually remove about 4,000 tonnes of edible refuse from its streets and landfills.

In the biodiverse eco-subsystems of Delhi, human–animal ritual feeding sites and practices sustain human, wildlife, feral, and semi-domestic animals at unprecedented breeding densities. Their coexistence and conflicts have been poorly studied from socioecological perspectives (Gupta 2016). People's innate love for living creatures, termed biophilia, often takes the form of religious beliefs wherein animals are forms, vehicles, or messengers of god (Kumar et al 2019a; Pinault 2008; Taneja 2015). Even in conditions where kites are aggressive, both Muslims and Hindus were found to revere kites. Muslims regard them as embodying sacred qualities, given their role of "winged emissaries," which take flight bearing sins, worries, or prayers-messages symbolised by the meat offered during ritual-feeding. Many Hindus believe that life forms are interconnected to one ultimate god-form and so tolerate nuisance from animal species, considering them holy beings or even solutions to astrological problems. Many Delhi residents are also sympathetic towards aggressive co-inhabiting animals because of empathy derived from animals' parenting behaviour and from the realisation that urbanisation has destroyed and degraded the natural habitats of wildlife. Urban residents were found to be well aware of the useful "ecosystem services" provided to their neighbourhood by kites and other animals which consume waste (Kumar et al 2019b).

Attacks on humans by defensive nesting kites were associated with places of ritual-feeding of kites, and with the prevalence of piles of edible waste, which make kites bold and fearless; almost inevitable where human and animal populations both exist at high densities (Kumar et al 2019a, 2019b).[1] In this "entangled urbanism" (Srivastava 2014), aerial/arboreal/ground dwelling animal life-forms enable a range of species, with varying capacities for dispersal, either to indulge in conflicts due to competition over limited resources, or to coexist via niche-segregation in systems dominated by humans. Such urban ecological niches raise the probability of zoonotic transfers.

Waste and Disease Threats

Microbiological pathogens are propagated through urban vectors associated with waste sites. Carcasses are one such site. The loss of the keystone species of vultures from the Indian subcontinent has severely altered the urban food webs and dispersion of carcasses, animal remains, and excreta. Whereas livestock carcasses used to form the main food for vultures, now they are inefficiently consumed by urban commensals such as dogs, rats, crows, and kites. Since dogs are understood to be the main source of rabies in humans in India, the considerable increase in their populations in wake of the decline in vultures has heightened the threat of rabies (Dhavala et al 2008). Politically motivated reverence for cows now discourages sanitation workers who supply cattle-hide traders with skins from taking the sociopolitical risks involved in preparing cattle carcasses, leaving them increasingly for foragers such as dogs.

In megacities like Delhi, the change in inter-species relations from coexistence to aggressive confrontation stems from population-resource dynamics, which raise the probability of zoonotic transfers. Coexisting species need to negotiate trade-offs between foraging benefits and the perception of threats from humans from other animals and inanimate sources (such as power lines and traffic) (Hulme-Beaman et al 2016; Kumar et al 2019b; Lloyd-Smith et al 2005). In the absence of all but preliminary research quantifying animal responses to (i) the effects of habitat destruction on species and ecosystems, and (ii) urban concentrations of humans and garbage containing feed for animals, questions about physical conflicts and animal-borne disease at the microbial human–animal interface need urgent answers (Ellis 2019; GoI 2016; Lloyd-Smith et al 2009). Rabies, for instance, is a major concern in Delhi, with over 200 dog bites reported in the capital daily (Singh 2017). Disproportionally higher conflicts have been noted in North and East Delhi, the parts of the capital known to have the lowest standards of solid waste management, including those for edible waste (*Hindustan Times* 2015; Lai et al 2005). Delhi also ranks among the top states in India for deaths due to H1N1 swine flu transferred to humans from backyard pigs fed with food-waste; the threat of zoonotic transfers increases at higher population densities. Increasing incidents of bovine tuberculosis are also a concern (GoI 2016). Many other health consequences of the human–animal interface remain poorly researched or unknown (GoI 2016). Although there have been no detailed studies conducted to evaluate livestock losses from rabies in India, dog-bites and consequent transfer of infection have been reported in almost all domesticated species (Dar et al 2014; Tiwari et al 2019).

Feral ecologies have been the subject of a number of state intervention programmes in Delhi and other megacities, including the drive to control rabies by neutering of street or stray dogs (Kumar 2014). Macaques, for example, have been captured and relocated to the outskirts of the city or sanctuaries, largely driven by the conflicts they create when they attack people and raid homes (*Down to Earth* 2015). These go hand-in-hand with the government's periodic attempts to "improve" and relocate informal settlements, abattoirs, and landfill sites, but with no records on the impacts of these interventions on the spatial and behavioural ecology of many commensal scavengers. When animal populations and human–animal relations are disrupted without consideration for co-inhabiting domestic animals/commensals, the host–pathogen equilibrium in a local subsystem is also likely to be disrupted. Commensals venturing into new areas in response to alterations in the dispersion of human food waste will alter the spatial distribution of zoonotic transfers taking place through physical conflicts mediated by commensal vectors. Hence, current gentrification drives aimed at improving health and hygiene in a city so heterogeneously developed suggest a paradox of heightened zoonotic threats in the environs of the

gentrified areas wherever commensals are pushed out into new urban habitats (Lloyd-Smith et al 2005, 2009).

Conclusions

Delhi has a large animal population being nurtured on its edible waste. One subsystem for waste and animals involves Delhi's kitchen and commercial food waste providing free raw materials for rearing backyard cows. In another subsystem, mixed roadside garbage piles that include edible waste provide extensive foraging opportunities for Delhi's animals. The combined effects contribute to one of the densest human–animal interfaces in the urban world. Despite this general density, subsystems of animal adaptation to the spatial concentration and dispersion of edible waste take patterned forms. Micro-level details of the physical environment—for example, the width of streets in which garbage is heaped—mediate access. Opportunistic animals need to negotiate the presence of people, vehicles, and other non-human species. Opportunistic birds also need to negotiate potentially obstructive overhead power lines. In such ways, urban architecture and the perceptions of urban people shape the feeding, breeding, waste-creating, and waste-mediating behaviour of Delhi's animals.

While urban animals are, for the most part, tolerated by human residents, field research noted that younger people are less interested in religious-cultural expressions and practices such as the use of waste meat for the ritual feeding of kites. A decline in tolerance and respect may trigger human–animal conflicts. In addition, when refuse disposal and sanitation are upgraded in technological and organisational terms, humans and animals will need to adapt further to coexist. New ways of thinking about urban animals need encouragement. Meanwhile, in the absence of high standards of waste disposal, avian scavengers such as kites might even be actively encouraged where potential breeding structures such as trees are close to edible garbage. On the other hand, ecological subsystems involving a range of mammalian scavengers at local garbage dumps and large-scale landfills are ripe conditions for inter- and intra-specific transfers of disease-causing pathogens, for example, pathogenic coliform bacteria, antibiotic-resistant bacteria, and prions (Sobsey et al 2006).

When urban poverty and waste management are predominant urban planning concerns, this focus on human–animal waste subsystems might seem a luxury. Although new research is urgently needed, the zoonosis already known to be mediated by the varied forms of waste co-produced and co-consumed by creatures such as domestic cows, semi-wild macaques and street dogs, and wild kites is a pressing development problem. As urban planners and policymakers grapple with the problems of rapid urbanisation, perhaps the biggest challenge is urban waste, and perhaps the currently most unrecognised challenge of waste involves the changing roles and services of animals cohabiting with humans, who themselves contribute to waste.

Note

1 The study also involved surveys through semi-structured interviews (N=278) to understand the tolerance of and coexistence with birds, and the extent and prevalence of attacks by breeding birds as an act of offspring defence (Kumar et al 2019b).

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