

Vulture, culture and more: putting human-dimensions back in the saddle for conservation policy

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Abstract

Vulture collapse in South Asia accompanied rapid urbanisation. However, the Indian-Subcontinent's "Action Plan for Vulture Conservation" and the Conservation of Migratory Species of Wild Animals' (CMS) "Multi-species Action Plan to Conserve African-Eurasian vultures" reflect poorly on how their scavenging services factored in the regional social-ecological tool - a nature-based-solution. We report the ethnography of the extinction of experience concerning vultures in the tropical megacity of Delhi to contribute to wildlife restoration policies in human-use landscapes. People anthropomorphised avian scavengers while sharing perceptions that promoted ritual feeding of crows and kites. It attracted and supported enormous bird-flocks in the region, an ecological response to the rapid niche-evacuation. Stakeholders' perceptions that offered links in vulture salience and charisma corresponded with respective socio-cultural legends, based on bird morphology, behaviour, and ecosystem services. Conflating with ethnoecology, cultural legends mediated human-animal interface, based on species-specific life-history traits. The latter inextricably tied humans and vultures in their population and demographic parameters and mutual tolerance in behaviour that promoted co-existence. Therefore, wildlife restoration in urbanising landscapes is a moving target, necessitating policies sensitive to progressive loss and/or changes in associative heritage through shifting economic and cultural practices, and socio-cultural stories. In order to uphold their erstwhile functional ecology, vultures would need to behaviourally fathom new built-up spaces, interference from competing scavengers and mediated misinformation.

Introduction

Vulture decline and its aftermath in expanding human-dominated landscapes of South Asia have been complex processes revealed by *transdisciplinary* research on the opportunistic obligatory avian scavenger¹. This complexity was shaped by multifarious interactions in and around the built environment, socio-economy and local cultures that correspond to faunal responses. First, the change in quantity, quality and spatial outlay of solid waste- a characteristic aspect of tropical urban ecosystems which supports an extraordinarily high density of scavengers- vultures, kites, crows, dogs, rodents, etc.^{2,3}. Secondly, socio-economic transitions oversaw several agricultural movements, like the green and white revolutions, and the development of milk cooperatives⁴ in the 20th century. These events fuelled the availability of carcasses, attracting and potentially contributing to the survival of huge flocks of avian scavengers. Third, raptor populations are typically limited by food and nest-sites³, wherein, relics of native vegetation, tree plantations and other man-made physical structures likely mediate accessibility to carcasses and offal (e.g. [5]). Lastly but perhaps most defining are cultural beliefs that sustain patronising tolerance for vultures and other commensals and scavengers, despite social legends which classify them as agents of death associated with bad omens⁶.

Vultures' ecosystem services are myriad, beyond the usually discussed biophysical aspects of their niche as obligate scavengers^{7,8}. For centuries, their gregarious feeding has been harnessed as a *nature-based-solution*⁹ in the disposal of cattle carcasses, simultaneously supporting village and town-based processing of bovine leather^{10,11}. Depending on the economics and stigma for urban and rural 'leatherwork' and 'leatherworkers' by specific communities, whose settlements were segregated from the mainstream village and urban dwellers, the extent of human-vulture direct encounters was mediated by certain caste (*Chamars*) and religious (*Muslims*) status¹⁰. Alongside, leather tanning contributed to small scale industries based on the bovine bone remains- e.g. bone meal fertiliser units in proximity of carcass dumping sites in Delhi^{7,11}. Prior studies on opportunistic commensals offer limited insights, considering how human dimensions found infrequent mentions while reporting opportunistic

commensal ecology, despite the evidence on inextricable socio-ecological associations in human and non-human animal agencies (e.g. ^{12,13}). Collectively, these human entanglements with non-human species reflect on myriad aspects of ecosystem services. In addition to the scavenging, commensals provide information/knowledge about human-dominated ecosystems that have found poor appreciation in literature, e.g. the practice of *dokhmenishini* or sky burial by the *parsi* (Zoroastrians) community, using vultures for cremation in *dakhma* or the *Tower of Silence*^{11,14}.

The dynamics of an erstwhile human-vulture relationship highlights similar connections between animal population densities, key anthropogenic resources and human beliefs at the fulcrum of urban well-being in tropics^{15,16}. However, except for a coarse estimation of the size of the overall Delhi's breeding raptor population, quantitative data for vultures and other raptors in this biogeographic region are extremely scarce^{2,5,17-19}. In Galushin's study², vultures constituted 5% of ~3000 breeding pairs of raptors sampled in 150 km², while Black Kites *Milvus migrans* were prominent urban raptors (83% or 2400 of all breeding pairs), way before the vulture-collapse in the region. Since raptors as a taxon have relatively long lifespans and young birds evolutionarily delay first indulgent breeding for the initial 3-5 years of life as predators³, the absence of information on the non-breeding population of pre-adults and post-prime adults precludes complete assessment ecological dynamics. Ecology of non-breeding population should cater higher attention in the case of opportunistic commensals, where the superabundance of food can impact breeding success and survivorship³. Finally, soaring avian scavengers like vultures and kites can fly anywhere between 30-125 km on foraging trips²⁰. In various folktales, their keen eyesight and sense of navigation in "landscapes of anthropogenically afforded foraging opportunities" have enabled entry within the socio-cultural fabric of urban ecosystems²¹.

Unlike the attempts in Europe²², reintroducing captive-bred vultures from various centres in the Indian subcontinent within or near the human use landscapes would be the first of its kind ecological restoration^{23,24}. About three decades have gone by since vultures crashed from 40 million to a few thousand, given that synurbic vulture populations were attuned to opportunistically consume cattle carcasses. Carcasses that contained *diclofenac*, a veterinary drug which affected liver and kidneys of vultures^{7,25}, caused indirect poisoning. Meanwhile, rapid increase in human population and their rapid urbanisation- wherein 65% or more people of the Indian subcontinent are currently estimated to be below the age of 35 years^{26,27} - effectively subjects *extinction of experience* in youngsters. Considering that most people in the region have not visually encountered vultures' scavenging ecosystem-services, *extinction of experience* involves loss of phenotypic and ecological salience. Fortunately, however, perceptual and cultural salience²⁸ are frequently promoted by 'synergies of reverence', which contributes to the resilience of mutual prosocial perceptions and behaviours for innumerable animal species in the region^{2,16}. Under the purview of co-production of urban ecosystems by humans and more-than-human agencies, people's perceptions modulate non-human animals' access to anthropogenic resources and shape human-wildlife interactions within SES in variably urbanised landscapes²⁹⁻³⁷. Still, the literature and thereby policies guiding the practice of restoring vultures in human-use landscapes are silent about the mechanisms that erstwhile shaped ecological, aesthetic and corporeal charisma for avian scavengers that affects their salience amongst public^{28,38}. Considering highly interspersed peri-urban, protected and human-use landscapes in the region, their association with food-subsidies are likely to increase proximity and exposure of wildlife to humans, and vice versa. It is an area of research that needs actionable implementation in the Global South^{31,39}.

While rare and endangered species get research and conservation attention, common species provide significantly higher ecosystem services⁴⁰, are easily noticeable by citizens, and have been known to face rapid population declines (e.g. red kites, passenger pigeon, vulture, etc)³. To contribute to these overlooked aspects that concern every wildlife restoration effort within or near human-use landscapes, we focused on common urban scavenging birds that are readily encountered interacting with residents in Delhi- Black Kites *Milvus migrans*, crows *Corvus splendens*, and erstwhile common vultures (*Gyps* spp. and *Neophron* spp.). We examined the 'affective attitudes' people have for animals in South Asia, generally driven by anthropomorphic beliefs. Our rationale focused on capturing the changing role of multiple human and nonhuman agencies through semi-structured ethnographic surveys that shed light on the drivers mediating the interactions of direct and mediated encounters of people with avian commensal scavengers. Analyses of complex relationships among biotic, physical and socio-cultural agencies on the cultural characterization of urban commensals by local citizens identified the merits as well as perils of anthropomorphising commensals. We discuss how the effects of urban driven homogenization extend beyond biophysical relationships, impacting human-animal relationships among multiple stakeholders.

Methods

This study is part of long-term research on the ecology and ethno-zoology of urban scavengers in Delhi, seeded to examine the ecological impacts of local vulture loss. The city has rich birdlife and the world's second-largest urban human population of 29 million inhabitants⁴¹, making it a melting pot of cultures that is composed of immigrants from across the Indian subcontinent⁴² (details in Supplementary material 1).

For the horizon scan of ethnoecological aspects in a heterogeneously-developed city, we adapted a Delphi-like ethnographic approach to incorporate Delhi's solid waste management, and a wide range of stakeholders and their interactions with avian scavengers in the frameworks that represent a tropical megacity's human-animal interface^{43,44} (Fig. 1). Since 2012, we have been longitudinally surveying commensals and people as co-producing units in the megacity of Delhi at 32 sampling plots of approximately 1 km². The design systematically covers all urban settings, from semi-natural to extremely built-up sites, including all the three sanitary-landfills (for details, see ^{15,16}; Supplementary material 1).

During the ongoing study, where ethnography followed a stepwise procedure, we interacted with 27.03 ± 2.31 new onlookers at our sampling units on every field visit (see Supplementary material 1). Horizon-scans involved people who voluntarily engaged in conversations. It solicited direct inputs on vultures' local extinction and the corresponding prominence of other urban scavengers. The overall estimate for this voluntary availability of citizens for semi-structured horizon scan is 61500 (n = approximately 250 field visits, every year, since 2012). While incorporating anonymity in all our previous reports^{5,15-18,45}, we have used iterated surveys, facilitated discussions, structured elicitation, and aggregation of individual perceptions and associations with animals to incorporate the full range of socio-cultural perspectives regarding opportunistic scavengers in the city. Through iterated interactions with new, random sets of respondents from the same stakeholder unit, we identified and mitigated typical individual-level psychological biases⁴³ (**Stage 1**). This helped mitigate potential biases of people from the data, considering our respondents revered or vilified myriad types of non-human animals, which contextualised their own professional or socio-cultural obligations. Out of the total estimated respondents, amongst 826 contributors (designated as decision makers with respect to human-animal interface), who were affiliated with stakeholder groups likely to have higher encounters with avian scavengers on a regular basis, 5.7 % were affiliated with academia and 5.5 % with NGOs (e.g. *World Wide Fund for Nature*, *Wildlife Trust of India*, etc.); 2.4 % were ritual feed-sellers (grains, fruits and

meat-chunks); 9.3 % worked for the government (zoo, municipality, health workers) and 2.1 % for religious organizations (priests or *Moulavis*); and 75 % were associated with informal waste-work sector (butchers, chicken and fish market cleaners, rag pickers, municipality contract labourer, contractors). The major section of more than 60,000 contributors also included residents who immigrated to the city from multiple regions and shared their native biocultural perspectives.

In **Stage 2**, before every iteration step, the lists of responses were thematically organized to identify the relationships in socio-cultural rooting of the respondents and their professional background. Subsequently, further contributors to this study from randomly available respondents were chosen to balance background, expertise, and other parameters of urban social diversity. Team members, who were multilingual, helped create the necessary familiarity by initiating conversations in native dialects to build mutual trust to interview the urban immigrants from the nearby states (see below). Simultaneously, the team also scanned the immediate surroundings where the surveys were conducted to obtain a relative index for **a.** anthropogenic resources; **b.** the abundance of kites, crows, dogs, other commensals and livestock; and **c.** prosocial or agonistic human and non-human animal interactions in shared space (**Stage 3**; see ¹⁷).

Ultimately, before each successive step, the usefulness of horizon scanning can only be judged retrospectively⁴⁶. Therefore, subsequently, in **Stage 4** (this study), the semi-structured and key-informant interviews we conducted to probe the social-ecological significance of urban opportunism by commensals were a surrogate for identifying major patterns in vulture-specific perceptions amongst citizens, community groups (abattoir and waste-workers), NGOs, government agency officials, and religious clerics. The interviews (n= 71) conducted by one of the authors (UG) in 2017 focused on common avian scavengers- kites, house crows and vultures through semi-structured conversations (details in Supplementary material 2). These species exploit anthropogenic food and have been studied to attain extremely high densities^{2,15}. At this stage, interviewees were selected by snowball sampling, after stratifying the potential respondents into various stakeholder units. Efforts also incorporated sampling professionals involved in animal husbandry, and with other wild or feral animals in shared urban space or zoological parks⁴⁷. All interviews for **Stages 1 – 4** were conducted by the authors in *Hindi*, other native languages (*Bhojpuri, Maithili, Bengali, Assamese*) or English, as deemed appropriate.

Further, we reworked final issue descriptions and grouped them into overarching themes (details in Supplementary material 1, 2). This focused study allowed us to cross-validate these thematic groupings and links between **(i)** political ecology driven by individual-to-society feedback for people; and **(ii)** individual-to-population feedbacks that characterise urban ecology of opportunistic avian scavengers like vultures, shaping their functional ecology in human-dominated landscapes (Fig. 2).

To clarify the policy relevance of issues pertaining to ethnoecology of human-vulture interface, and potentially suggest refinement of vulture conservation breeding practices, we collated interviewees' perceptions to draw upon the issue-specific impacts of vulture-loss for each stakeholder unit (**Stage 5**-this study). We expected salience for avian scavengers to be driven by our subjects' socio-cultural, professional and economic backgrounds, corresponding to patch-level variations for socio-ecological systems. Inductive-opinions, embedded in folk-biology were expected to be accrued via direct encounters that shape ecological, aesthetic and corporeal charisma. Semi-structured interviews enabled flexibility to identify patterns in avian scavengers' salience that was contingent on the interactions expected between factors that affect social-ecological constructs- e.g., age, profession, gender, and domicile.

Ethics statement

Approval for the semi-structured interviews, as part of ethnography, was granted by the Central University Research Ethics Committee (**CUREC**), University of Oxford (reference: SOGE 17A-82) and by the Training, Research, and Academic Council (TRAC) of the Wildlife Institute of India, Dehradun (WII). We conducted all interviews in accordance with the relevant guidelines and regulations.

Results

A summary of salience and charisma for vultures and other avian scavengers

The phenotypic and ecological salience for vultures were restricted amongst people older than 35 years- subjects not generally domiciled in top-tier cities- who encountered large scavenging-flocks in the past. Older males (>35 years) and subjects who were professionally associated with animals (municipality, zoological-park and NGOs working on animal welfare and conservation) shared direct experience, stories and knowledge about vultures and other avian scavengers (summarised in Supplementary materials1, 2). Similar to how multiple morphological cues are used by taxonomists to classify and name a species, folk names, perceptions and practices associated with avian scavengers depended on locally prevalent folktales, based on long-time coexistence. Cultural legends that explained avian scavengers' keen eyesight and flight capability reflected inductive opinions about the exaptation of morphological features enabling synurbization. The amalgamation of socially anthropomorphised approaches associated with the local political economy and biophysical ecology of commensals collectively extended the carrying capacity of urban ecosystems for selected scavengers (Fig. 3).

All anecdotes that mentioned direct vulture encounters were associated with village/locality-based carcass dumping areas carefully set aside from the residential blocks to harness their scavenging services (Fig. 1b). For rural systems, people informed that in the absence of vultures' services, carcasses are often dumped in open water-bodies (canals or rivers), buried underground with salt, or discarded in open (see below). The livestock carcasses in megacities like Delhi were collected by the municipal workers, but only from the designated 'dairy-colonies', e.g. at *Ghazipur* in Delhi. Thus, the absence of vultures' services in tending carcasses limited where all urban-poor could practice 'small-unit animal husbandry' in backyards, collectively stressing the perils of livestock maintenance in heterogeneously developed tropical cities. Their narratives (details in supplementary materials) had frequent mentions of competitive release impacts on stray dogs and rodents, underscoring heightened human-dog conflicts and threats of disease spread.

Youngsters who never encountered vultures in wild, and/or female subjects who were less outdoorsy than male members of their families discussed the cultural salience of vultures, based on folktales, television and documentaries. Considering the sympatric opportunism exhibited by several avian scavengers for human-offal over accumulated garbage- an aspect more prominent at the sanitary landfills that currently support enormously large flocks of migratory black-eared kites *Milvus migrans lineatus* (n= 10,000 birds at *Ghazipur*. see ⁴⁹)- vernacular names for vultures and kites were used interchangeably (Supplementary material 2). Contrary to our expectations, immigrants who worked on landfills, tending waste in the proximity of multiple commensal species, reflected poorly on salience or charisma associated with avian scavengers. Given their socio-economic indulgences and poor connection with their native biocultural heritage, their indifference to mega-congregations of kites reflected the poor autonomy immigrant informal workers have over cultural expressions to nature within cities, where they settle as

subalterns³⁹. However, the prevalence of ritualistic animal feeding, and animal husbandry also provided livelihoods to another set of stakeholders amongst the immigrant urban poor in Delhi.

Discussion

This study elaborates on beliefs and perceptions about common avian scavengers amongst cultural mosaics represented by heterogeneously-developed tropical megacities like Delhi that comprise of multiple stakeholder units. We contribute to advance the resolution of human-animal interactions, which are interdisciplinary and difficult to achieve via standalone ecological or ethnographic studies. Our results contribute folk-biological perspectives that are *transdisciplinary* and offer insights on how people ordinarily understand the biological world in rapidly urbanising ecosystems shared with opportunistic commensals. In cities like Delhi, millions of scavenging populations of myriad species live on waste and ritually offered food-subsidies by thousands of devout people who indulge in diverse practices, expressing patronage to animals. This is probably the largest human-animal interface in the world¹⁶. Human-animal interactions in tropical cities are distinct from their western counterparts⁵⁰, driven by people acknowledging age-old ecosystem services by animals, potentially configuring regional urban *nature-based-solutions* e.g. in solid waste disposal¹⁶. Cities within the Global South are conglomerates of immigrants that impact social traditions and practices at multiple scales¹⁴. Thus, dissociation of urban immigrants from their biocultural roots impacted their attitudes and ecological salience for non-human animals, even for frequently encountered avian scavengers^{33,51,52}.

Unravelling ecology of opportunistic synurbic organisms to support their conservation will need distinction in how we characterise 'cities', which are confined in physical geography. Urban systems, however, are not limited or defined by political boundaries³². When characterising organismic ecology well entwined with the populous, we need to account for the co-production of materials, information (tangible and intangible archives), people, power relations, etc. – to establish forms of interconnection that most meaningfully constitute the urban for humans and non-humans in shared spaces^{53,54}. Unfortunately, as vulture-restoration efforts are being consolidated to achieve numerical response for a far greater quantity of human-offal, the eventual lag phase would not just be modulated by birds' life-history traits. Even the access to food-subsidies would be impacted by urban-development which entails increased power transmission lines, considering that vultures and other large birds like Great Indian Bustard are electrocuted by overhead power lines or windmill collision⁷. The functional response of vultures in human-use landscapes, unlike the small populations currently confined to protected areas, would oversee newly co-produced ecosystems, contextualising ecological opportunism that fits the socio-cultural and socio-economic milieu. Based on the four domains of ***population, demography, behaviour and ethnoecology*** that we explore in more detail below contextualise urban scavengers and people in social-ecological systems^{34,36,37,55} SES.

First, as an upper-trophic wide-ranging raptor, vultures fall under those avian groups that successfully colonised and thrived in human-dominated landscapes, attracted to the frequent allocation of anthropogenic resources. Raptor ***populations*** are typically limited by food and nest-sites³, wherein, the latter constrains the level of resource-tracking by individuals attuned to opportunism (e.g. ¹⁵). However, unlike the commensal-scale urban niche for kites and crows, vultures' services were resolutely harnessed by locals through the allocation of designated feeding sites - an erstwhile practice analogous to today's "vulture-restaurants"⁵⁶. It not only had implications for solid waste and disease management but also enabled the maintenance of the world's largest livestock population in poverty-stricken regions^{7,8,57}. Till the last century, this vulture-mediated *nature-based-solution* for solid waste disposal simultaneously addressed economic, sustainability and socio-cultural goals- a regionally motivated feat

incorporated by highly variable communities across South Asia^{7,25} and elsewhere¹⁰. Therefore, for the Indian subcontinent's likely future, the largest milk-producing region of the world, we reckon to couple: **(i)** dairy-colonies' displacement as the urban gentrification drive⁵⁸; and **(ii)** releasing vultures from conservation-breeding facilities^{7,25}. The latter would, of course, depend on careful, multi-stakeholder and multi-scalar planning to afford accessibility of safe feeding, roosting and nesting sites for vultures, whose availability could easily be exploited as a tool to simultaneously address urban waste and poverty^{15,16}. For instance, north-western Delhi, where informal livestock-rearing colonies' resettlement is planned⁵⁸, lies in proximity to the *Aravallis* range that is currently an active, safe nesting zone (Authors' unpublished data). Correspondingly, policies pertaining to vulture restoration shall solicit simultaneous contributions from the federal and Non-Governmental Organisations (NGOs) that concern the environment and forests, animal husbandry practices and resettlement of the urban poor.

Second, the **demographic** shifts in vulture populations have accompanied changes in human population structure across the globe, especially in the Global South (Census Organisation of India, 2011; ⁴¹). Our surveys informed that migration to cities selectively de-couples younger generations from the joint-families, disrupting direct as well as oblique biocultural transmissions. Previously, these formed the basis for mutual tolerance⁵⁹. Cities' physical urban sprawl and far-ranging urban impacts will likely affect successful vulture-reintroduction. Therefore, demographic repair for vultures should factor in cultural dynamics in humans to support re-attainment of mutually conducive niches in rapidly urbanising ecosystems ^{59,60}.

Third, while our subjects offered deep insights into how religious beliefs motivated them to patronise and tolerate vultures in localities, unfortunately, we have a poor understanding of how these birds dealt with the **behavioural bottleneck** that involved trade-offs in urban environments in terms of defending their young against humans, while exploiting anthropogenic food sources⁴⁵. Recent studies on birds that occupy and exploit anthropogenic resources stress the factor of animal-personalities generated under the selection of individuals that could breed within the higher-end spectrum of adaptation to urban life⁵. But unlike multiple birds that have been studied to aggressively attack human beings to defend offspring, e.g. kites¹⁷, and magpies⁶¹, vultures are not known to attack humans^{39,62,63}. Therefore, we speculate that vultures-populations breeding within cities were constituted by individuals that had synurbic personalities, developed via selection for tolerance to human proximity as a behavioural strategy ^{15,17}.

Unfortunately, this urban opportunism was also the basis for ecological trap⁶⁴ that fuelled rapid decline of populations via consumption of cattle-carcasses which had diclofenac-residues in urban areas^{7,25}. In terms of the erstwhile functional ecology of avian-scavengers that conjugated with animal-husbandry practices, behavioural-phenotype(s)^{65,66} of the captive-bred vultures might preclude their settlement in human-use landscapes, rendering the small populations exposed to multiple threats at the currently altered human-wildlife interface⁶⁶⁻⁶⁸. Alternatively, urban opportunism on cattle carcasses can also be species-specific tolerance of proximity to humans, selecting for White-rumped vultures *Gyps bengalensis* that constituted >80% of all vultures in South Asia before decline^{7,25}. Collectively, based on aforementioned links in human and non-human agencies, changes to human-vulture interface have contributed to a long-drawn social-ecological trap for both agencies⁶⁹. Given that media assisted in spread of anthropomorphic socio-cultural legends about vultures, as well as misinformation regarding what led to their loss and/or treatment as bad omens, socio-cultural shifts can erode patronising attitudes that previously allowed Indians to tolerate vultures⁷⁰.

Fourth, we weave the aforementioned *population, demographic and behavioural* perspectives for the human and non-human animal agencies that co-produce and constitute the 'urban' in the Global South. Under the domains of SES, for cities under variably urbanised status, these constitute regional *ethnoecology*. Previous studies^{71,72}, including a few in the region^{5,45}, have shown that commensal species' functional ecologies are ascribed via centuries of coexistence, enabling metabolism of human offal by opportunistic species at multiple trophic levels. For instance, food waste is a valuable subsidy to livestock and poultry owners in South-Asian cities and towns¹⁶. Thereby, the urban ecology of the human-animal interface in urbanising systems is an unintended, informal selection of animal rearing practices. These ethnic-practices sustain and support millions of poor people, configuring domains of political economies and political ecologies with respect to which animals can cohabit in rapidly changing tropical SES⁷³. Along with commensals, citizens in urban tropics share living spaces with livestock in the backyard, which consume edible waste as nutrient-rich feed. It reduces the costs of milk and meat production⁷⁴⁻⁷⁶. Scavengers like vultures, dogs, kites, rats and crows, thereafter, consume the organic remains, as human-mediated commensal agencies, with highly variable synurbic status⁷⁷. Therefore, for the old world, the fastest declines witnessed in the vulture populations should not be treated as a single event isolated from simultaneously occurring changes in the human-wildlife interface and socio-economy. Such events are driven by, and, in turn, further cascades urban growth and development that shapes local culture, built environment and social-ecological processes^{74,78}. Meanwhile, tropical cities have witnessed massive increase in their solid waste since the vulture decline e.g. Delhi's waste grew by 300% since 2002⁷⁹. Unlike their western counterparts, the ecology of human-nature interactions in tropical megacities³³ respond to the geography of human religion, hygiene and poverty via **(i)** interactions of socio-economic and socio-cultural processes amidst, **(ii)** rapid spatio-temporal alterations over availability and accessibility to food subsidies that are inextricably entwined with; **(ii)** population and behavioural dynamics that characterise functional urban ecology of non-human animals in human-dominated landscapes³⁶ (Fig. 4).

Further, vultures' loss has had its share in contributing to the burden of diseases that spill from animals to humans (zoonoses)⁸⁰. Given that South Asia and Africa share the highest zoonotic burden, human-animal interactions within finite spaces have reportedly been associated with an increase in the population of stray dogs and other warm blooded commensals that cause rabies^{80,81}. These commensals that share urban opportunism underwent competitive release in the absence of vultures⁸⁰. The latter's resurrection will, therefore, be impacted by competition over anthropogenic resources, involving commensals' opportunism that is currently contingent on regional cultural geography¹⁶. Considering the perpetual increase in solid waste and its poor disposal in South Asia^{48,82} that supports dense populations of free-ranging animals, successful seeding of captive-bred vultures will be challenging, considering the projected urbanisation of 500-million citizens over the next 30 years^{30,35,36,41,83}.

Furthermore, a comparison of current precarity for vultures in Asia, Europe and the African continents (see Table 1) reflects the distinguishable socio-cultural as well as socio-economic factors for respective regional ethnoecological practices. It involves agroecosystems in human-use areas interfacing the protected area systems⁸⁴. Within Europe and Africa, illegal use of poison baits is the most important human-induced factor for local extinction or decline in vertebrate megafauna, including Red Kites and Vultures^{85,86}. Additionally, vultures are vilified in many regions in Africa, from where studies have not reported ethno-ornithological aspects that still motivate people to patronise vultures and other animals^{5,16,17}, as reported here, and by Taneja⁸⁷. In the wake of recent changes to urban political ecology in the Global South, we need to plan and define corresponding functional ecological domains for vultures and other opportunistic commensals^{36,53,54,88-91}.

Table 1: A comparison matrix of current conservation threats, policy tools for vultures in Asia, Europe and the African continents, and the impacts of regional losses reflects the distinguishable socio-cultural as well as socio-economic factors for respective regional ethnoecological practices. Adapted from CMS Raptor MOU Technical Publications^{8,92}

Region	Vulture spp	CR Status	Major Policy intervention	Socio-cultural, persecution status	Threats	Impact of vulture loss	References
Asia	Bearded Vulture <i>Gypaetus barbatus</i>	NT		belief based persecution in Nepal	persecution, decline in food availability	increase in population of mammalian scavengers like dogs, genetic bottlenecks	93
	Egyptian Vulture <i>Neophron percnopterus</i>	EN	Ban on diclofenac		electrocution, NSAID poisoning		94,95
	Red-headed Vulture <i>Sarcogyps calvus</i>	CR		reported in Cambodia	NSAID poisoning, habitat loss, electrocution		96
	Himalayan Griffon <i>Gyps himalayensis</i>	NT		reported in Cambodia	NSAID poisoning, habitat loss, electrocution		97
	White-rumped Vulture <i>Gyps bengalensis</i>	CR		reported in Cambodia	NSAID poisoning, habitat loss, electrocution		98
	Indian Vulture <i>Gyps indicus</i>	CR			NSAID poisoning, habitat loss, electrocution, unintentional poison baits		98
	Slender-billed Vulture <i>Gyps tenuirostris</i>	CR			NSAID poisoning, habitat loss, electrocution, unintentional poison baits		98
	Griffon Vulture <i>Gyps fulvus</i>	LC		reported in Cambodia	NSAID poisoning, habitat loss, electrocution, unintentional poison baits		98
	Cinereous Vulture <i>Aegypius monachus</i>	NT	ban on diclofenac	persecution for feathers	unintentional poison baits, electrocution, decline in food availability, NSAIDS, persecution		99,100
	Lappet-faced Vulture <i>Torgos tracheliotos</i>	EN			insufficient data		

Africa	Bearded Vulture <i>Gypaetus barbatus</i>	NT	research and policy decision in making	Unintentional poisoning (baits), collision with powerline, lead poisoning	genetic bottlenecks	101	
	Egyptian Vulture <i>Neophron percnopterus</i>	EN		Unintentional poisoning (baits), collision with powerline, decline in food availability		102	
	White-headed Vulture <i>Trigonoceps occipitalis</i>	CR		intentional poisoning	poison baits, sentinel poisoning, habitat loss, decline in food availability		103,104
	Hooded Vulture <i>Necrosyrtes monachus</i>	CR		persecution for wildlife parts	bushmeat trade, poison baits, sentinel poisoning		103-105
	White-backed Vulture <i>Gyps africanus</i>	CR		persecution for wildlife parts	poison baits, sentinel poisoning, habitat loss, decline in food availability, electrocution		103,106
	Cape Vulture <i>Gyps coprotheres</i>	EN		belief based use-African Traditional medicine	poison baits, electrocution		107-109
	Rüppell's Vulture <i>Gyps rueppelli</i>	CR		belief based use-African Traditional medicine	poison baits		104,110
	Griffon Vulture <i>Gyps fulvus</i>	LC		belief based persecution			
	Cinereous Vulture <i>Aegypius monachus</i>	NT					found occasionally
	Lappet-faced Vulture	EN		belief based use	poison baits, habitat loss and		110-113

	<i>Torgos tracheliotos</i>			disturbance, sentinel poisoning		
Europe	Bearded Vulture <i>Gypaetus barbatus</i>	NT	vulture feeding sites; research and policy decisions on powerline collision and poisoning underway	Unintentional poisoning (baits), collision with powerline, lead poisoning	genetic bottlenecks	114–116
	Egyptian Vulture <i>Neophron percnopterus</i>	EN		Unintentional poisoning (baits), collision with powerline, lead poisoning		117,118
	White-backed Vulture <i>Gyps africanus</i>	CR		-		found occasionally
	Rüppell's Vulture <i>Gyps rueppelli</i>	CR		-		found occasionally
	Griffon Vulture <i>Gyps fulvus</i>	LC		Unintentional poisoning (baits), collision with powerline, NSAIDs		62,119
	Cinereous Vulture <i>Aegypius monachus</i>	NT		decline in food availability		120

Poor prevalence of religiously motivated patronising attitudes for commensals in youngsters⁵- a generational shift we noticed in our horizon scan- will eventually alter cultural tolerance for backyard-biodiversity. Loss of biocultural diversity for backyard species will homogenise the human agency for vultures across the old world in future^{85,121}. Thus, in near future, we expect increase in the cases of indirect poisoning of the vultures that consume depredated cattle carcasses deliberately poisoned by people to avenge the loss caused by mammalian carnivores. We based this argument on the exposition of relatively small protected areas (average size = 486 km²)[⁸⁴] that increases their interface with agroecosystems witnessing rapid loss in tolerance for wildlife in South Asia ^{122,123}. In the wake of urban changes that entail habitat fragmentation and biocultural loss, a general increase in agonistic attitude towards wildlife¹²⁴ is expected to spill over to South Asian vultures in future⁷. Therefore, restoration for vultures and other wild fauna would require accommodating the SES dynamics for tropical megacities. It should inculcate a nuanced understanding of spatial extent of ethnoecological differentiation for the non-human organisms in SES that is analogous to patch dynamics in ecology^{125,126}.

Conclusion

In conclusion, social-ecological framework used in this study models the contingency of biodiversity conservation in the human-dominated landscapes on ecological as well as social, cultural and economic factors. The loss of vultures quintessentially depicts how limited social-ecological understanding delayed actions on the conservation and management of a once-common group of species. For poverty-stricken urbanising ecosystems of the developing world, the organismic criterion of habitat selection by opportunistic animals is contingent on food-affording socio-economic drivers and cultural beliefs at the local to regional scales. Therefore, integrating human socio-cultural estimates while seeding individual animal units during restoration practices would affect population-level behavioural consequences and back^{67,68}. In turn, expected progressive rationalisation of refuse disposal and detachment of younger generations from ritual practices and beliefs, which modulate tolerance for non-humans, make wildlife restoration a moving target within developing countries. Further, conservation practices that entail restoration and/or sustenance of wildlife in human-use landscapes should be privy of multi-domain functional responses of organisms. Considering the fact that straight-jacket quantitative biophysical evaluations often overlook ecology of opportunistic behaviour in commensal species, biocultural heritage and political ecologies are coproduced via mutual-reciprocations in shared tropical environments. Conservation efforts need to cater to conundrums between modernisation and improving human living conditions while upholding ecological and cultural salience for non-humans in ways that preclude attainment of social-redundancy for target species like vultures.

Declarations

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Author Contributions

UG conducted the focal interviews of 71 focal-subjects in 2017 and prepared a preliminary draft for the partial fulfilment of her M.Sc. thesis at Oxford. NK supervised the study. Both the authors designed the study, conducted fieldwork between 2012-2021, developed the first draft of this manuscript and approved the final version.

Conflicts of Interests

The authors declare no conflict of interest. The funding agencies had no role in the study design and fieldwork.

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Figures

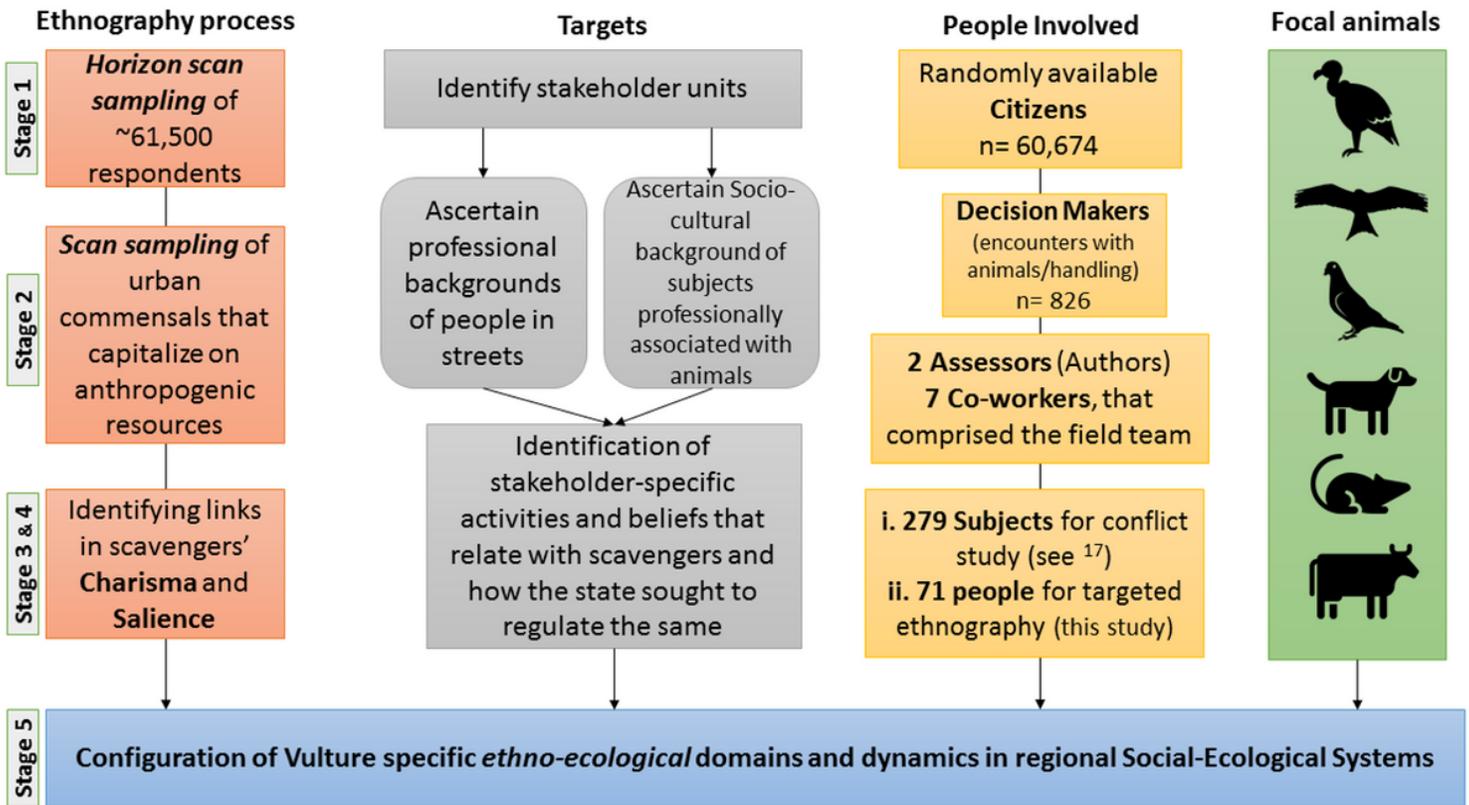


Figure 1

Adaptation of a Delphi-like ethnographic-approach in five aforementioned steps enabled: (i) horizon scan of ethnoecological aspects (ii) identification of general variations in human-animal interface in space and time (n = 61,500) (iii) insights into how perceptions for avian scavengers were based on correlations between socio-cultural, economic and professional backgrounds, and (iv) an understanding of how people who were professionally associated with animal care and conservation, and/or circumstantially encountered scavenging animals (e.g. waste and municipality workers, etc.) (n= 826) were vital as decision makers in sustaining a thriving human-animal interface in a heterogeneously-developed tropical megacity of Delhi.

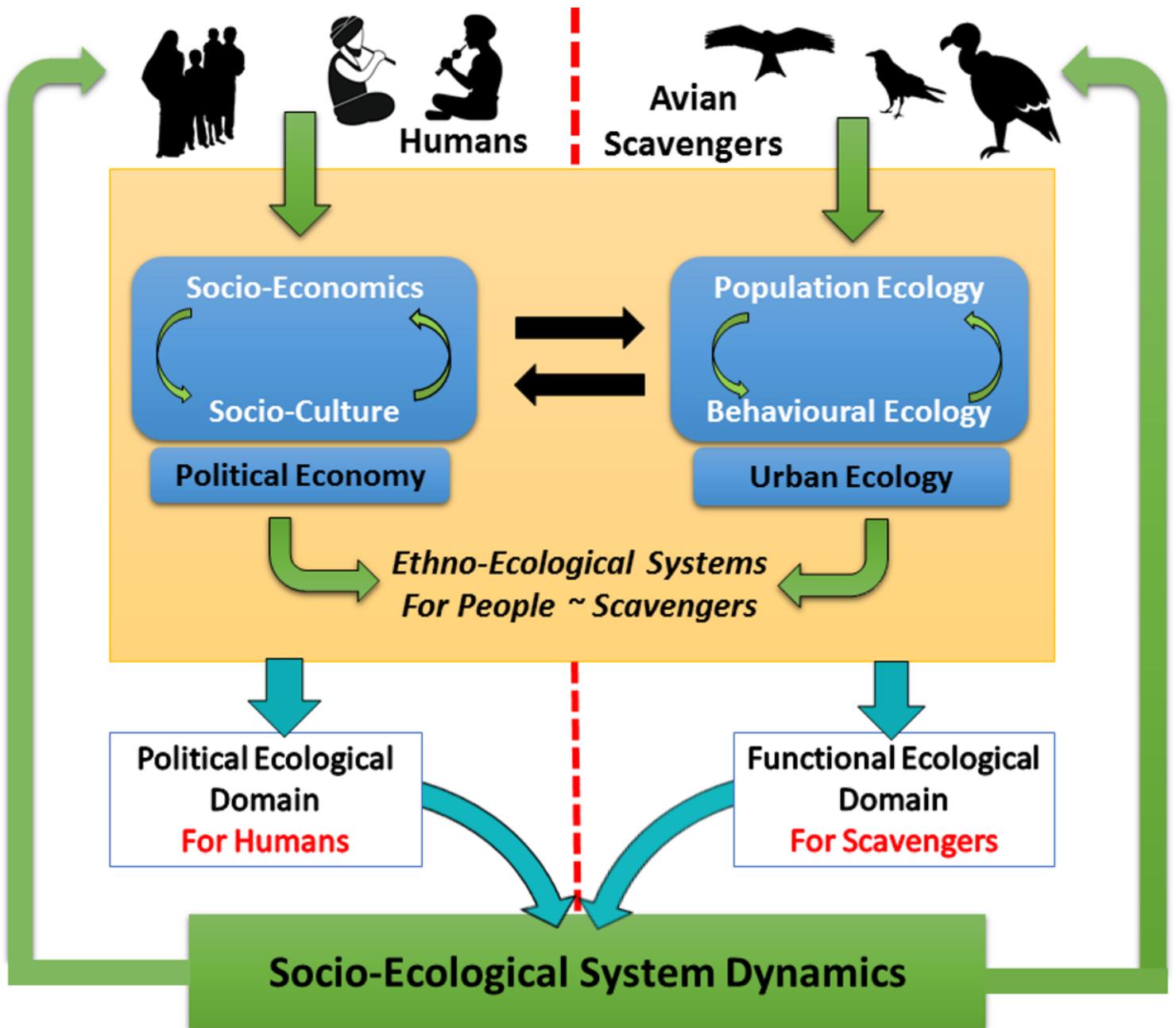


Figure 2

Based on (i) this ethnographic study, and (ii) an unprecedented, long term ecological dataset^{5,16–18,45,48,49} on how food subsidies support enormous populations of kites, dogs, macaques and semi stall-fed livestock, our Social-ecological System (SES) framework combined the frameworks for political ecological domain pertaining to human agency and the functional ecological domain shaping the non-human animal agency (here, vultures). This SES framework also underscores the importance of two bi-directional feedback loops for vulture restoration in South Asia, linked via the ethno-ecological dynamics, which is an outcome of centuries of coexistence.

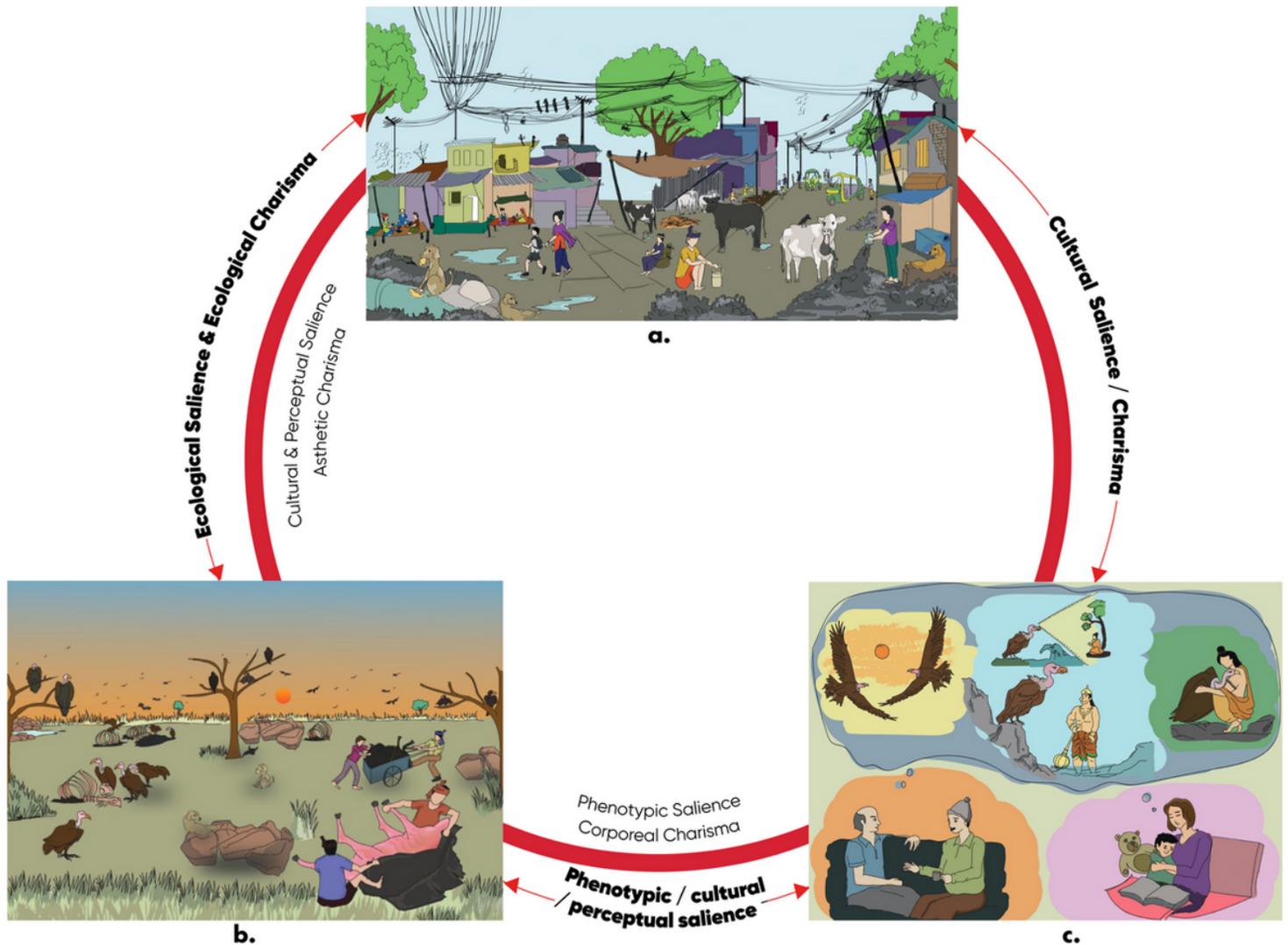


Figure 3

Conceptual framework to represent one of the many community-governed social-ecological-systems³⁴ in urbanising tropics. Here, it exemplifies how human-agency in South Asia erstwhile factored and harnessed opportunistic responses of vultures in space and time through: a. Innumerable nature based solutions based on human-animal proximity in shared living spaces in a tropical urban landscape; b. Social-cultural and socio-economic aspects that mediated designation of spaces for carcass disposal by vultures and involvement of people of certain caste (Chamars) and religion (Muslims) in leatherwork; and c. Balancing of stigma for vultures through socio-cultural legends, where reference for vultures' physical volant capabilities and keen sense of sight are topics of reverence, forming biocultural heritage. This conceptual framework builds on the non-human charisma and saliense discussed by Lorimer³⁸ and illustrates why the ecology of human-nature interaction in temperate systems differ from tropical human-use landscapes³³. Overall, the ecological as well as ethno-zoological history of human-animal interfaces in rapidly urbanising tropics hold key to sustenance and/or restoration of wildlife in human-use landscapes.

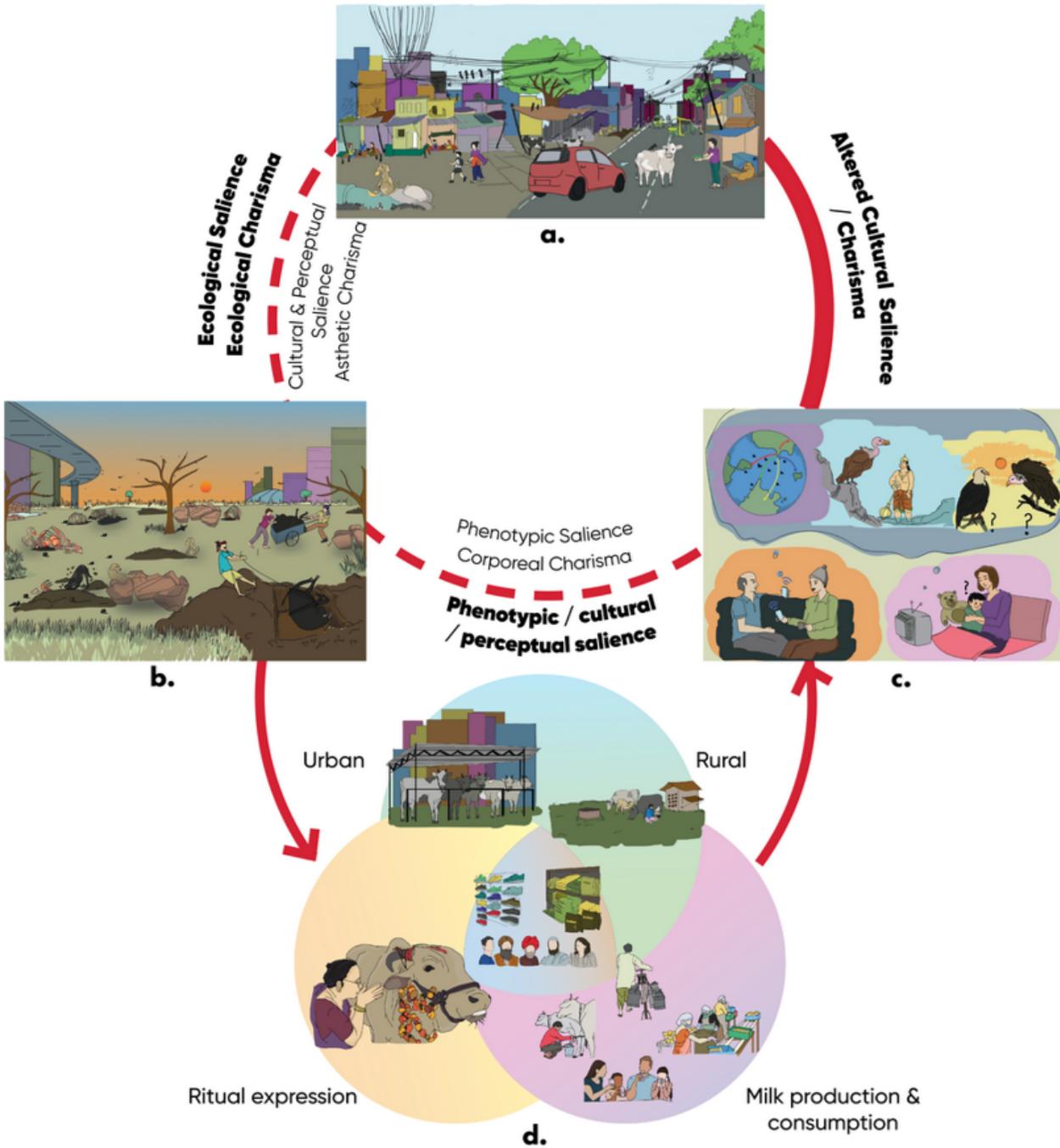


Figure 4

Conceptual framework to represent how human-culture interface has attained novel status in the wake of South-Asian quasi-extinction of vultures through: a. Gentrification driving extinction of nature based solutions based on decreasing human motivation for sharing living spaces with animals in a tropical urban landscape; b. Simultaneous urbanisation and vulture loss impacting the social-cultural and socio-economic aspects that now mediate competitive release in other commensals over carcasses left or buried in limited spaces, or thrown in open water bodies; and c. loss of direct encounters of vultures and changes in demographic parameters of humans living in urban areas with access to television and internet affects biocultural heritage and spreads mediated misinformation about their local-extinction due to “technology-assisted” migration to Japan and USA. These social-ecological disassociations represented by broken red lines impact the non-human charisma and saliency involving

vultures38. Overall, through a linked perspective of livestock maintenance for animal protein and leather, the section d. represents how urban practices across the world are getting homogenised in space and time. It also exemplified there is poor understanding of how similar urban pressures and globalisation drivers may differently shape and/or impact a diverse biocultural heritage, comprised of communities and their faith-systems at the fulcrum of social-ecological landscapes.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Supplementaryfile1UGuptaNATECOLEVOL210413523A.docx](#)
- [Supplementaryfile2GuptaUNATECOLEVOL210413523A.docx](#)