BLACK KITE PROJECT

PHASE - VI

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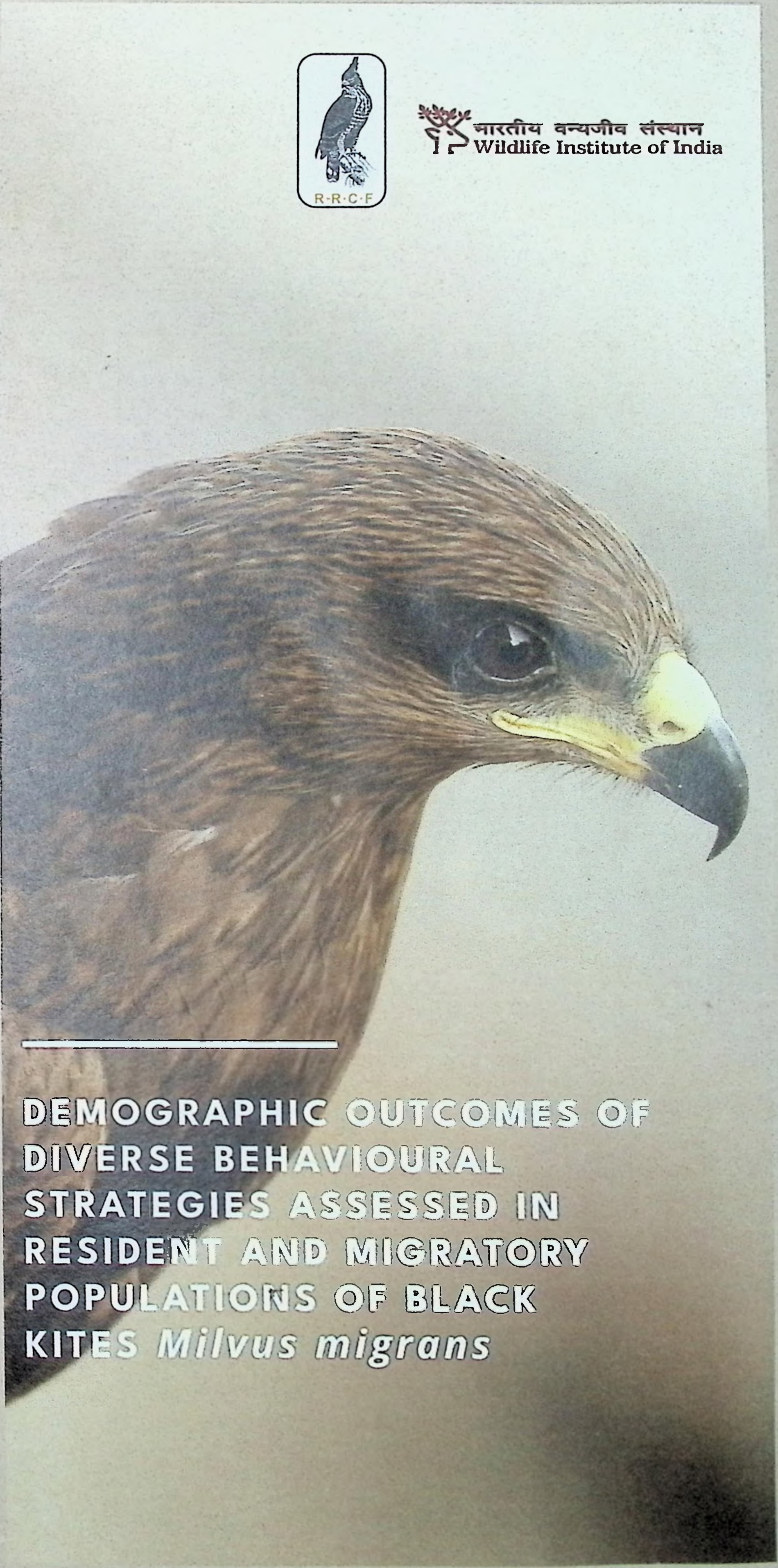
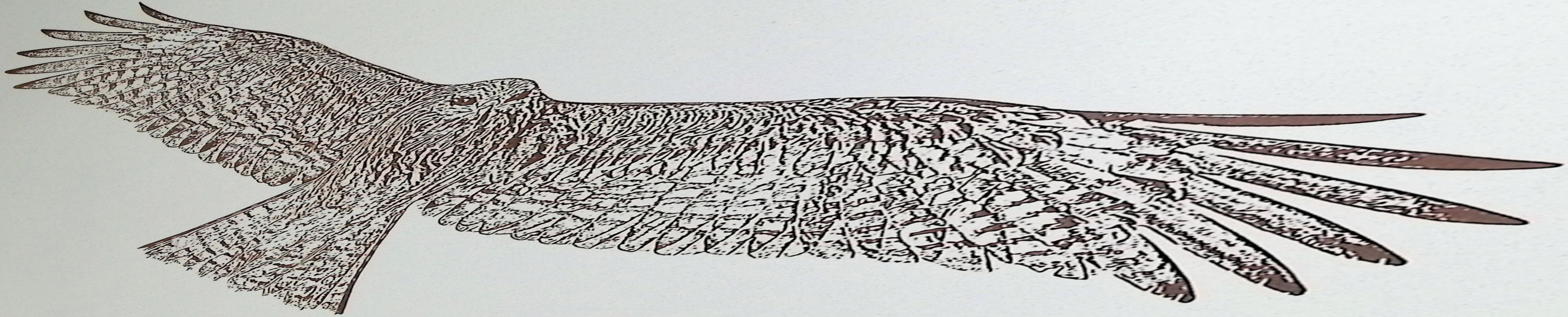


DEMOGRAPHIC OUTCOMES OF DIVERSE BEHAVIOURAL STRATEGIES ASSESSED IN RESIDENT AND MIGRATORY POPULATIONS OF BLACK KITES *Milvus migrans*

2020-24



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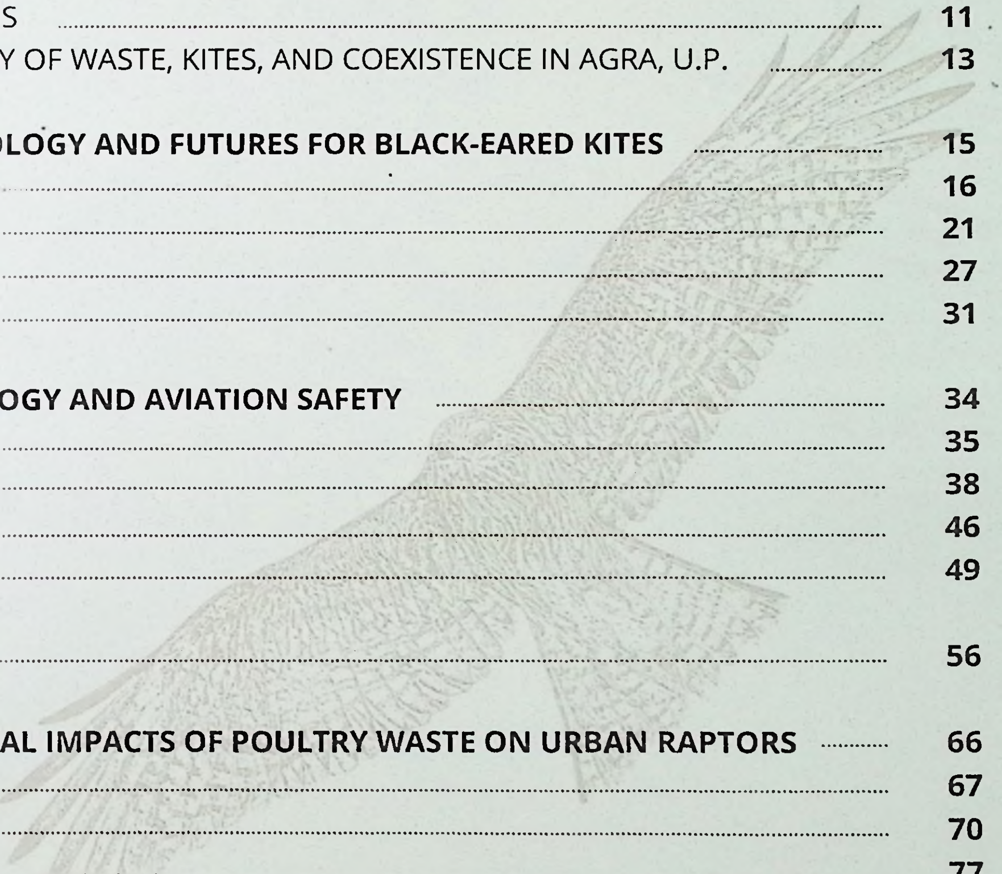


BLACK KITE PROJECT

IS A COLLABORATION BETWEEN WII AND RAPTOR RESEARCH & CONSERVATION FOUNDATION, MUMBAI

R·R·C·F

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

EXECUTIVE SUMMARY

The Black Kite, an opportunist, facultative scavenger in the South Asian urban ecosystems, is a highly successful bird of prey, adapting to various habitats from natural landscapes to bustling cities (Fig.1). This adaptability makes them one of the most numerous raptors globally (Ferguson-Lees & Christie, 2001). In the Old World, these kites are resourceful and opportunistic eaters, thriving on abundant food sources from human refuse and prey species like pigeons and rats in urban areas. They readily exploit human-generated waste, allowing them to maintain a healthy population and favourable conservation status (Galushin, 1971). In Indian cities like Delhi, they reign as the top avian predators within the urban ecosystem. Studies since the 1960s suggest their breeding density has remained stable. While most raptors require specific ecological conditions, Black Kites exhibit remarkable flexibility (Kumar et al., 2020a). They primarily nest in trees, indicating a need for green spaces within the city. However, a small portion (less than 5%) utilise man-made structures for nesting (Fig. 2). The ample availability of trees in Delhi provides suitable nesting grounds (Kumar, 2013; Kumar et al., 2019).

The abundance of garbage in cities - often amassing in the form of large landfills - provides kites with a readily available food source. Additionally, the positive attitude of residents in South Asia towards these birds allows them to breed undisturbed near human settlements. This human tolerance translates to moderate breeding success, with around half of breeding

Fig. 1. *A typical congregation of Black Kites in Old Delhi responding to ritual tossing of meat by Muslims that follow Sufi traditions (Jama Masjid area).*
Photo Credit: Fabrizio Sergio

pairs raising chicks to fledging (Kumar et al., 2014). The high density of Black Kites in southern Asian breeding grounds offers a unique opportunity for research. Scientists can compare these populations to European Black Kites, which have been extensively studied since the 1950s. Pioneering research in the 1990s on European populations focused on factors influencing chick survival, including hatching order, sibling competition, and food availability. These studies have become benchmarks for raptor biologists (Ferguson-Lees & Christie, 2001; Newton, 1979).

A crucial finding from European studies is the link between food availability and brood reduction (where some chicks die in the nest). When food is scarce, chicks compete more intensely, and some may not survive (Viñuela, 1996). Black Kites in Delhi exhibit hatching asynchrony (chicks hatching at different times) and brood reduction, likely influenced by the varying food availability across the city's diverse urban landscapes. To capture these ecological nuances, researchers have been using trail cameras in nests across different urbanisation gradients to study relationships with urban variables. These data are further combined with observations to assess hatching patterns, chick survival, growth rates, and nesting behaviour. Delhi hosts two subspecies of black kites: the resident breeding *Milvus migrans govinda* (small Indian kite) and the migratory *M. m. lineatus* (black-eared kite) that arrives from Central Asia and Southern Siberia via the Central Asian Flyway across the Himalayas. GPS-tagging revealed that *M. m. lineatus* kites migrate 3300-4700 km from their breeding grounds in Russia, Kazakhstan, Xinjiang (China) and Mongolia to Delhi in 3-4 weeks, crossing the Himalayas at elevations up to 5000-6000 m (Kumar et al., 2020b).

Fig. 2. *Black Kites are highly adaptable avian scavengers in South Asia, occasionally seen nesting on artificial structures.*

BLACK KITE PROJECT

(A comprehensive, long-term raptor ecology study in India, 2012 - 2024)

This research commenced with an initial investigation into the breeding ecology of kites and the phenological attributes of their breeding populations within the metropolitan city of Delhi during the year 2012 (Phase I). Here, it was established that their breeding densities in the national capital have remained stable since the 1960s, despite the virtual extinction of old-world vultures from the Indian subcontinent by the turn of the century (Kumar et al., 2014). Subsequently, the research team has engaged in the annual monitoring of approximately 150 nests with the objective of comprehending the manner in which various urban elements, such as waste management practices and human population density, impact parental feeding behaviour and the dietary composition of chicks (Fig. 3). These factors, in turn, exert an influence on chick growth, health, stress levels, and ultimately, their survival. Additionally, from Phase II onwards (2014-2016), the research team has undertaken an exploration of the role played by sibling competition in mediating these relationships (Kumar, Gupta, et al., 2018).

Fig. 3. *Black Kite Project team has been diligently monitoring the breeding ecology of these avian scavengers since 2012-13, collecting data from >150 nests every year.*

Through the focus on the behavioural ecology of kites (Phase III: 2016-18), we established how human cultural practices and attitudes may well be the most defining dimensions of the urban niche of opportunistic scavengers like kites (Kumar, Gupta, et al., 2018). This phase involved a comprehensive assessment of the breeding ecology of Black kites, and their aggressive interaction with residents along the sampled urban gradient within the megacity of Delhi. For this, we used the habitat selection criteria of kites (Kumar et al. 2018) and inspected the behaviour of breeding kites at 101 territories (total 657 visitations), and tested their offspring defence (Kumar, Qureshi, et al., 2018). We found that defence increases with proximity to ritual-feeding sites and availability of offal, apart from progression in the breeding stage. This period also included the beginning of Phase -IV (2017), an attempt to understand the migration of the *Milvus migrans lineatus*, the subspecies from the Central Asian Steppes wintering in the urban quarters of the Subcontinent from September to April every year. We deployed 13 GSM e-obs tags and 5 GSM tags from Microwave Telemetry Ltd. USA (Kumar et al., 2020b) (Fig. 4 and 5).

Fig. 4. *In 2017-18, the Black Kite project deployed 18 GSM-GPS transmitters to track the migratory Black-eared kites that form massive congregations at landfills and abattoirs in large cities.*

For the fifth phase of this project (2018-20), we studied the ways in which this species managed to adapt, respond and exploit such an extreme urban environment by running analyses at individual as well as population-level, through sampling at 32 independent plots of 1 km², randomly scattered to cover all the urban configurations present within the National Capital Territory of Delhi, which has an area of 1500 km2. In particular, we focused on the dependence of this population on anthropogenic subsidies, afforded as human waste (in the streets or at refuse tips) and as intentional "ritual offerings" of meat scraps for religious purposes, especially by people of Islamic faith that are concentrated in "Muslim settlements".

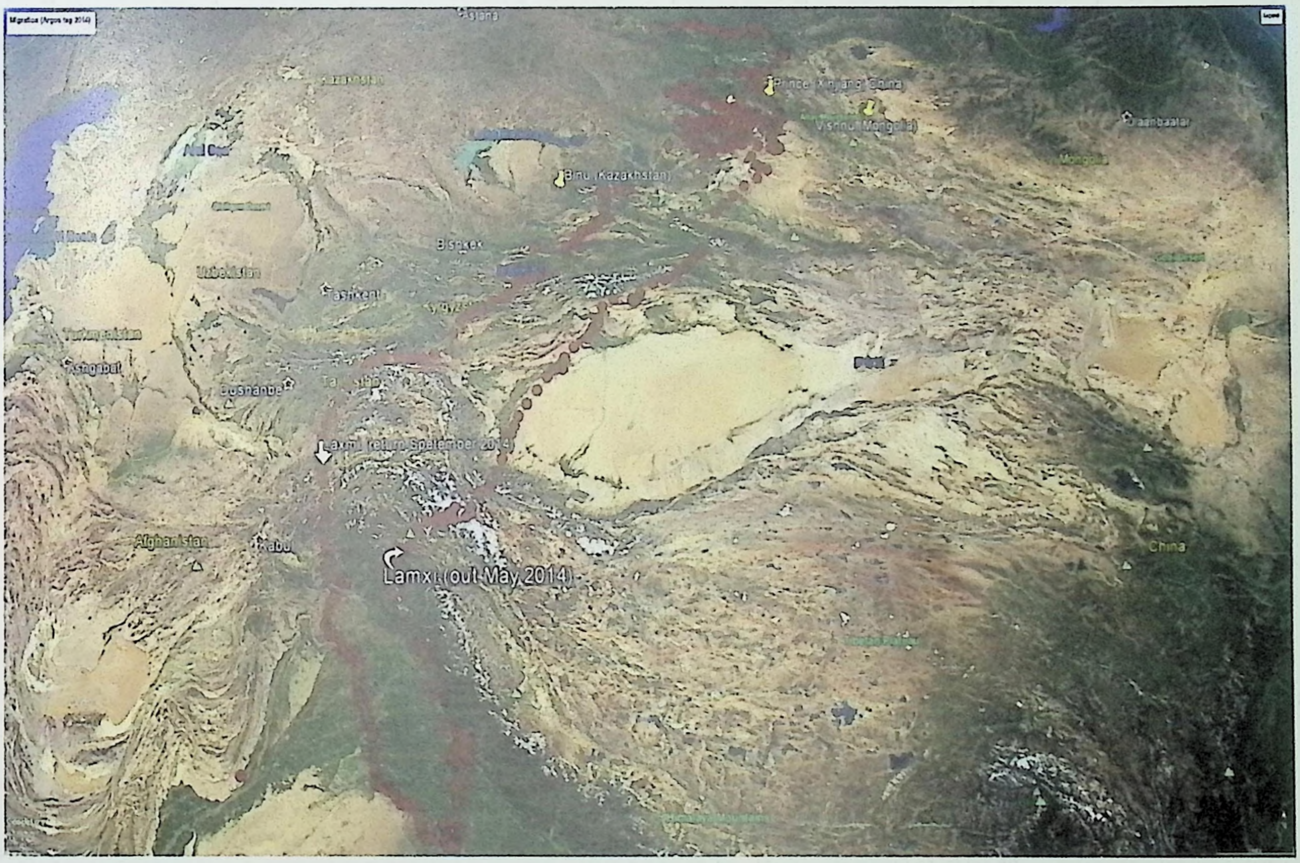


***Fig. 5**. The migratory tracks of the first kite (named Laxmi, after the field assistant) that was tagged in April 2014, using the Argos-GPS tag donated by Dr. Fabrizio Sergio. This was a remarkable finding that enhanced the basic and applied ecological aspects of the project further supported by RRCF in 2017-18.*

I. Black Kite Project: *Phase VI (2020 -2024)*

Raptor Research & Conservation Foundation, Mumbai's (RRCF) support through the Sixth continuous monitoring phase (2020 - 2024) of the Black Kite Research Project sustained its efforts in gathering breeding ecology data from 32 locations spread across a 1500 km² region within the National Capital Territory of Delhi. Notably, this period encompassed significant occurrences of the COVID-19 pandemic from 2020 to 2022. Consequently, the research captured facets of resource availability during a time when human movement and waste dispersion were restricted, as solid waste management faced disruptions in various parts of the city. The Black Kite Project team conducted a comprehensive study encompassing breeding ecology, foraging behaviour, and technological advancements for wildlife tracking. A select group of kites from the local breeding population (n =5) and a sample of 20 birds equipped with GSM tags from the migratory population were subject to remote monitoring.

Aims & Objectives	Status
Aim 1: To understand resource partitioning between the two subspecies of kites found within our study area, in terms of a. Food b. Habitat and c. Activity **Objective 1:** To explore how urban-configuration, e.g. spatial-cognition over food-resources using data on home range HR and Daily Travelled Distance DTD, sequester behavioural strategies along the diel and seasonal cycles for both kite subspecies.	• See Chapter 1 and 2
Aim 2: To understand the mechanism and outcome of trade-off in kites' behavioural bottleneck (i.e. conflicting interests) of nesting/roosting/foraging in proximity to humans **Objective 2:** To find the genetic, physiological and histo-pathological impacts of semi-colonial nesting in response to enormous food opportunities	• See Chapter 3 • All samples have been collected from the field and await further processing.

1) Nesting Ecology: Over the past four seasons, our team engaged in an extensive monitoring program of approximately 150 black kite nests across 10 strategically selected locations within the bustling city of Delhi. Through meticulous observations and data collection, we have gathered invaluable information on their nesting preferences, clutch sizes, and fledging success rates. By studying such a large sample size across diverse urban landscapes, ranging from residential neighbourhoods to industrial areas and green spaces, we gain a deeper understanding of how these birds adapt and thrive in a city environment.

Our findings have revealed that kites exhibit a remarkable ability to adapt to urban habitats, occasionally utilising various structures such as electricity pylons, lamp posts, etc., for nesting. Additionally, our data suggests that the availability of suitable nesting sites and proximity to food sources, particularly landfills and garbage dumps, play a significant role in their breeding success. Furthermore, our study has provided insights into the challenges faced by kites in an urban environment. These include exposure to changing aeroecology, habitat modification, and potential conflicts with humans. By understanding these challenges, we can identify measures to mitigate their impact and promote scavenging ecosystem services by this magnificent raptor species.

Our ongoing monitoring program contributes to the broader body of knowledge on the ecology and behaviour of kites, providing valuable data that can inform the science of urban coexistence and developing green infrastructure in urban planning. It underscores the importance of safeguarding natural habitats and green spaces within cities, ensuring a harmonious coexistence between wildlife and humans.

2) Camera Traps Reveal Nesting Secrets: In urban landscapes, nest camera proved beneficial information about breeding activity of the resident breeding kites. To understand the ecology of parental behaviour and chick development in such a dynamic environment, we have been deploying ~ 20-25 cameras each year on the nests since 2015-16, which continued through the last four seasons. These devices, strategically placed along the urban gradient at several randomly chosen nests, captured images 24X7, based on motion detection, shedding light on the intricate dynamics of avian family life.

The high-resolution cameras afforded intensive records of parental feeding routines, meticulously documenting interactions between parents and their offspring. Overall, each season we captured 3 - 4 million images that allowed researchers to observe the chicks' growth and development in real-time, charting the impacts of the urban environment on fledgling success. Beyond parental care, the camera traps also revealed potential threats within the urban environment. Predators such as civets, squirrels, macaques and crows posed a danger to the chicks, and the footage documented patterns in attacks. These observations highlighted the challenges faced by urban birds while opportunistically obtaining benefits from anthropogenic food subsidies amidst human habitation. By analysing the frequency and duration of parental visits, the types of food brought to the nest, and the impact of environmental factors such as weather and other disturbances on chick development, we aim to contribute to a deeper understanding of the adaptations and strategies employed by birds to successfully raise their young in the face of urbanisation.

3) Tracking of Resident Kites: In the sixth phase we executed GSM tagging (n = 5) of the resident breeding birds to understand their ecology in the metropolis of Delhi, India. Recognising the importance of monitoring the spatial movement decision concerning the camera trapping to understand unique challenges posed by densely populated areas, researchers embarked on using GSM-GPS platform terminal transmitter deployment, a cutting-edge tracking technology. These transmitters, equipped with GPS and accelerometer sensors, enabled real-time tracking and data collection, providing valuable insights into the movement patterns and behaviour of these facultative scavengers.

This project objective aimed to evaluate the effectiveness of this tracking technology in urban environments, where the presence of tall buildings, complex infrastructure, and human activity can pose significant obstacles to traditional tracking methods. By monitoring the tagged birds, we are gaining a deeper understanding of how black kites navigate the urban landscape, utilise available resources, and interact with their surroundings. The data collected through this project will be instrumental in advancing our knowledge about the ecology and ecosystem services of kites in Delhi. Specifically, the project will shed light on the following key aspects:

1. **Movement Patterns:** The tracking data will reveal the fine-scale movement patterns of black kites within the urban environment. We will be able to identify important foraging areas, roosting sites, and commuting routes, providing insights into the birds' habitat use and resource selection.

2. **Urban Adaptation:** The project will investigate how kites have adapted to the challenges of living in an urban environment. We will examine the birds' behavioural responses to human activities, such as infrastructure, pollution, and the presence of people.

3. **Relying on Readily Available Food Sources:** A critical aspect of the project is to understand how kites rely on readily available food sources in the urban environment. Researchers will analyze the birds' feeding behaviour, including the types of food they consume and the locations where they find sustenance. A unique aspect of the research focuses on the black kites' reliance on "ritual subsidies" – food offerings provided by Muslims as part of religious practices. The project team emphasises the importance of studying foraging behaviour within this context, as these easily accessible resources undoubtedly influence the kites' breeding ecology and movement patterns within the city.

The data collected will help inform birdstrike mitigation conservation strategies (discussed subsequently), urban planning decisions, and public education initiatives aimed at protecting urban biodiversity and their habitats (Fig. 6).

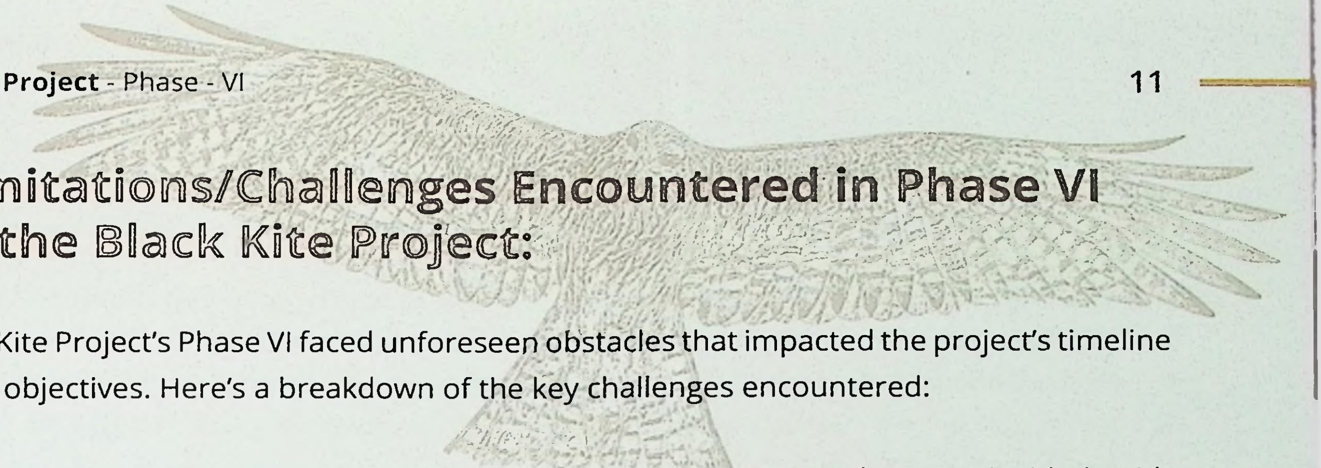
Fig. 6. *The data collected by GSM tagged kites will help inform birdstrike mitigation conservation strategies (discussed subsequently), urban planning decisions, and public education initiatives aimed at protecting urban biodiversity and their habitats.*

II. Status Report on Phase - VI (2020 - 2024): Aims and Objectives

A. Following the analysis of 10-year-old telemetry data from 20 Black-eared kites tagged since 2014, we preliminary understood habitat selection (stopovers) by kites migrating out of or into Delhi and the National Capital Region (NCR). To achieve this objective, approximately 120 point-locations of track confluence (an index for stopover described later in **Chapter 1**) were identified and utilised to varying degrees by one to all 20 kites. Furthermore, we employed a general linear model to assess the influence of environmental and human variables on the site fidelity exhibited by 20 tagged kites migrating from Delhi NCR to Jammu and Kashmir (J&K). The general linear model, featuring Poisson errors and a logit link function, considered the number of GPS-tagged kites at each site fidelity point (ranging from 1 to 20 kites using the same location) as the dependent variable.

B. In collaboration with the Indian Air Force and the Department of Forest and Wildlife, Government of the National Capital Territory of Delhi, we successfully implemented birdstrike threat mitigation measures. This was achieved through the utilization of data collected from thirty kites tagged since 2014, comprising twenty migratory and ten resident breeding kites. By analysing this data, we developed a plan for the co-option of a Meat-Feeding Ritual (**enclosed annexure; Chapter 2**).

C. We conducted a quantitative assessment of ecosystem services provided by migratory kite populations on the largest landfill in Asia, *Ghazipur*, Delhi. This research facilitated our understanding of the ecological implications of poultry waste on urban raptors during a global pandemic. Additionally, we evaluated the potential impact of the anaerobic decomposition of organic waste, which could contribute to climate change due to the release of methane, a potent greenhouse gas (**Chapter 3**). This component will contribute to the formal investigation of the physiological repercussions associated with the consumption of poultry waste by migratory kites, as detailed in our forthcoming research publications.



III. Limitations/Challenges Encountered in Phase VI of the Black Kite Project:

The Black Kite Project's Phase VI faced unforeseen obstacles that impacted the project's timeline and some objectives. Here's a breakdown of the key challenges encountered:

- **COVID-19 Lockdown:** Unfortunately, the global COVID-19 pandemic coincided with Phase VI, leading to significant delays in genomics analysis. Research laboratories faced operational restrictions and reduced capacity, hindering the progress of the 150 samples sent to the Tata Institute for Genomics and Society (TIGS). This vital aspect will be carried forward and addressed in the subsequent phase of the project.

- **Avian Influenza and temporary unavailability of Tracking Technology from the UK Collaborators:** The project's utilisation of Movetech Inc. tags, sourced from a British telemetry company, was disrupted due to an avian influenza outbreak in Great Britain. This outbreak caused significant losses (>70%) in seabird nesting colonies, a critical area of research for British telemetry companies. Consequently, these companies prioritised supplying tracking equipment for local efforts, impacting the availability of Movetech tags for our project. As a result, we could only use the budget for five GSM tags (out of the total grant of Rs. 16,20,000).

IV. Mitigating Birdstrikes During Republic Day Flypast: A Social-Ecological Approach

Challenge: Aeroecology and aviation safety often collide in urban areas. Rapid urbanization creates abundant food sources and suitable habitats for birds, leading to costly birdstrike incidents. Globally, the aviation industry experiences over 21,000 birdstrikes annually, causing losses exceeding $1.2 billion. In Delhi, black kites (Milvus migrans) pose a significant threat during the prestigious Republic Day flypast.

Our Approach: This study investigated a novel mitigation strategy that leverages both ecological and social factors. We focused on managing black kites, whose diet relies heavily (around 90%) on anthropogenic food sources. We implemented two key interventions:

1. **Waste Management:** We suggested improved waste management practices within the 15 km ceremonial flight path zone, reducing readily available food for kites.
2. **Cultural Co-optation:** We strategically utilized the traditional meat-tossing ritual practised by Muslim communities in Delhi. By carefully timing and positioning meat offerings outside the flight path, we aimed to temporarily displace kite flocks away from the flight formations

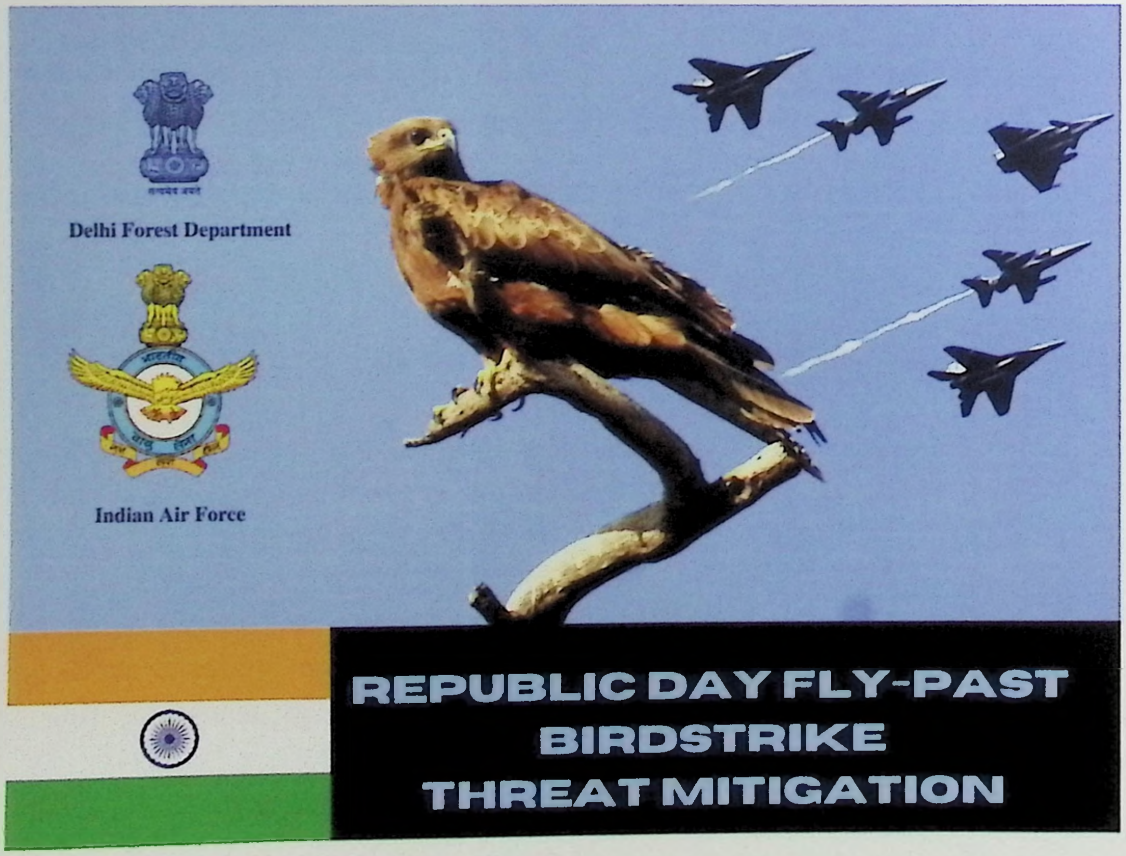
during the crucial flypast.Our strategy achieved some success, attracting kites to designated locations outside the flight path. However, limitations emerged:

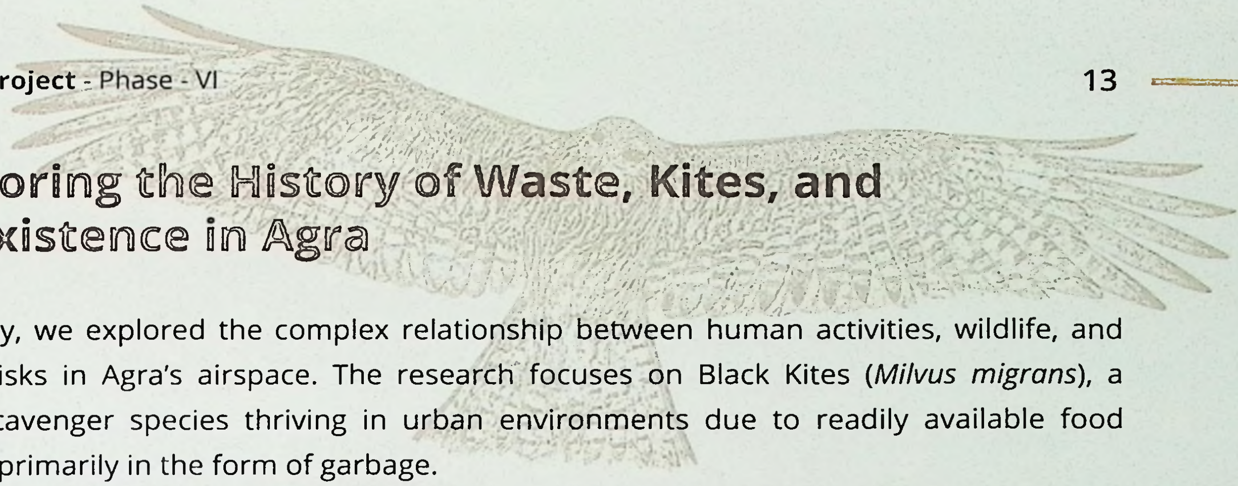
- **Weather Dependence:** The effectiveness of meat tossing was hampered by unforeseen weather conditions (overcast skies) that limited kite visibility.
- **Social Considerations:** Insufficient engagement with Muslim communities who traditionally perform the meat-tossing ritual meant some kites were already well-fed and less responsive to additional food sources.

Learning for the Future: This study highlights the importance of a socio-ecological approach to managing synurbic species (species adapted to living alongside humans). Conflicts involving these animals often involve cultural sensitivities and vary seasonally. Our research underscores the need to address social-ecological linkages to minimize stakeholder conflicts when managing wildlife and commensals in urban areas. Future efforts should prioritize:

- **Weather preparedness:** Investigating optimal tossing distances for varying weather conditions (using GPS data).
- **Community engagement:** Collaborating with Muslim communities to synchronize meat-tossing rituals with flypast timings, maximizing the impact on bird displacement.
- **Food source management:** Implementing long-term strategies to minimize readily available food sources (e.g., open-air food stalls) within the flight path zone.

By integrating ecological insights with social awareness, this study offers valuable lessons for mitigating birdstrike threats in urban environments with sensitive human-wildlife interactions.





V. Exploring the History of Waste, Kites, and Coexistence in Agra

In this study, we explored the complex relationship between human activities, wildlife, and birdstrike risks in Agra's airspace. The research focuses on Black Kites (*Milvus migrans*), a common scavenger species thriving in urban environments due to readily available food subsidies – primarily in the form of garbage.

Urbanization and the Rise of Opportunistic Scavengers:

Human-dominated landscapes significantly impact biodiversity. However, adaptable birds like kites exploit these changes. They capitalize on abundant resources, particularly food and habitat provided by urban infrastructure. This includes waste disposal practices that create predictable, albeit low-quality, food sources like landfills. Agra, situated near the migratory route of millions of birds, serves as a shared space for both aircraft and avian populations. This creates a potential conflict zone. The study emphasizes the need to understand the historical and contemporary factors influencing Black Kite behaviour to mitigate birdstrikes.

Waste as an Anthropogenic Food Subsidy:

The research delved into the connection between Agra's urban history and the spatial distribution of garbage-based food subsidies. Landfills, once disregarded, are now recognised for their ecological impact. They create new "Anthropo-stratigraphic" layers, influencing biodiversity and climate change.

This highlights the importance of understanding the historical context of waste management in shaping current bird behaviour and distribution. Landfills not only attract opportunistic birds but also contribute to environmental issues like altered local climates and disruptions to natural habitats.

Understanding Kite Behavior Through History:

Agra's rapid urbanization has significantly altered the spatial distribution of garbage, providing an abundant food source for kites. This surge in opportunistic birds poses a serious threat to aviation safety. The study underscores the need to:

- Analyze the historical drivers that shaped kite behaviour and interaction with the urban environment.
- Understand how habitat configurations within the urban ecosystem influence kite movements and interactions.

These insights will be crucial for developing effective birdstrike mitigation strategies.

Integrated Surveillance Technologies for Monitoring and Mitigation:

The pilot survey emphasizes the need for a comprehensive research approach, integrating data from various sources:

1. **Ocular Monitoring:** This real-time method provides high-resolution data on kite activities like flocking, mating, and foraging. It also helps assess the impact of infrastructure changes, food availability, and socio-cultural practices on bird behaviour.
2. **Testing UAV Surveillance:** This method offers a top-down view for monitoring kite movements across larger areas, providing valuable data on their directionality and spatial patterns.
3. **Exploring GPS-Tagging:** This remote assessment method has the potential to track kite movements over vast areas, offering insights into their behaviour through camera trap surveillance.

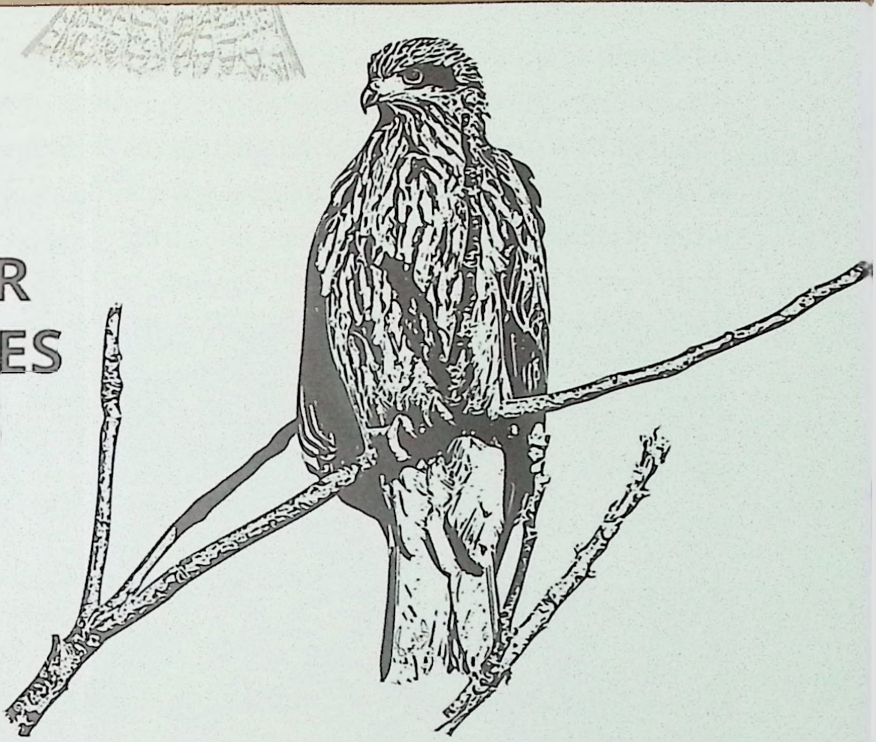
Integrating these technologies with data analysis using Artificial Intelligence and Machine Learning can lead to effective birdstrike mitigation strategies.

Conclusion:

This study presents a novel approach that combines historical analysis, ecological understanding, and advanced surveillance technologies. By leveraging these methods, Agra can develop strategies for managing urban bird populations and promoting a more harmonious coexistence between wildlife and aircraft. The findings from this research will be valuable for other urban ecosystems facing similar birdstrike challenges.

CHAPTER 1

- Chetan Krishna Bandhu, Nishant Kumar



URBAN ECOLOGY AND FUTURES FOR BLACK-EARED KITES SOARING ACROSS HIMALAYAS

Abstract

The global loss of habitats, the increase in human-wildlife conflicts, and the effects of climate change have played a significant role in the rapid decline of birds of prey. Among the many top trophic organisms that face significant challenges, raptors are among the least studied. Nonetheless, select species, such as the Black-eared Kite, an opportunistic raptor that winters in tropical regions have exhibited a remarkable capacity for adaptation to urban environments throughout Southern Asia and Australia. We aimed to explore the ecology of wintering Black-eared Kites *Milvus migrans lineatus* inhabiting rapidly urbanising regions of North India. A specific emphasis was placed on their fidelity to stopover sites during their migratory journeys while these birds arrive in and depart from the Indian Subcontinent. Ground-truthing exercises at selected site-fidelity sites (n = 120) ascertained through migratory route confluences revealed that *Lineatus* kites exhibited a preference for areas near landfills, dense vegetation, and semi-urban environments. GPS telemetry data from 20 tagged kites were analysed to model stopover site fidelity as a function of environmental or anthropogenic habitat correlates. Through Generalised Linear Modelling (GLM), we ascertained that the fidelity of stopover sites, or the frequency of their utilisation, was contingent upon the urban configuration. Specifically, open areas that facilitated the avoidance of active human interaction for kites while simultaneously providing convenient access to dumpsites/landfills and parkland or woodlots for communal roosting were crucial. An investigation into network analysis, utilising the frequency of site fidelity exhibited by multiple kites, yielded insights into the potential spatial redistribution of these opportunistic scavengers over time and space in the event of closure, decommissioning, or dismantling of landfills. The combination of these two analytical approaches emphasised the critical importance of incorporating specific ecosystem services provided by kites in a manner that does not create conflict for aviation, especially military aircraft, considering the spatial proximity of landfills to cities that often have airstrips located on the outskirts. The integration of non-human entities into urban planning could not only contribute to optimising their ecosystem services related to waste management but also uphold the socio-culturally mediated coexistence observed in South Asia.

Keywords: Black-eared Kites, Migration, Movement Ecology, GPS Telemetry, Human-wildlife interaction, Coexistence

INTRODUCTION

As humanity undergoes a gradual transition towards urban environments, projections indicate that approximately 70% of the global population will reside in cities by the year 2050 (World Urbanization Prospects, 2019). This concentration of resources necessary to sustain such a substantial number of individuals within a relatively small portion of the global landmass, encompassing <4%, has certainly had its impacts on non-human life forms. While human activities frequently exert detrimental effects on biodiversity, resulting in population declines or species losses, certain adaptable species have demonstrated a remarkable capacity to exploit anthropogenic resources and human presence for their benefit. These species, commonly referred to as urban exploiters or synurbic organisms, notably exhibit elevated breeding densities in close proximity to or within landscapes influenced by human activities. Environmental changes occur consistently, necessitating evolutionary adaptations among life forms, a process spanning thousands or even millions of years. However, in instances of rapid anthropogenic physical and chemical transformation of Earth, populations of numerous species may find themselves unable to respond effectively to novel cues, habitat fragmentation, and stochastic alterations to resource dispersion, all of which contribute as limiting factors.

Despite the apparent plethora of varied animal species dwelling within urban ecosystems, recent investigations have highlighted the existence of heterogeneity in the capacity of individuals, populations, and species to adapt to swift urban transformations. For instance, species such as

House Crows, Eurasian Blackbirds, and Squirrels have exhibited varying degrees of phenotypic plasticity in their responses to these changes. The metropolitan city of Delhi, which ranks among the foremost greenest cities for its avian species richness, hosts exceedingly large populations of resident and migratory Black Kites *Milvus migrans*. The intriguing congregations of these birds over landfills in numbers as vast as 10,000 pose several inquiries regarding the social and ecological processes that enable these raptors to exhibit their highest breeding density in the national capital (Kumar et al., 2014) (Fig. 1). These birds have coexisted in close proximity to human settlements, exploiting food subsidies derived from garbage units in villages, towns, and cities. Recently, the work of Kumar et al. (2020) has revealed that a substantial proportion of these birds that form immense flocks on garbage units are composed of migratory Black-eared Kites *Milvus migrans lineatus*.

Fig. 1*. Thousands of Black-eared Kites Seen at Ghazipur Landfill Site in Dehi; Picture credit: Fabrizio Sergio*

Black kites are facultative, opportunistic scavengers. In South Asian urban areas, they primarily utilise tall artificial structures and woodlots for communal roosting. They engage in soaring flight behaviour, characterized by graceful flight patterns facilitated by thermal currents. This enables them to glide effortlessly across urban landscapes while scanning roadside piles for potential foraging opportunities (Santos et al., 2017; Lanzone et al., 2012). Cities with heterogeneous development, such as Delhi, provide an ideal combination of green cover and proximity to extensive dump sites, thus offering the two essential habitat resources for birds of prey: habitat and food (Figure 1). However, the specific location patterns or areas preferred for roosting and feeding during their long migration journey should be studied more. Previous research indicates that kites from northern latitudes select specific urban habitat types for opportunistic foraging. Unlike the resident breeders in the Indian Subcontinent, they are associated with vegetated landscapes characterised by prominent greenery and ample water availability.

Aerial collisions involving opportunistic scavengers such as kites and aircraft pose a significant concern. This consideration arises from the unique and adaptive habitat selection of *lineatus* kites in close proximity to human settlements. This behaviour enables them to minimise encounters with humans while simultaneously capitalizing on available food resources. A recent study conducted by Srinidhi et al. (2020) revealed that over 60% of all birdstrikes resulting in damage are caused by kites. Consequently, we investigated how site-specific patterns in the utilisation of urban landscapes, known as site fidelity to stopover sites, influence the interplay of kite ecology and anthropogenic factors in Northern India. These kites have been monitored since 2014 at various locations along their migratory routes between Delhi and the Trans Himalayas.

Since these raptors avoid dense forests and rely on urban areas for scavenging, understanding how newly built tropical cities along their ancient migratory routes (utilised for millions of years) have impacted these kites is crucial. This will help us see how these cities influence the birds' selection of stopovers within the Indian Subcontinent. Studies on birdstrikes have demonstrated that aircraft collisions occur closer to the airfields at low altitudes when the aircraft have limited opportunities to detect and manoeuvre away from potential incoming threats during takeoff and landing at approximately 1067 m height, which is within 10 km from the airstrip's location. This implies that any environmental factor that causes bird congregation within 10 km of an airstrip can perpetuate birdstrike threats in the region. This study also presented an opportunity to explore a new frontier of human-wildlife conflicts in aerospace, approaching it from an interdisciplinary perspective by analyzing patterns with discourses within urban societies, planning, urban ecology, sustainability, health, and human-wildlife coexistence.

LITERATURE REVIEW

Migration ecology of raptors and kites

Many raptor species exhibit migratory behaviour, undertaking extensive journeys between their breeding grounds and wintering areas to adapt to seasonal climatic variations and fluctuations in food availability (Bildstein, 2006). During their migration, various geographical features such as mountain ranges, bodies of water, rivers, and urban landscapes influence their flight paths. Soaring raptors of medium (kites) to large size (vultures) have demonstrated utilisation of thermal updrafts to gain altitude and soar, aiding in energy conservation during their protracted migratory journeys (Newton, 2023). Both obligatory and optional migration strategies have been observed among raptors, primarily driven by environmental conditions (Newton, 2012). Disruptions to customary migration routes arise due to human-induced factors, including development within critical migratory corridors and the fragmentation of stopover sites (Bildstein, 2006).

Within the *Milvus* genus (old world kites), Black Kites are members of the *Accipitridae* family. The Old World hosts up to seven subspecies of these birds, which have a wingspan of approximately 160 centimetres and can be found in Europe, Asia, Africa, and portions of Australia (BirdLife International, 2021). Being obligatory scavengers, these raptor species frequently inhabit areas near garbage dumps, river bodies, and carrions. Due to their remarkable adaptability, they can easily adjust to human settlements (Blanco, 1997; Kumar, 2019). The rapid environmental stochasticity of these urban systems, in conjunction with the traditional practices of feeding by devoted citizens, renders these raptors exceptional providers of ecosystem services and regulators of vector-borne diseases (Blanco, 1997). The breeding ecology, nesting habits, and reproductive success of kites vary significantly due to anthropogenic resources. They have been observed to engage in communal roosting behaviour, gathering in large numbers in urban areas (Mazumdar, Ghose, & Saha, 2017).

Two of the seven subspecies of kites from Eurasia and Central/Northern Asia are renowned for their north-south latitudinal migratory patterns. The distances traversed during these migrations vary, ranging from the Arctic Circle to the Equator. In the context of the Indian subcontinent, their primary routes traverse the extreme ends of the Himalayan Mountain range, specifically the Trans Himalayas and the Eastern Himalayas (Juhant & Bildstein, 2017). One of the earliest documented instances of migration for these *lineatus* kites in India was conducted by Choudhary (2005). This confirmation was based on the recovery of a bird from Manipur that had been previously ringed in Mongolia. Accumulated evidence suggests that *lineatus* kites also engage in partial migration (Ali & Ripley, 1987). This implies that certain populations may migrate seasonally or locally, while others may remain resident, particularly when residing in urban ecosystems where sufficient food provisioning is available (Grimmett et al., 2011). During long-distance migrations, these kites have been observed to follow coastlines when crossing large bodies of water. This behaviour reduces their energy expenditure and minimises risks

(Agostini and Duchi, 1994). Additionally, research conducted by Litérak et al. (2022) identified specific stopover sites along the migration corridor, where the kites refuel and replenish their energy reserves. The Central Asian Flyway, recently elucidated for soaring raptors by Kumar et. al., (2020) is a significant migratory route that encompasses the Himalayas and serves as a pathway for these birds during their migrations.

Site-fidelity in kites and birdstrike threats

In long-lived k-selected species such as kites, progressive experience enables them to optimize resource acquisition, whereby individuals frequently revisit the same location based on previous successes. This phenomenon, examined at various levels of organization, is known as site fidelity (Munger, 1984). In the context of migratory avian species that rely on both intrinsic and extrinsic cues for navigation, site fidelity facilitates the successful repetition of migratory journeys. For example, Newton (2023) has discussed the significance of site fidelity in ensuring population viability in a world rapidly affected by anthropogenic influences. Given that migratory kites are diurnal migrants and make nightly stops during their journeys, their stopover choices should enable the maximization of net energy gain relative to their migratory efforts. In studies conducted by Agostini and Duchi (1994) and Sergio et al. (2014), researchers observed that individuals consistently improve their migratory performance by incorporating experience in ways that minimize exposure to natural and anthropogenic risks, ultimately increasing survival rates.

Considering the opportunistic behaviour of kites, the ecology of site fidelity frequently conflicts with aviation safety when spatial convergences occur where avian scavengers responding to food subsidies interfere with aircraft operations. Sodhi (2002) has addressed this novel competition in the context of aerospace. Soaring birds are undoubtedly a significant concern due to their ability to effortlessly glide within confined spaces for extended periods, which coincides with their foraging and mating rituals. Raptor species are particularly susceptible to collisions with aircraft as they glide and soar at high altitudes. Airstrips are often associated with patches of grass typically surrounded by woodlots, offering a suitable habitat for raptors that capitalise on prey provided by grass-associated species while nesting in the surrounding tall trees.

The efficient management of birdstrikes has primarily concentrated on habitat management within the boundaries of airfields, frequently neglecting the urban ecosystems that exist beyond these limits. Although airfield management has demonstrated some effectiveness in deterring passerines and other small bird species, a landscape approach may prove more effective for large soaring birds that can easily travel several kilometres in search of resources. In practice, strategically placing garbage units can redirect flocks away from hazard zones, while simultaneously enabling scavengers to provide valuable ecosystem services, as demonstrated by Pfeiffer, Blackwell, and DeVault (2020). Attempts have been made to integrate remote sensing technology for the detection and deterrence of bird congregations that pose a threat (Thorpe, 2016).

MATERIALS AND METHODS

Research Objective and Questions

To study the Ecology of wintering populations of Black-eared kites within rapidly urbanizing North Indian Urban Spaces.

Q.1. Which habitat correlates (e.g., dumping ground or water bodies) explain the patterns in Site fidelity shown by 20 kites GPS tracked (2014 – ongoing) between Delhi and Jammu Kashmir / Ladakh?

Q.2. How do these habitat correlates link with birdstrike threats?

Study Area and Design

The research area encompassed a continuous geographic region in the northern Indian landscape, with a primary emphasis on the National Capital Region centred on Delhi, extending to the northernmost Indian territory of Jammu and Kashmir and Laddakh. The study involved remotely following the tracks observed through GPS analysis up to the northernmost territory of India, as depicted in Figure 2. This focal region was bordered by the Great Indian Desert to the west, the Ganga floodplains to the east, the Aravalli hills (one of the oldest mountain ranges in the world) extending to Delhi, and the Himalayas to the north. The Delhi region also includes the Yamuna floodplains and the Aravalli hills area. As we move further north from Delhi, we encounter the Shivalik hills, and even further north, we reach the higher reaches of the Himalayas. The region is classified as a Tropical Dry Deciduous Forest, located within the Ganga and Yamuna Plain, transitioning into montane forests in the Himalayas. A diverse range of tree species is found in this montane region, including Teak, Sal, Chesham, Poplar, Chir, Pine, and Deodar (Champion & Seth, 1968).

Within the Northern India region, significant cities that encompass the study area include Delhi, Gurugram, Noida, Faridabad, Ghaziabad, Meerut, Hapur, Aligarh, Agra, Panipat, Ambala, Chandigarh, Zirakpur, Jalandhar, Adampur, Ludhiana, Jammu, and Srinagar. As illustrated in Figure 3, numerous airports directly align with the migratory routes of the Black-Eared Kites. In recent years, the region has experienced substantial population growth, leading to increased urbanization (National Capital Region Planning Board, 2022). Projections suggest that the regional population may exceed 90 million by the year 2031, establishing it as the largest such region within India (Statista Research Department, 2023).

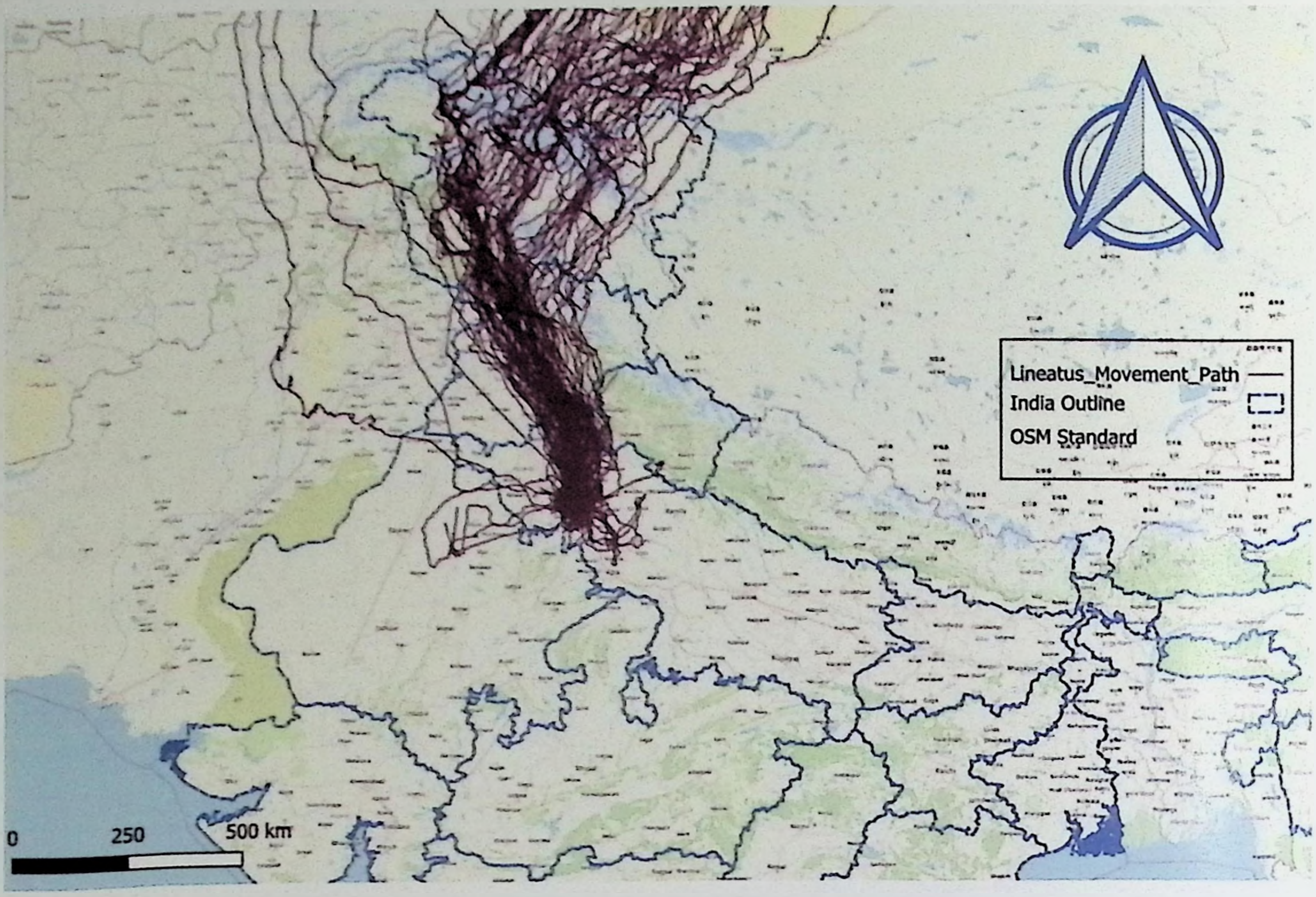


Fig. 2. *The map depicting the spatial boundaries of the study area, accompanied by the delineated movement trajectories of nineteen tagged Lineatus kites.*

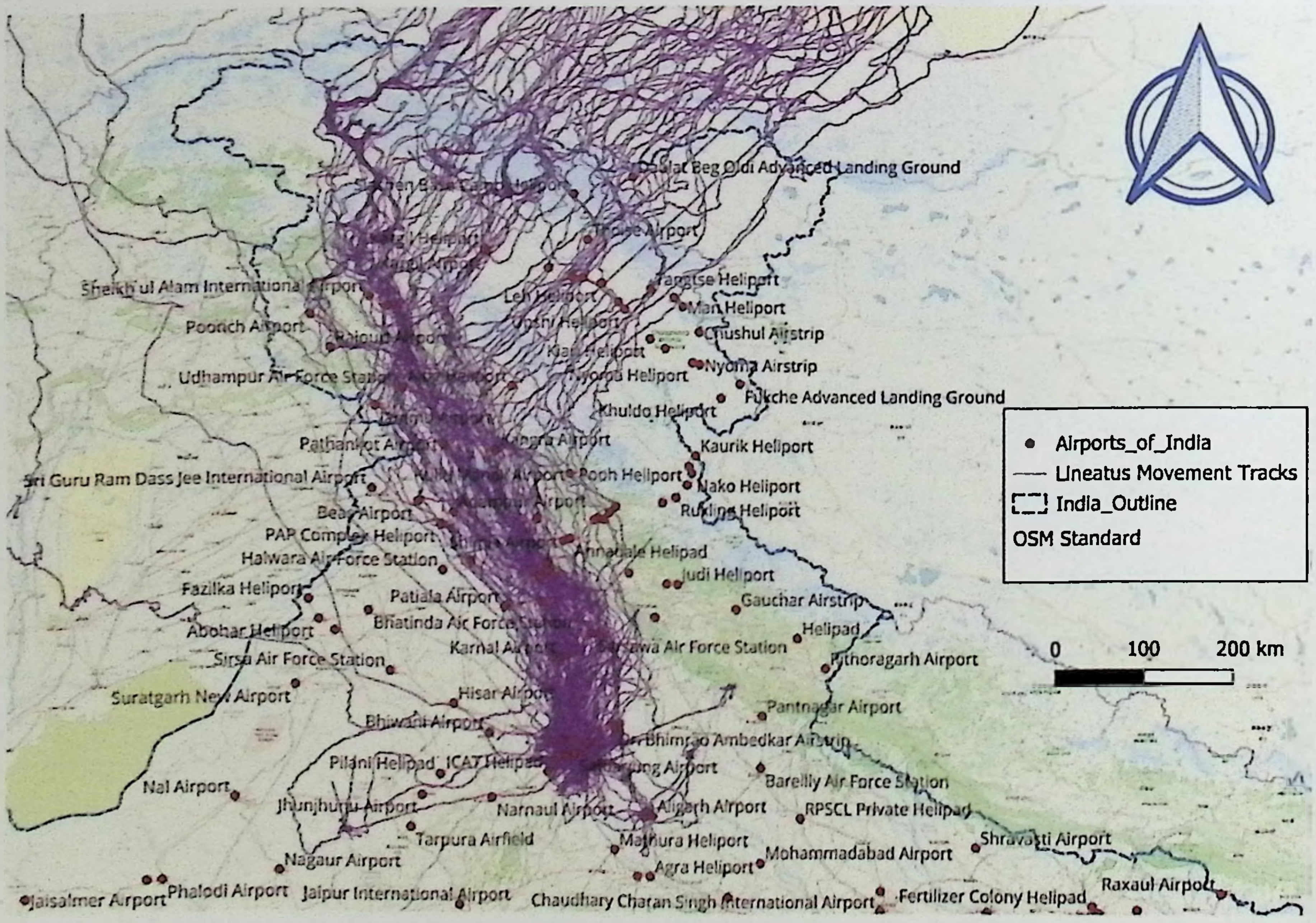
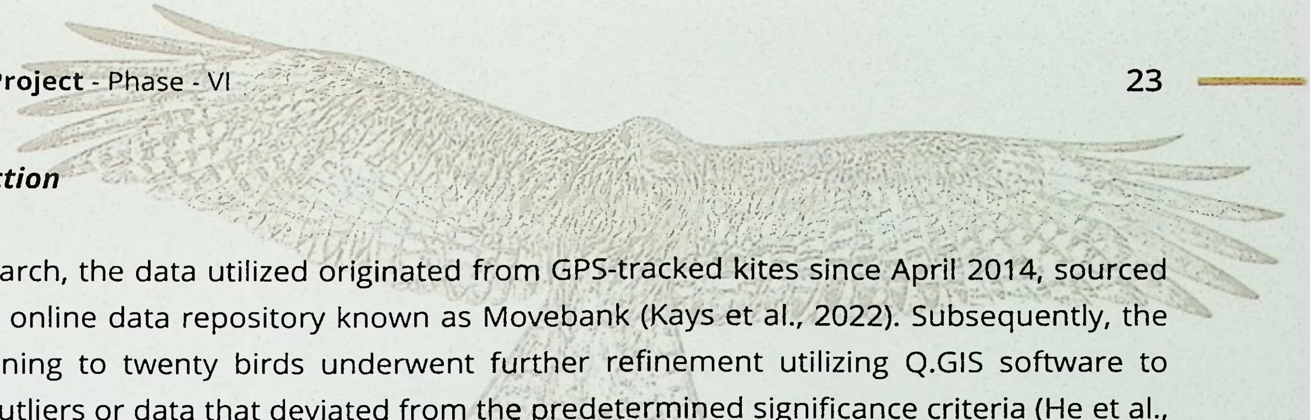


Fig. 3. *All Airports Situated Within the Northern Region of India Along the Migratory Route of Black-Eared Kites*



Data Collection

In this research, the data utilized originated from GPS-tracked kites since April 2014, sourced through an online data repository known as Movebank (Kays et al., 2022). Subsequently, the data pertaining to twenty birds underwent further refinement utilizing Q.GIS software to eliminate outliers or data that deviated from the predetermined significance criteria (He et al., 2023). Following the screening of the raw data for irregularities, these datasets were processed in QGIS software version 3.34.5-Prizren (QGIS Development Team, 2024) for the spatial analysis of movement tracks along the migratory route. The tracks were integrated as a vector layer through the 'add delimited text layer' feature under 'Layer' for each tagged kite data. Spatial analysis was conducted by visualizing the tracks overlaid on top of the OSM standard map within QGIS.

Following the addition of layers for all twenty tagged birds, we analysed site fidelity points (an index for stopover sites determined based on track confluences). This analysis utilised a fixed scale of 1 centimetre to 100 kilometres for all locations where the tracks began from the Delhi region until Jammu and Kashmir. During the visualisation process, we designated a track as a Site-Fidelity Point (SFP) if it exhibited continuous crisscrossing and repetition at the aforementioned scale (Fig. 4). This type of track visualisation, displaying multiple tracks converging, traversing, and crisscrossing, indicates that the kites selected specific areas during their migratory journeys for an extended period, repeated over the years (Munger, 1984). Employing this methodology, we identified 115 SFPs. The comprehensive list of all 115 SFPs can be found in the Appendix 1 -6. Subsequently, we ranked these SFPs based on the number of kites that visited each location (as indicated by the track data of tagged kites showing track congregations at the same point). After ranking these points, the top seventy were selected for further analysis, ensuring a stratified representation of SFP locations that were utilised by a single kite versus those utilised by more than one kite.

Fig. 4. *Example of how we selected the site-fidelity points on the map using Q-GIS.*

Field validation to measure habitat features at varying scales

To obtain a thorough grasp of the environmental factors influencing the choice of SFPs, we incorporated field validation into our research methodology. To mitigate potential biases, we strategically selected sampling locations across the gradient of SFP usage by one to 20 kites. Notably, over 50% of the sites were situated within the Delhi NCR region, with the remaining sites located in areas north of Delhi. To facilitate our analysis, we categorised the sites into two distinct strata: the Delhi NCR region and the Rest of the Region. This stratification enabled us to scrutinize potential variations in SFP usage patterns between the two geographic regions. Subsequently, based on rankings of these kites as mentioned in the preceding section, the top ten ranked locations were identified from both regions (see Appendix 1-6). To investigate how the frequency of SFP use varied amongst tagged kites across the Delhi to J & K mosaic of urban structure, human densities and practices, we measured a series of environmental, urban and human variables previously found to be important components of habitat quality and food availability in this population. These variables are detailed in Table 1 and were devised so as to characterise: (1) the access to predictable food subsidies from landfills; (2) the access to the closest roosting site; (3) proximity to the nearest water body; (4) the extent of openness of the region that allows migratory kites to avoid active interaction with people (5) the extent of impervious surface/built area. Further details of the recorded variables and their ecological rationale are given in Table 1.

Feature	**Description**
Distance to Nearest Dumpsite (Km)	Distance (in kilometres) from the site fidelity point to the nearest dumpsite or dumping area, measured using Google Earth satellite imagery. With increasing access, we expected a higher frequency of SFP usage by kites.
Distance to Nearest Roosting Site (Km)	Distance (in kilometres) from the site fidelity point to the nearest vegetation or green area, measured using Google Earth satellite imagery. With increasing access, we expected a higher frequency of SFP usage by kites.
Distance to Nearest Waterbody (Km)	Distance (in kilometres) from the site fidelity point to the nearest water body, measured using Google Earth satellite imagery. With increasing access, we expected a higher frequency of SFP usage by kites.
Extent of Open Area	Binary value (1 or 0) indicating the presence of an open area around the site fidelity point. Determined by analyzing the portion of the woodlots/built-up area visible in the satellite imagery. (1 = Open Area Present, 0 = No Open Area). We anticipated that open areas would serve habitats that attract kites when they have garbage/landfills that attract these migratory scavengers, as they capitalise on food subsidies while simultaneously minimising their frequency of encounters with humans. (Refer to Kumar et al., 2020, for additional information.)
Extent of Urbanity	Ordinal Gradient score (1, 2, or 3), representing the level of urbanisation around the site fidelity point. Determined by visually estimating the proportion of built-up area in the satellite imagery. (1 = Least Urban, 2 = Moderately Urban, 3 = Most Urbanized). We expected urbanisation (large towns or cities) to create foraging opportunities for kites over landfills.

Table 1. *Variables measured to model the frequency of the use of Site Fidelity Points (SFPs) (by 01 to 20 GPS-tagged kites), as a function of several environmental variables within the areas between Delhi and J & K (India).*

Qualitative Data

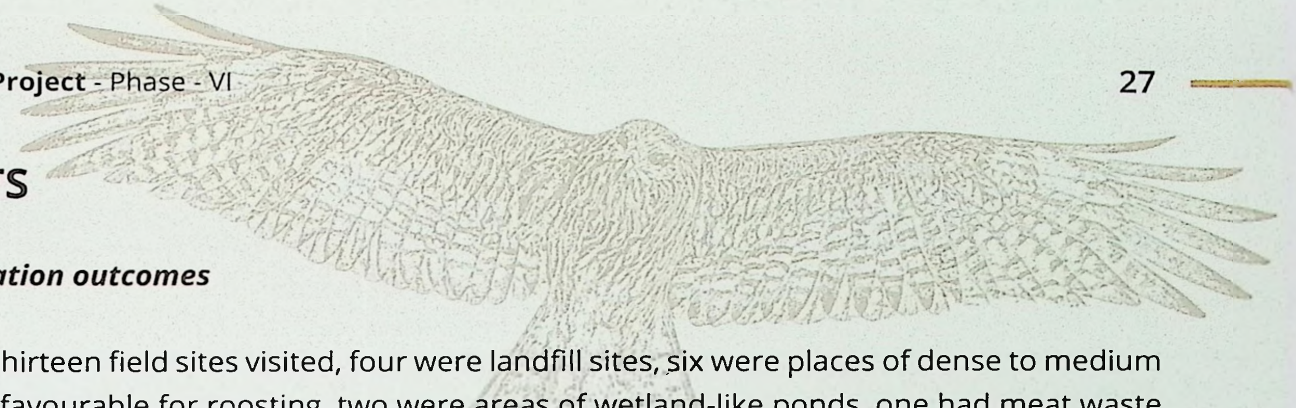
We have been conducting semi-structured interviews with officials of the Indian Air Force since 2015-16 to gain an understanding of the current patterns in birdstrike issues, and measures employed to address threats. The interviews were transcribed promptly to ensure the preservation of the information obtained during the conversation. Any additional data or information was requested via email channels for further clarification and elaboration.

Statistical analyses

We employed a general linear model (Zuur et al. 2009) with a backward stepwise procedure to examine which environmental factors explained the degree to which kites used 115 SFPs (Table 1). To reduce collinearity and the number of variables presented to the GLM, we employed the variable reduction method proposed by Green (1979) and commonly employed in habitat selection studies (e.g. Austin et al. 1996; Soh et al. 2002). In this method, pairs of strongly inter-correlated variables ($r > 0.60$) are considered as estimates of a single underlying factor, and only one of the two is retained for analysis, usually the one likely to be perceived as more important by the study organism. Collinearity was subsequently checked further by examining the variance inflation factors (VIF) of the explanatory variables, which were always low (< 2; Crawley 2007; Zuur et al. 2009).

All multivariate models were built by a frequentist approach through a backward stepwise procedure following Zuur et al. (2009): all explanatory variables were fitted to a maximal model, extracted one at a time from the maximal model, and the associated change in model deviance was assessed by the significance of a likelihood-ratio test; the procedure was repeated until we obtained a final model which only included significant variables (Zuur et al. 2009). To avoid over-parameterization, we ensured never to fit more than N/3 variables to each maximal model, where N is the sample size of the analyzed dataset (Crawley 2007). Interactions were fitted only when we had a priori hypotheses about their potential effect, based on our field observations and knowledge of the population. Model assumptions were checked by investigating QQ plots, histograms of residuals, and plots of standardized and normalized residuals against fitted values and explanatory variables (Crawley 2007; Zuur et al. 2009). All GLMs were implemented in R.3.0.2 (R Development Core Team 2009). When necessary, variables were logarithmically, or arc-sine square root transformed in order to achieve a normal distribution. All tests are two-tailed, statistical significance was set at $\alpha < 0.05$, and all means are given ± 1 SE.

We conducted network analysis using the Gephi software tool. The kites, each identified by their unique tag ID, and all of the habitats they inhabited, were represented as nodes within the network. The edges of the network were defined by the interactions between these tagged kites and various habitat correlates. The network was constructed with the tagged kites as the source nodes and the different habitats visited by them as the target nodes. The comma-separated value (CSV) file containing the node and edge data is provided as Appendix 1-6.



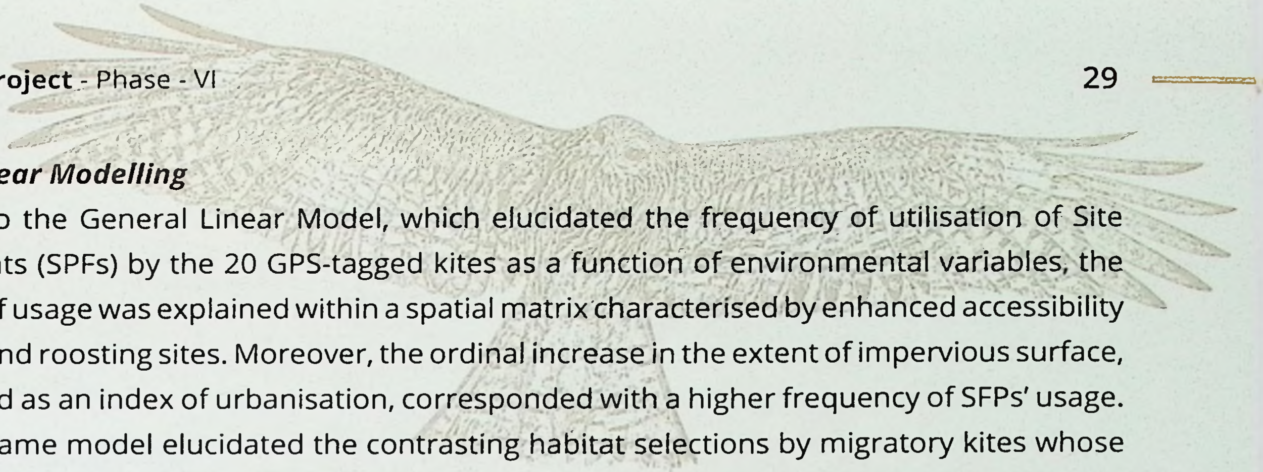
RESULTS

Field validation outcomes

Out of the thirteen field sites visited, four were landfill sites, six were places of dense to medium vegetation favourable for roosting, two were areas of wetland-like ponds, one had meat waste and the other had open ground and waste surrounding it, and one was located near the Yamuna floodplains along the riverine ghats in Delhi and NOIDA border with ample rubbish in the water. Although the sample size for field validation is not a comprehensive representation of the total SFPs, it provided sufficient details to inform our GLMs for further analysis. The objective was also to gain an understanding of the diverse habitats frequented by these kites and to identify explanatory variables that make those sites conducive for their repeated visits. While detailed field notes were prepared, the summary for these sites is tabulated below, focusing on certain significant observations made in all thirteen different habitats. Migratory kites exhibit a proclivity for direct human encounter in cramped city spaces and favour vegetated areas. While wintering, their dietary habits were primarily influenced by the availability of deceased carcasses or human-supplied refuse. The majority of their site-fidelity locations feature a body of water in close proximity. Expansive open areas provided these birds with suitable conditions for locating and capturing food subsidies and/or their prey.

Site	Description (this is the post-migration period for lineatus)	Kite Activity (May)
Ghazipur Landfill Site & Poultry Market	Extensive landfill site flanked by poultry and fish markets on either side. The highest concentration of kites was observed in this location. Kites were feeding on discarded poultry waste. Their movements were limited during peak market activity.	*High*
Maharajpur Green Area	A well-regulated area characterised by extensive secluded bound plantation with towering Eukalyptus trees, providing an ideal environment for avian roosting. Ranked as the second-highest site, located three kilometres from Ghazipur.	Medium
Yamuna Flood Plains	Along the Yamuna River, there is an accumulation of trash at various points. This accumulation comprises a diverse range of items, including fish, deceased animals, and trees that serve as roosting sites. Furthermore, the confluence of tracks often coincided at elevated electrical towers.	Medium

Site	Description (this is the post-migration period for lineatus)	Kite Activity (May)
Ghaziabad	A park with a railway track is located in the background. Several kites were discovered roosting close to a diminutive body of water. The convergence of tracks frequently coincided at elevated electrical towers.	Low
Jamia Milia Islamia Campus	Large vegetation patch with eucalyptus trees. Construction threatens future use for roosting.	Low
Bhalswa Landfill	Large landfill with less visitation than Ghazipur. Kites are concentrated in areas with fresh waste. (Figure-9)	Low
Okhla Landfill	Engineered landfill with waste segregation. Kite presence is confined to areas with fresh waste.	Low
National Zoo & Sunder Nursery	Lush green, highly maintained area with regular human presence. Primarily resident Govinda kites roost here. Abundance of food remains from animal feed.	Low (resident kites)
Chandigarh	Various locations including landfills, semi-forested patches, and a large forested area used for dumping animal carcasses. The area is now under real estate development.	High
Panipat	Large ash dumping ground with a central lake. Open areas with surrounding lakes. A strong stench indicated carcass dumping.	Low
Mauli Near Barwala	Farm pond with evidence of poultry waste dumping. Surrounded by open farmlands.	Low
Ambala	Cantonment area with restricted access but satellite imagery suggests ample green space for roosting. Agricultural fields surround the area.	Medium



General Linear Modelling

According to the General Linear Model, which elucidated the frequency of utilisation of Site Fidelity Points (SPFs) by the 20 GPS-tagged kites as a function of environmental variables, the frequency of usage was explained within a spatial matrix characterised by enhanced accessibility to landfills and roosting sites. Moreover, the ordinal increase in the extent of impervious surface, which served as an index of urbanisation, corresponded with a higher frequency of SFPs' usage. Lastly, the same model elucidated the contrasting habitat selections by migratory kites whose frequency of SFPs' usage increased if food subsidies were offered in a relatively open area that enabled them to consume garbage while minimising frequent human encounters.

Network Analysis

The diagrammatic representation of bipartite networks, derived from the frequency of visitation to SFPs by twenty GPS-tagged kites, yielded a graph with both the tagged kite ID and habitat represented as nodes. The kites (depicted in green), exhibiting a strong association with frequently visited sites (SFPs; represented in pink), were positioned centrally within the graph. The dimensions of the circles (nodes) were directly proportional to the level of connectivity, with larger circles indicating a higher degree of connection and vice versa. Furthermore, an examination of the network graph reveals that specific sites, such as *Ghazipur* Landfill, Maharajpur, Bhalswa Landfill, and Najafgarh *Jheel*, potentially influence the selection of wintering habitats by migratory kites within a rapidly urbanising landscape.

Another intriguing observation deduced from the graph is the impact of urban changes in waste allocation for non-humans in the form of garbage piles/landfills that have cascade effects. It pertains to the scenario wherein certain nodal landfills are eliminated, prompting an inquiry into the subsequent ramifications for the network and its response. In this context, it suggests that if a specific site fidelity location, such as a landfill site and its corresponding roosting area (e.g., Maharajpur), were to be removed, it would be pertinent to consider the potential implications for the kites that frequent these areas. Employing the same principle, we discovered that the network is no longer centred around that particular landfill, and numerous smaller clusters have emerged. This indicates that removing such large predictable sites would compel the kites to seek alternative locations to fulfil their feeding requirements. Consequently, these extensive landfill sites serve as centralised feeding or foraging grounds for these migratory birds, and any alterations would have a consequential impact on how these birds utilise their habitats (Fig. 5 and 6).

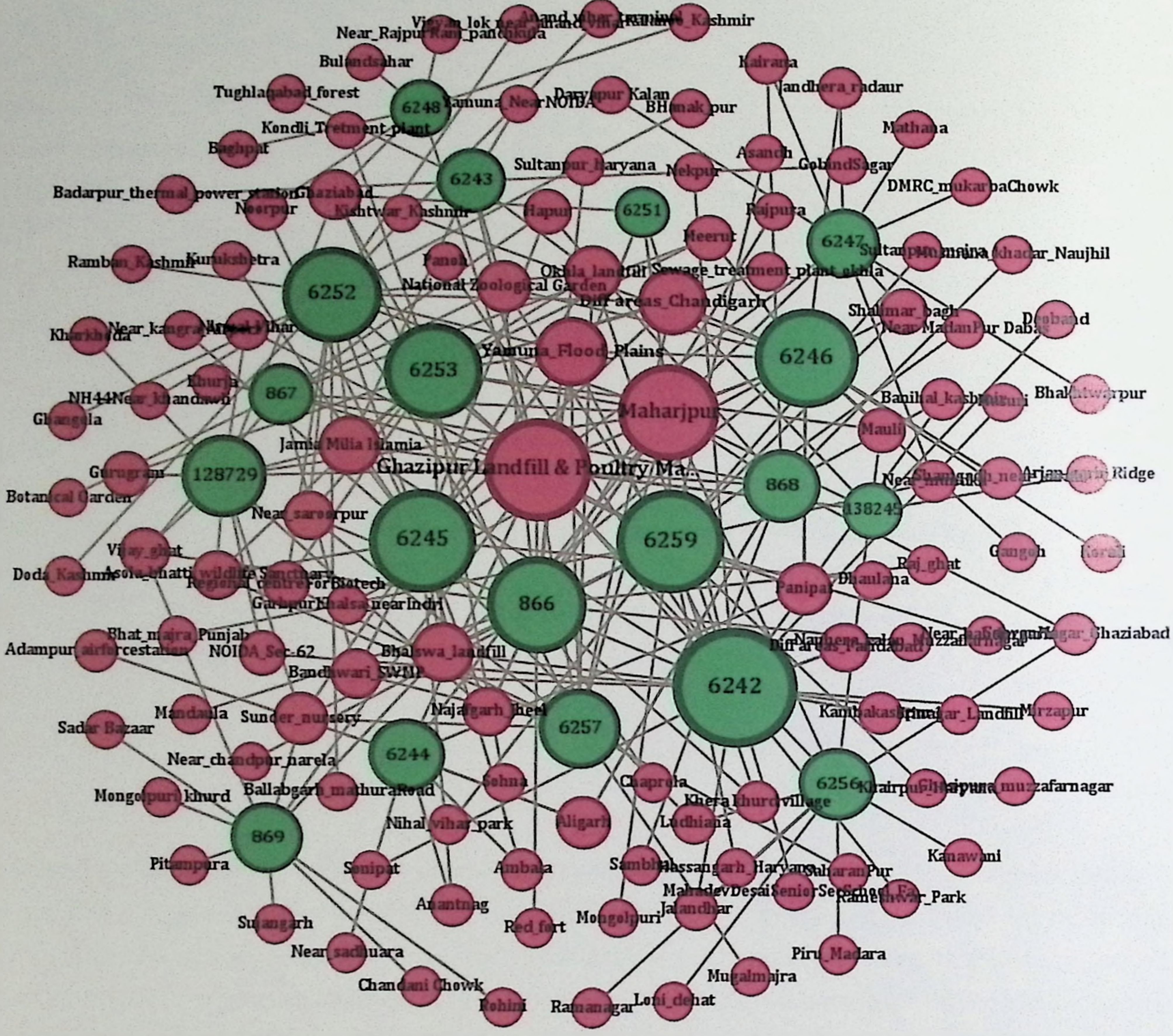


***Fig. 5**. Bipartite network of kites and their wintering habitat selection with respect to site fidelity points.*

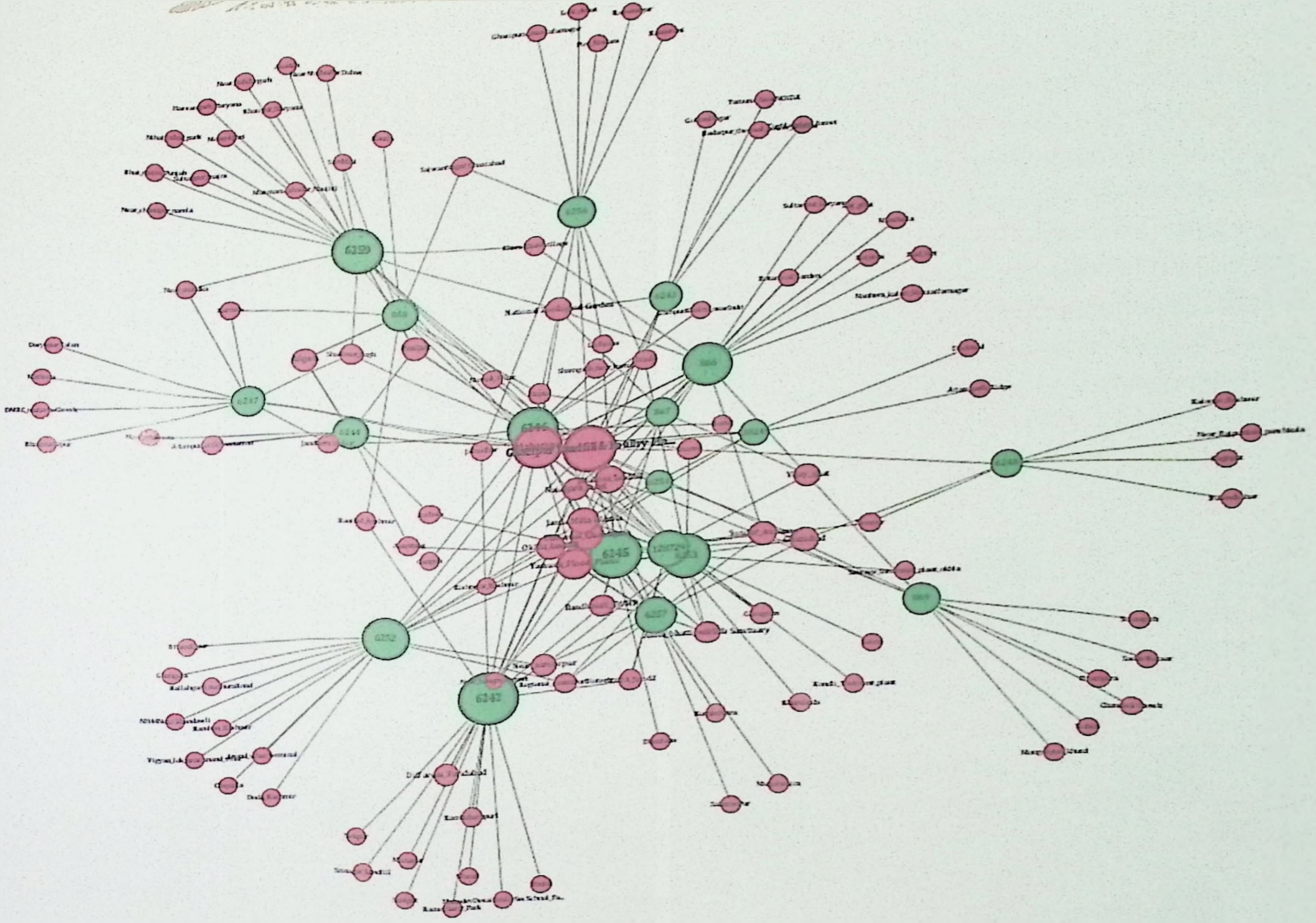


Fig. 6. Network of Black-eared kites and their habitat selection in Yifan Hu Layout (Hu 2005).

DISCUSSION

Our findings establish that migratory kites exhibit distinct habitat preferences, despite their apparent ability to forage in diverse locations. The patterns of usage of SFPs indicate that seemingly ubiquitous species that opportunistically feed on garbage also possess specific habitat requirements. This observation necessitates a comprehensive examination of how anthropocentric modifications within urban ecosystems impact the suitability of habitats represented by these SFPs. While some studies have begun to explore the role of anthropogenic food subsidies in mediating habitat suitability, this field remains relatively understudied. Field validation revealed the critical importance of roosting sites, given the specificity of location choices that remain consistent for each bird over two to seven years of continuous monitoring. Consequently, urban opportunism depends on the ability of these habitats to provide essential safety and protection from humans, other predators, inclement weather conditions, and anthropogenic disturbances. These factors ultimately influence the survival and fitness of the birds.

Furthermore, as noted by Mazumdar, Ghose, and Saha (2017), kites exhibit a distinct preference for tall trees, such as Eucalyptus, which are believed to contribute to their safety. Roosting sites are strategically situated in areas with minimal human activity, allowing for efficient access to feeding grounds, such as landfills. The selection of feeding habitats was influenced by the predictable availability of prey/human refuse, lesser competitors and predators, and accessibility that helps optimise energy reserves for migratory kites (Kumar et al., 2020b; Panuccio et al., 2014; Sergio 2003). In this paper, we further elaborate on our findings, exploring the novel domain of conflicts within the aerial landscape and the potential future of spaces shared between humans and avian scavengers.

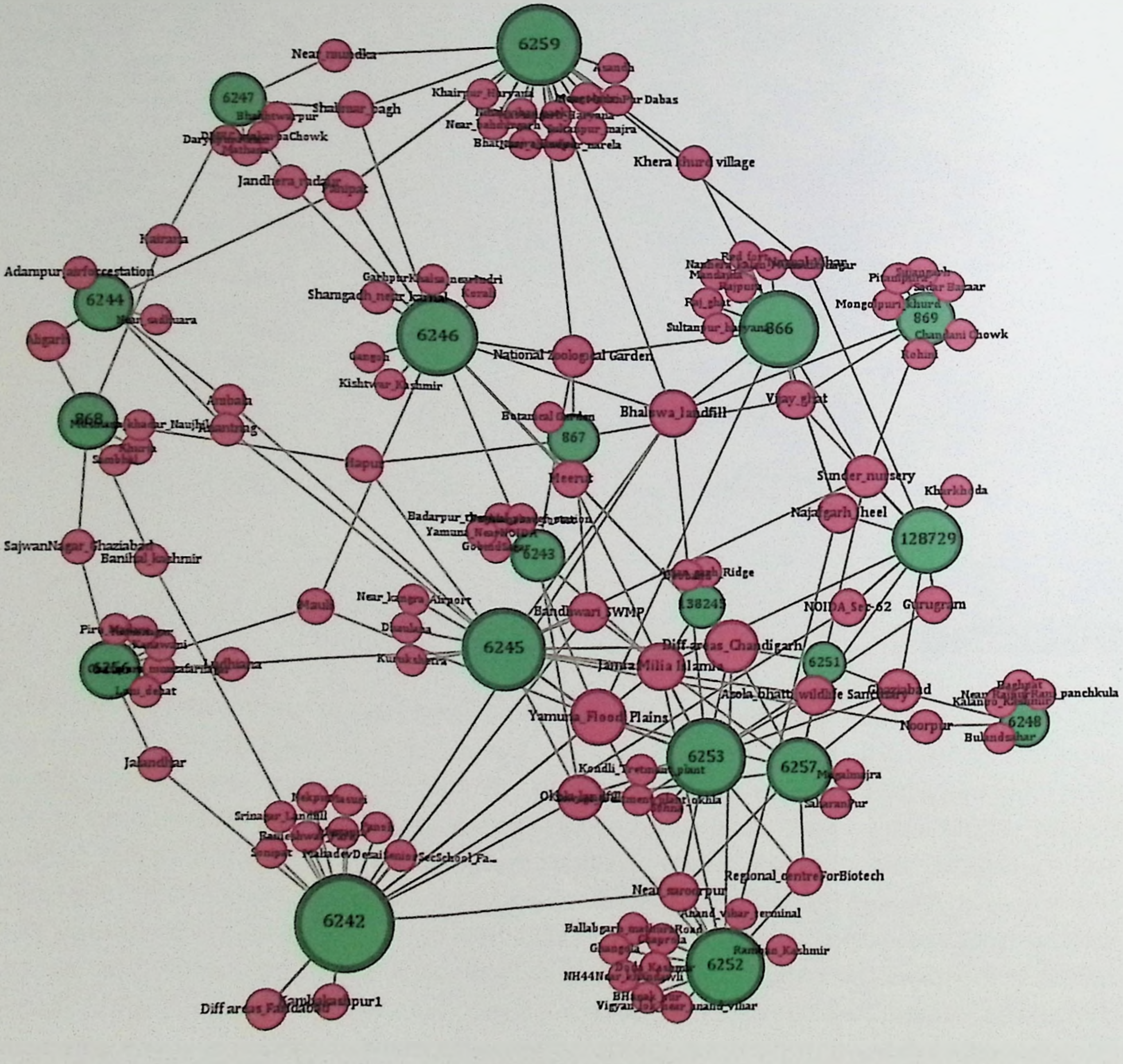


Fig. 7. Alterations to the bipartite network when large landfills were removed to simulate the ongoing municipal drives to flatten and discontinue their usage in Delhi.

Aeroecology: New Frontier of Human-wildlife coexistence - conflict conundrums

Due to the anticipated ongoing growth of air travel, novel technologies such as drones or unmanned aircraft are proliferating, amplifying the potential for conflicts. Simultaneously, the aerial pathways for avifauna are progressively experiencing rapid changes to biophysical parameters due to human activities, diminishing the habitats available for birdlife. As a consequence, safety concerns are likely to intensify, propelling the domain of coexistence in the airspace to the forefront. The increasing frequency of aerial mishaps will inevitably result in escalating financial implications. Cities, being dynamic entities, undergo modifications over time, extending selection pressure on nonhuman species sharing spaces. Consequently, the implementation of a structured ecological-conscious urban planning framework becomes imperative to address these challenges. As noted by Geddes (1949) in his seminal work titled "Cities in Evolution," the integration of ecological principles into the design of urban landscapes arises as a fundamental necessity. The concept of lumpen urbanisation (Gidwani and Maringanti, 2016) and planned illegalities (Bhan, 2013) profoundly illustrate the prevalent types of informal settlements found at the peripheries of major cities.

Looking Forward: A Sustainable Future for Black Kites in Urban Areas

Our research provided valuable insights into the complex habitat selection patterns displayed by kites in urbanising environments. Through an understanding of their resource requirements and the potential consequences of urban development, movement ecology offers a scientific approach to devising effective conservation strategies that will ensure the continued survival of kites in these dynamic landscapes. Historically, kites have exhibited a remarkable capacity to adapt to the evolving landscapes of the Old World. By thoughtfully incorporating their needs into our urban environments, we have the opportunity to foster a sustainable future that benefits both humans and these fascinating avian scavengers.

This study highlighted the significance of migratory kites' preference for green spaces, such as parks, gardens, and undeveloped areas, as foraging and roosting grounds. This finding aligns with the observations of Kumar (2019). While acknowledging the importance of preserving existing urban green spaces, the results suggest that strategic greening of areas in proximity to landfills can enhance the scavenging ecosystem services provided by these opportunistic avifauna. Such initiatives in urban planning would not only facilitate the bioremediation of waste but also mitigate potential consequences related to zoonotic diseases and climate change effects resulting from the anaerobic decomposition of organic waste in landfills. Ensuring the availability of essential habitat for kites during the planning of landfills and avoiding the placement of airstrips in their vicinity can contribute to the overall liveability and well-being of urban residents (Fig. 7).

Furthermore, the study underscores the need for education and public awareness campaigns to foster a greater understanding and appreciation of ecosystem services by kites among urban residents. By promoting responsible behaviours, such as avoiding feeding kites in critical birdstrike risk zones and disposing of trash properly, we can mitigate potential conflicts between humans (aircraft) and wildlife, promoting coexistence.

CHAPTER 2

- Nishant Kumar, Urvi Gupta, Nikita Gupta, M Hisham K, Yadvendradev V Jhala,
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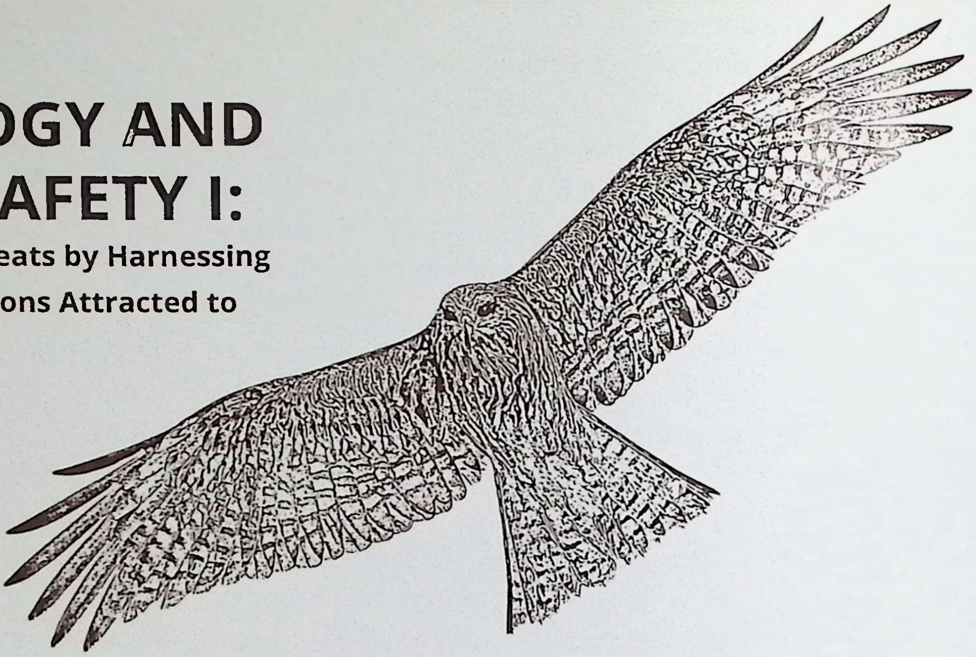
AEROECOLOGY AND AVIATION SAFETY I:

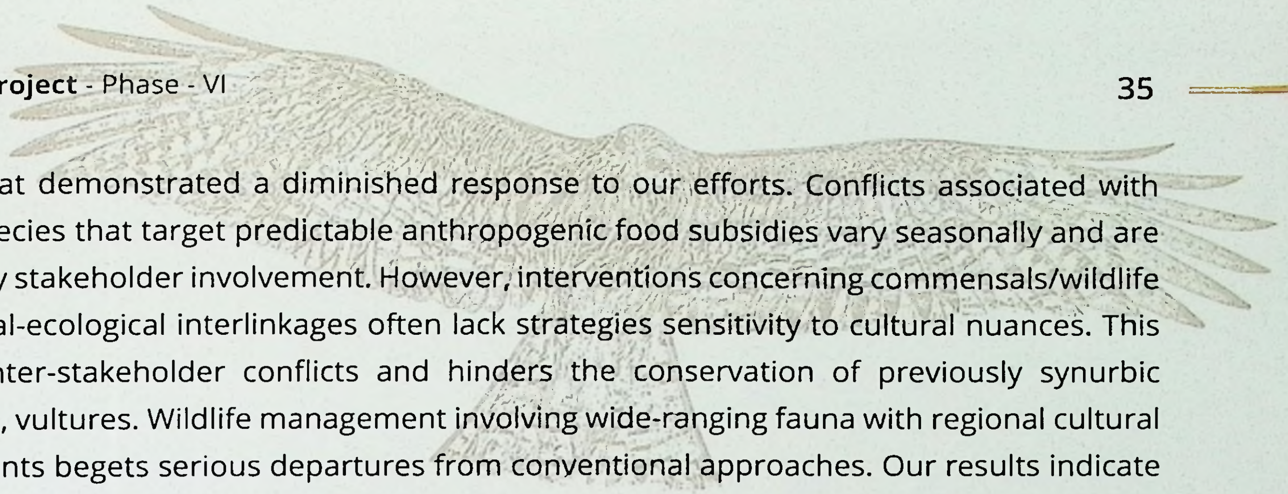
Mitigating Birdstrike Threats by Harnessing Urban Raptor Congregations Attracted to Meat-Feeding Ritual



Abstract

The intersection of aeroecology and aviation safety within urban areas is a critical issue, as birdstrikes pose significant risks during takeoff or landing. This problem is amplified by rapid urbanisation and the projected 5% annual growth in air traffic. Worldwide, the aviation industry incurs losses of $1.2 billion from over 21,000 birdstrikes annually, attributable to birds responding to anthropogenic food subsidies and securing habitats.

Since 2022, we have been mitigating birdstrikes by the Black kite, globally the most abundant raptor, during India's Republic Day Parade in Delhi. This is achieved by managing kites' access to waste, and temporarily displacing hovering flocks by co-opting their congregations in response to the ritual meat-tossing that forms around 90% of breeders' diet. This gregarious behaviour was strategically leveraged to divert kites away from the ceremonial flight strip, based on kites' home range and altitudinal-gradient matrices, and by carefully matching meat-induced flocking with the arrival of flight formations. The efficacy of this mitigation strategy was somewhat constrained due to a lack of coordination with the Muslim community, who traditionally feed kites at mosques and insufficient readiness for reduced visibility during adverse weather conditions. Intervention misalignment with Muslims resulted in already well-



fed kites that demonstrated a diminished response to our efforts. Conflicts associated with synurbic species that target predictable anthropogenic food subsidies vary seasonally and are mediated by stakeholder involvement. However, interventions concerning commensals/wildlife having social-ecological interlinkages often lack strategies sensitivity to cultural nuances. This escalates inter-stakeholder conflicts and hinders the conservation of previously synurbic species, e.g., vultures. Wildlife management involving wide-ranging fauna with regional cultural entanglements begets serious departures from conventional approaches. Our results indicate how conflict mitigation/management involving tropical species must consider their inextricable ties with human activities, cultural practices, politics, history, socio-economics, and urban planning at multiple spatiotemporal scales.

1. INTRODUCTION

Land use and human population changes impact wildlife within and outside cities (Anonymous, 2016), but there is poor information on how they affect the use of aerospace by birds. By 2033, worldwide urbanisation and concentration of wealth would double the number of 'aviation mega-cities' to 91, leading to >5% annual growth in air-passenger traffic over the next 10 years (Airbus, 2014). This higher air-traffic, in addition to the anticipated use of manned/unmanned drones for freight and other purposes, pits birds and aircraft against each other in limited aerospace. Typically, this conflict pans out in the form of birdstrikes (Sodhi, 2002), creating an aeroscape of threat for the aviation industry.

The remarkable growth in global air transportation has resulted in increasingly congested skies, as witnessed by the significant expansion observed on a worldwide scale. Within the context of India, the quantity of air passengers has undergone significant expansion, from 2.67 million in the year 1970 to 167.49 million in 2019 (Arrondo et al., 2021). Consequently, the increase in aircraft operations has led to a corresponding increase in bird collisions. Drawing on global estimates cited in Weishi et al., (2021) - now two decades old - the aviation industry reportedly incurs annual losses of $1.2 billion due to over 21,000 birdstrikes. Building on the aforementioned global context, it is estimated that the Indian Subcontinent alone experiences more than 2,000 birdstrikes annually. This regional issue is further underscored by data from the Indian Air Force (*pers comms*), which reported three incidents during the rehearsal for ceremonial flights on India's Republic Day in January 2023 alone.

Birdstrike incidents, a significant concern in aviation safety, involve a wide range of avian species from small passerines to large soaring birds such as pelicans, storks, vultures and kites (Dolbeer, 2006; Perrow, 2017). The circumstances leading to birdstrikes can be broadly categorised into four types, based on the ecology and behaviour of the involved avian taxa. The first category encompasses situations where birdstrikes are precipitated by sudden and stochastic flock formations near aeroplanes (*Making Airspace for Birds and Planes | Audubon,* 2012), a phenomenon frequently depicted on the internet (*No, a Flock of Birds Did Not Attack an Airplane,* 2018). The second pertains to bird flocks migrating to and from their wintering areas, exhibiting temporally and spatially patterned formations (Newton, 2010; Sodhi, 2002). The third and arguably most challenging category involves birds that opportunistically respond to anthropogenic food subsidies and/or habitats (Baxter et al., 2003). Finally, during ceremonial flight formations, like the Republic Day Parade in India, dozens of military aircraft fly in fixed formations at low altitudes- which are more susceptible to birdstrikes since the majority of strikes happen at altitudes under 1000 metres (Metz et al., 2021; authors' unpublished data). Such directional flight formations are incorporated in salutation ceremonies across the world, endangering the aircraft, as well as the invaluable lives of pilots and citizens.

Factors that influence the flock strength of opportunistic birds are primarily related to spatial autocorrelations between non-human habitat preferences, technical requirements for airstrips, and the municipal obligations of sanitising urban areas (Shao et al., 2020). To begin, highly populated urbanising areas, either currently possess or are likely to acquire airstrips that are typically viable on the city outskirts (Kasarda, 2000). Since the majority of birdstrikes happen at low altitudes when the aircraft cannot abruptly avoid bird flocks, zones of take-off/landing often become threat hotspots (Metz, Ellerbroek, Mühlhausen, Kügler, & Hoekstra, 2021). Secondly, urban centres, acting as hubs for immigration, accommodate diverse communities. These communities frequently employ unique expressions to demonstrate their connection to the natural world (UNESCO, 2016), e.g. the practice of ritual feeding (Kumar, Singh, et al., 2019; Pinault, 2008; Taneja, 2015). In addition to direct feeding, densely populated urban environments frequently generate enormous litter, including roadside refuse and substantial landfills, catering food subsidies to animals (Kumar, Singh, et al., 2019). Starting in the late 20th century, municipalities across the world have utilised landfills as a means of isolating waste from populated areas. Landfills also accumulate substantial food subsidies away from human settlements (Cavé, 2014; Ferronato & Torretta, 2019; Gandy, 2016; Shahmoradi, 2013). These factors generate spatial autocorrelation among airstrip locations, landfill placement, and avian scavenger foraging areas. These spatial autocorrelations are advantageous for migratory birds travelling from northern latitudes to the equator. Birds within these large flocks face competing selection pressures to adapt to human proximity while taking advantage of food subsidies (Kumar, Qureshi, et al., 2018; Kumar et al., 2020). Accordingly, the interrelated connections between avifauna and human-induced food sources have garnered considerable attention in research exploring their impact on migratory strategies and the resultant concentration of birds in winter habitats situated along significant migratory flyways (Gilbert et al., 2016).

Various measures have been implemented by organisations associated with aviation and aeroecology to mitigate the occurrence of birdstrikes or minimise their impact (details in the methods). In terms of technical solutions, the primary focus of bird avoidance strategies has been on improving the safety features of engines to render them more resistant to birdstrikes. For instance, Lockheed Martin and Boeing have collaborated with the Smithsonian Institution in the United States to conduct research aimed at identifying species that are commonly involved in airstrikes (Dolbeer et al., 2023). Another approach involves utilising weather radar systems in conjunction with digital imaging techniques and bird distribution maps to detect and predict potential birdstrike threats, thereby mapping the risk landscape for aviation (Gauld, 2022). Real-time measures to enhance airfield safety and reduce birdstrike risks include modifying aircraft flight schedules, altering or limiting bird habitats, implementing wildlife removal protocols, employing bird harassment techniques, and introducing interventions designed to make the airfield less attractive to birds (Dolbeer et al., 2023). The utilisation of on-board bird harassment equipment has demonstrated limited efficacy (Metz, Ellerbroek, Mühlhausen, Kügler, Kern, et al., 2021).

Despite initiatives to track patterned flocking, birdstrike mitigation strategies often prove insufficient, owing to inadequate contextualisation of behavioural and life history dissimilarities across species, populations, and subpopulations. In cases where certain species form social-ecological linkages (Kumar, Gupta, et al., 2018), their behaviours and life histories can intertwine with specific human beliefs and practices (Kumar, Singh, et al., 2019). This can lead to unfavourable outcomes when mitigation planning overlooks these anthropogenic factors. Efforts to alleviate the situation through interventions such as habitat management, e.g., temporarily intensifying solid-waste disposal, or abruptly halting ritual-feeding practices to limit the threats from avian scavengers, may inadvertently become counterproductive. This is because these mitigation measures often fail to contextualise the species-specific choices that birds make when accessing and utilising foraging and habitat resources.

In this article, we delve into an innovative approach to mitigating the birdstrike threat posed by Black kites *Milvus migrans* (hereinafter kites), a species implicated in 62% of all aircraft collisions in India. This approach was born out of a collaborative effort involving multiple stakeholders, who convened under the aegis of Delhi's Chief Wildlife Warden. The joint committee's objective was to devise ecological solutions to mitigate birdstrikes, with a particular focus on the Republic Day ceremonial flight past in the national capital. Our proposed solution drew heavily on prior research on kites in Delhi (Kumar, 2019). A significant aspect of this mitigation intervention pertains to the cultural practices and beliefs of the local Muslim community, specifically the ritual tossing of meat chunks, which forms >90% of the diet of breeding kites. This ritual has been studied for its impact on kite behaviour and spatially explicit demographic responses. In the ensuing sections, we discuss how we co-opted this ritual practice into our mitigation strategy, thereby integrating cultural practices with scientific research to address a pressing ecological issue. We also explore the broader implications of this approach for birdstrike mitigation strategies, where conventional approaches have yielded limited success.

2. METHODS

2.1. Study Area

Delhi, seated within a network of rapidly expanding satellite cities, is home to over 30 million people and spans an area of 1500 km^2 (Census Organization of India, 2011; UNO, 2018). The city's layout is polycentric and diverse, featuring a variety of urban configurations that defy a linear urban-rural gradient, representative of South Asian urbanism (Shahmoradi, 2013). The climate here is semi-arid, with an average annual rainfall of 640 mm that primarily occurs during the monsoon season in July and August. The city experiences a wide temperature range, with average minimum temperatures of 8.2°C in winter and average maximum temperatures of 39.6°C in summer (IMD, 2022). The regional vegetation is classified as 'northern tropical thorn forest' (Champion & Seth, 1968).

The city displays three critical aspects that significantly influence the interactions between humans and avian scavengers. First, the inadequate solid waste disposal systems have led to the emergence of informal livelihoods, which are central to waste processing and contribute to the persistence of roadside garbage piles (see Kumar et al., 2019 for details). These piles vary in size and content, fostering a cultural reliance of citizens on the private services of the urban poor, who work to move, sift and dispose of waste in association with various facultative avian scavengers (such as kites, crows, egrets, and pigeons), and opportunistic mammals. This detritus and associated non-human organisms impart a distinctive visual and olfactory ambience to tropical urban settings, epitomising the sensory aspects of tropical urbanisation (Doron, 2021). Second, the recent increase in meat consumption patterns in Delhi and its surrounding regions is creating subsystems of animal waste. These changes are challenged by the increasing volumes of unsegregated waste and animal byproducts, coupled with the scarcity of suitable waste disposal sites. Finally, conflicts over alternative waste space arrangements have arisen among civic authorities tasked with urban planning and solid waste management (Kumar, Singh, et al., 2019).

2.2. Species of concern: resident and migratory populations of kites

The Black kite is a medium-sized raptor that is currently considered to be one of the most numerous and successful birds of prey in the world. A generalist, opportunistic feeder, it can reach extremely high densities where food concentrations allow it (see Desai & Malhotra, 1979; Ferguson-Lees & Christie, 2001; Kumar et al., 2014). It may occupy habitats ranging from undisturbed to completely urban. This opportunism and capability to exploit human-modified habitats has afforded the species a generally favourable conservation status, with frequent reports of recently increasing populations, despite some local declines (Kumar et al., 2014).

The ability of kites to adapt to human environments is most evident in populations that nest in urban areas; these old-world kites form spectacular concentrations of wintering birds *M. m. lineatus* over landfills (Kumar et al., 2020). In these settings, kites use the urban ecosystem for nesting and for feeding on human waste, roadkill, animal carcasses, and garbage. They are often found hovering in small to large flocks, over open spaces or at garbage dumps in large cities. When these dumps are located near airports or military airstrips, the concentration of kites can create serious management problems due to the risk of collisions with aircraft (Kumar et al., 2014; Satheesan & Satheesan, 2000). This capability to adapt to human landscapes reaches its extreme in populations that nest or winter in fully urban conditions, as frequently observed in Asia and Africa. These kite populations rely on a network of human refuse across these urban areas, which could have significant implications for their survival and migration patterns (Newton, 2010). Kites' use of Delhi's aerospace is shaped by three historical factors: the prevalence of litter in streets, the city's conspicuous mediaeval infrastructure due to its historical status as a walled city (Gupta, 1981), and the cultural disposition of people towards kites, most prominently the act of centuries-old religious practice of feeding meat scraps to kites (hereafter termed "ritual-feeding"). These elements influence the behaviour of kites (Kumar, Gupta, et al., 2019; Kumar, Qureshi, et al., 2018), leading them to frequent areas near humans and infrastructure, posing a potential risk to aviation.

2.3. Identification of stakeholders to address birdstrike threat.

The Indian Air Force (IAF) has been actively addressing the issue of birdstrikes, a significant threat to aviation, since 2008. However, birdstrikes have been recorded to affect flights and ceremonial flight pasts since 1970s. In the interim, the IAF also commissioned research on aspects of birdstrike mitigation in collaboration with the Bombay Natural History Society (BNHS) through the 1970s, focusing on various aspects like species identification. Cognisant of the seriousness of the situation, the IAF established an Ornithology Cell under the Directorate of Aerospace Safety (DAS) at the Air Headquarters in 2010. The Cell has representatives at all major IAF airfields. It is responsible for monitoring and recording bird activity throughout the year. The DAS also records kite activity and birdstrike threats during the Republic Day Ceremonial Flight Past (RDC), a task that has been diligently performed for the past 28 years. Over the past decade and a half, IAF has been engaged in an ongoing dialogue with the Ministry of Environment, Forest & Climate Change (MoEF&CC), and the respective state units, underscoring the urgency of addressing the birdstrike issue.

The comprehensive strategy for birdstrike mitigation extended beyond airbases and focused on urban areas, considering the anthropogenic food sources and habitats that attract birds. This discourse, marked by its longevity and the IAF's commitment, has negotiated a spectrum of potential solutions, from deterring kites to more extreme measures such as capture, restraint, and even culling. The IAF's persistent appeals, requesting permission to cull or trap problematic birds underscore the seriousness of the birdstrike issue. This continuous effort is a testament to the IAF's dedication to finding a sustainable solution to birdstrikes by achieving a balance between aviation safety and environmental conservation.

In the last decade, a significant investment was made by IAF and the Wildlife Institute of India (WII), aimed at investigating birdstrikes and the ecology of kites, respectively. The research conducted by WII not only established connections with previous studies on kites in the region (Galushin, 1971; Malhotra, 2012) but also extended the understanding of the distinction between migratory and resident populations of kites. These ecological insights informed the IAF's approach to the Department of Forest and Wildlife (DoFW). In January 2022, the DoFW brought together WII, several ornithologists, and additional experts from Wildlife Rescue to formulate birdstrike mitigation strategies.

Furthermore, DoFW actively engaged key stakeholders from the aviation industry, as well as subject matter experts. Recognising the role of waste management in controlling bird populations, the DoFW and IAF partnered with the Municipal Corporation of Delhi to reduce food waste. Notably, local communities (or their representatives), who are responsible for nourishing various avian species, including kites, were not involved in this initiative. We also collaborated with the National Zoological Park, Delhi to enhance management practices of large soaring birds, e.g., storks and pelicans (details in Appendix). Despite the documented propensity of kites for ritual feeding locales situated close to green zones having high tree cover conducive to nesting (Kumar, Gupta, et al., 2018, 2019), the mitigation approaches could not factor ramifications of resource coupling in an urban environment characterised by heterogeneous development for the sustained presence of kites along the RDC.

2.4. Integrating applied ecological insights to address the birdstrike threat on RDC

Despite their prevalence and frequent proximity to human populations, the migratory patterns and wintering locations of the sizable Black-eared kite populations situated in and around the National Capital Region in India remain largely uncharted. This region is distinguished by the hosting of the world's largest congregation of such medium-sized raptors. Their migratory route is an extended flight path, ranging in length from 3,300 to 4,800 km, which follows a narrow course along specific Trans-Himalayan and East-Himalayan corridors. Kites traverse the Himalayan mountain range at remarkably high elevations, exceeding 6500 m above sea level, in particular, passing by Mount K2 in the Karakoram Range (Kumar et al., 2020).

Furthermore, the breeding population of the resident breeding kites in Delhi has remained stable over the past six decades (Kumar et al., 2014). The primary diet of the kites is composed predominantly of human subsidies, most notably ritual offerings, which account for the most significant concentrations of this raptor. Because of their dependence on intentional "ritual offerings" of meat scraps for religious purposes, kites are not uniformly distributed in the city but over-selected green pastures in the city that are in proximity to areas that afford foraging benefits- with high human density, poor waste management and a road configuration that facilitated ready access to resources provided by humans, in particular to Muslim colonies that provided ritual subsidies (Kumar, Gupta, et al., 2018). With kite density tightly tied to Muslim subsidies, this social-ecological relationship was further modulated by nest-site availability, mainly as tree availability. The woodlots/parklands/avenue plantations within the RDC ceremonial flights surrounding *Kartavya Path* are frequently besieged by a persistent presence of hovering kites, likely attracted by the potential nesting opportunities in proximity to Old Delhi ritual feeding locations.

Because ecological responses are accompanied and mediated by behavioural adjustments, organisms thriving in and around cities often generate potential conflicts with humans. In this case, frequent exposure of kites to humans while birds accessed ritual subsidies emboldened kites (Kumar, Jhala, et al., 2019; Kumar, Qureshi, et al., 2018). Consequently, an investigation of the efficacy of kite hovering deterrence was undertaken in the year 2022, through the induction of fear amongst regional kite flocks. This was achieved by trapping kites close to the ceremonial flight. Despite significant effort over two days, only a small number of kites were successfully trapped (n = 10). As the desired results were not achieved, and kites continued to venture into the same area, this finding aligns with the experiences of the WII team (see methods in Kumar et al., 2020), who led the trapping efforts. Their prior experience of using meat tossing near mist nets to trap kites for GPS telemetry informed this conclusion.

In 2023, we obtained permits to implement an innovative strategy to mitigate birdstrikes. Our approach hinged on the coordinated use of kites' gregarious behaviour concerning their attraction to ritual meat tossing (see Kumar et al., 2018 for additional information). To test the efficacy of our method, we conducted a controlled experiment at nine locations, and two control points where we counted the number of kites near the RDC strip. We hypothesised that the birds would be drawn away from the flight path and toward the designated meat-tossing areas, thereby reducing the number of kites near the RDC strip and effectively mitigating the threat in aerospace created by hovering kites. Our approach could attract kites away from the flight path without harming or distressing them. This was a significant step forward, as it represented a safe, effective, and environmentally friendly way to reduce the risk of birdstrikes during RDC and similar events. In contrast to the previous method, this was non-invasive, limiting any possible harm to the birds. Information regarding planning and its implementation can be found in the Appendix.

During the RDC, strategic luring of kites away from the flight path was meticulously planned to mitigate birdstrikes. To facilitate this, the Indian Air Force (IAF) provided flight path data for both helicopters and jet aircraft, which operate at altitudes ranging from 200-400 feet and 900 - 1200 feet, respectively. To assess the severity of risk in vertical space, we leveraged data from 30 GPS-tagged and monitored soaring kites in the capital, examining patterns in their altitudinal column usage. Furthermore, to ensure parity in the aeroecology of these birds and aircraft, data relayed by these loggers between 1000 hrs - 1300 hrs, the duration of RDC, was selected.

Consequently, we were able to utilise data from seven resident breeders and eight migratory birds that were remotely monitored in January of each year (2014-22).

The selection of the experimental sites was based on careful planning and an understanding of the historical record of meat tossing in the area. We anticipated that kites would respond more strongly to the ritualistic practices at traditional sites near mosques in the older parts of the city. With the help of telemetry data from tagged breeding male kites, whose home ranges typically extend up to 2 kilometres from their nests (Kumar, Gupta, et al., 2018), we established a 2-kilometre buffer zone around the 15-kilometre flight path, within which no meat tossing was allowed (see Fig. 1). Drawing on previous research and empirical observations on kite behaviour in response to ritual meat tossing, we developed a network linking the experimental intervention sites (which had no prior record of meat tossing) with the traditional sites, maximising the effect. A previous study by Kumar, et al., (2019b) found a strong correlation between breeding propensity and the level of resource tracking by kites, which is constrained by the presence of green cover. Hence, we accounted for potential impacts of such meat tossing, such as habituation, and considered the impact of ritual feeding in areas with high tree cover. We further collected data on local availability of food subsidies (small, roadside garbage units), urban variables such as towers and pylons, where kites could perch after grabbing the meat chucks, and human variables that could impact the strength of kite congregation, away from the flight strip.

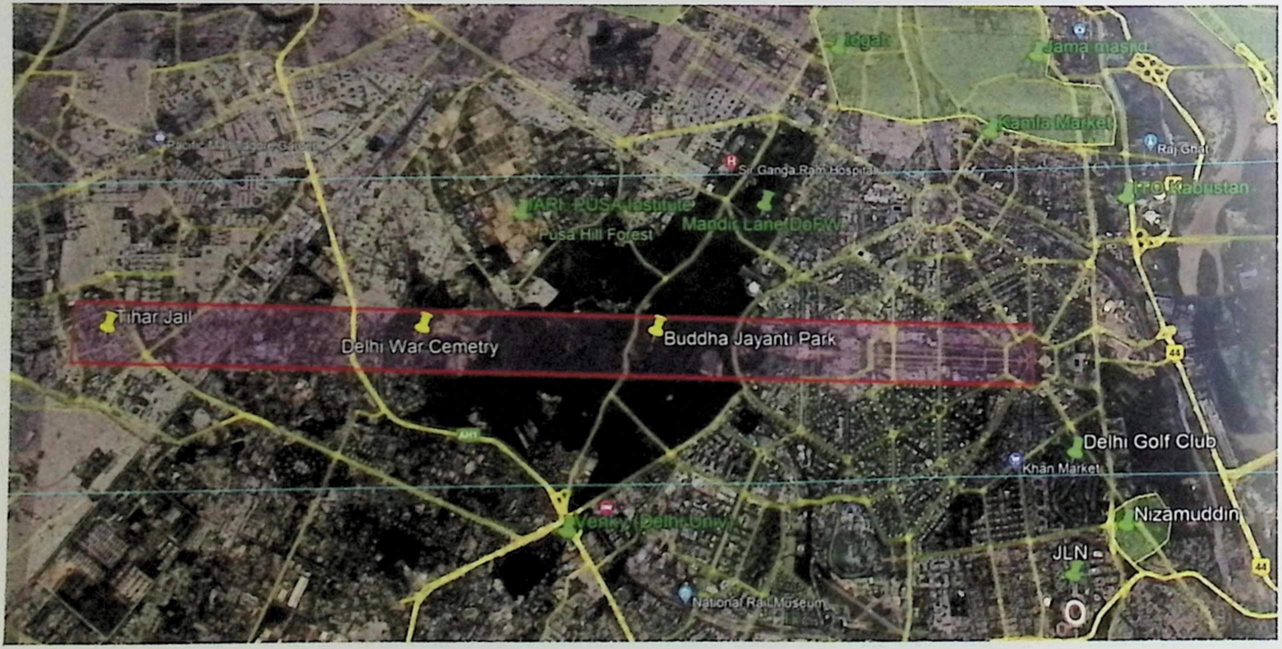


Fig. 1. Google Earth Imagery showcasing the Republic Day flypast path indicated by the Yellow location pins. The map also depicts the "aerospace of concern" bordered by the light blue rectangle, i.e., the 2 km belt areas on either side of the flypast path. This 2 km belt area is based on a GPS telemetry study (n = 9) since 2014. The light green shaded polygons depict areas where the ritual tossing of meat to kites is a century-old practice. Green location pins depict meat-tossing locations.

We trained teams that carried out experimentations on December 26th, 2022. To enhance the efficacy of our efforts, we conducted three practice sessions on randomly selected days leading up to the final event on January 26th, 2023. We arranged for 20 kg of fresh buffalo meat (lungs/ other viscera) and 5 kg minced chicken meat to be hand-tossed into the air/spread on the ground, in a manner like that already practised within the local communities, to draw kites towards our chosen locations (Fig. 2). Meat tossing activity was divided into two 30-minute events, matching the arrival of two aircraft fleets on RDC. The efforts also included Asia's largest poultry, egg, and fish market at the *Ghazipur* landfill site in our efforts. At *Ghazipur*, we laid out >120 kg of meat at various platforms to attract and hold the massive flocks of migratory Black-eared kites (Kumar et al., 2020).

Fig. 2. *Our mitigation strategy involved tossing meat at strategic locations (n =9) in the national capital, following the research work of Kumar et al. 2018a and 2019b.*

2.5. Data collection and analysis

Since we aimed to leverage this unique interplay between avian behaviour and human cultural practices in urban environments, we explored the possibility of coordinating our interventional efforts with traditional meat tossing. Muslims perform this ritual locally at the break of dawn, coinciding with the first of the day's five prayers. Based on the unpublished data from over 150 trail cameras on kite nests we had a prior understanding that the majority of provisioning occurred before noon each day. This observation suggested that the provisioning behaviour of male kites from nesting pairs is attuned to food subsidies offered through the first two Muslim prayers, every day, before 10:00 am. In the absence of such coordination, there was a potential risk of sizable kite flocks that were already well-fed before 10:00 am. These kites were expected to focus on securing breeding territories in proximity to traditional ritual feeding areas. The availability of secure tree cover with minimal human intervention in the RDC flight strip area, which lies within the mean home range (~2 km) distance from old Muslim establishments in Delhi, likely contributed to the constant presence of kites (IAF count data citation from Air HQ).

Our proposed strategy involved keeping the kites devoid of ritual feed on randomly chosen days of experimental intervention. On these days, the birdstrike mitigation team and the community were expected to work in tandem, anticipating a higher response by kites and, consequently, improved outcomes. We incorporated conversational ethnography into our research to gauge the potential for community support and coordination of efforts (Hesse-Biber & Leavy, 2006; Watkins & Swidler, 2009). At all the traditional sites that were incorporated in this exercise, *Jama Masjid, Nizamuddin,* and *Idgah*, we sought to understand the extent to which the Muslim community (n = 15 - 20 individuals interviewed at each site) would support the specific task of mitigating birdstrikes on military aircraft by coordinating their ritual meat tossing with experimental interventions. In light of the evidence from the trail cameras on nests, the dimensions of the meat chunks were calibrated to ensure that kites would need to alight on a perch and partake of this food subsidy.

Further, to facilitate a robust estimation of kite count, we deployed three or more individuals at each experimental (n = 9) and control (n = 2) location. Their independent assessments contributed to the derivation of mean count data. We coordinated the density estimation for kites that were perched on trees and flying in the visible aerospace across all sites using Zello (Pradhan, 2022), a smartphone application (Table 1). Since our approach involved the appropriation of kites' attraction to ritually tossed meat, the trial sessions before 26th January 2023 allowed us to fine-tune the rate and the number of bouts of meat tossing. The flight formations were separated into two batches, with the first running from 10:30 AM to 11:00 AM, followed by a thirty-minute interval, and the second commencing from 11:30 AM to 12:00 PM. Kite censuses were carried out, maintaining meat tossing as a treatment. Counts were obtained before, during, and following the event. Data from all experimental and control teams were centrally collated using a Google Form. The final study design is summarised in Table 1. To juxtapose kite-flock densities as a paired treatment (meat-tossing) across the two tossing events, kite count data was collated and subjected to univariate comparison by employing a paired sample t-test in SPSS version 23.0. All tests were two-tailed, with statistical significance set at $\alpha < 0.05$. Additionally, all means are presented as ± one standard error.

Table 1: *The experiment schedule of kite counts in the aerospace on the days of rehearsal and final fly past. With respect to the meat tossing activity at nine locations, we expected predictable movement of kites to reduce their density at Kartavya Path (Rajpath) and Buddha Jayanti Park.*

Counting before the meat tossing	
10:15 am	Count # 1
10:20 am	Count # 2
10:25 am	Count # 3
Meat Tossing [Phase - I]: begins at 10:30 am	
10:35 am	Count # 4
10:40 am	Count # 5
10:45 am	Count # 6
10:50 am	Count # 7
10:55 am	Count # 8
Break: *time for experimental observations*	
Counting before the meat tossing	
11:15 am	Count # 9
11:20 am	Count # 10
11:25 am	Count # 11
Meat Tossing [Phase - II]: begins at 11:30 am	
11:35 am	Count # 12
11:40 am	Count # 13
11:45 am	Count # 14
11:50 am	Count # 15
11:55 am	Count # 16
Break: *time for experimental observations*	

3. RESULTS

A. Evaluating the altitudinal and urban gradient of birdstrike threat by kites.

In total, we acquired ~130,000 suitable data points for 15 individuals we tracked from both subspecies of kites. Based on this data, we plotted a frequency distribution of kites' aeroecology, illustrated as the function of successive increase in altitude (Fig. 3). By overlaying the altitudinal preferences of helicopter (200-400 feet) and jet aircraft (900-1200 feet) formations onto this graph, we ascertained that aircraft formations mostly avoided the altitudinal band (400-800 feet) where the risk of birdstrike was highest. An analysis of the threat posed by birdstrikes, based on the upper limit of flight altitude data collected from tagged kites, revealed that flights conducted above 1750 feet would significantly reduce the risk of birdstrikes, by 99%. Furthermore, if flights were to operate at altitudes exceeding 3200 feet, the likelihood of birdstrikes by kites reduced to a negligible level of 0.1%. This decision shall be a risk-allocation trade-off, based on weather and visibility of the RDC flight formation from the ground (threat likelihood assessed from the area under the curve; Fig. 3).

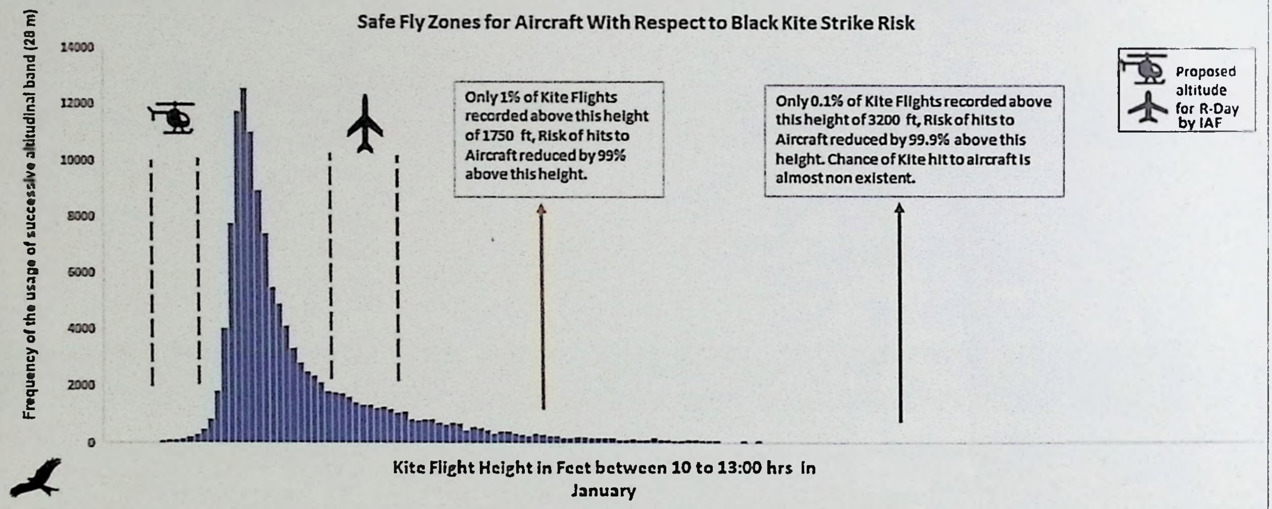


Fig. 3. Frequencies *(Y axis) of the* ***altitudinal ranges*** *(X-axis) used by Black-eared Kites, based on ~130,000 data points from 15 birds that were GPS tracked from 2014 – 2022; picked along flight past schedule, ~1130 hrs, we used the data points obtained between 1000 - 1300 hrs.*

In the context of home ranges (n = 8), breeding pairs were confined to an area within a radius of 2 km from the nest. We could note a sex-specific dichotomy in spatial utilisation of the urban areas, with males expanding their range radially outwards from the nest up to 3 km. Females, however, were restricted to a displacement of 500 m from their nest until their chicks reached 35 to 40 days. However, kites were no longer tied to their nesting territories during the non-breeding season. They explored opportunistic foraging locations up to 11 km away from their nest (n = 3), occasionally including landfills. Nesting/roosting in woodlots offered safety from potential human intrusion.

Movement ecology data was not available for non-breeding individuals of the resident subspecies; however, we observed they demonstrated a strong affinity for garbage. Adult migratory Black-eared kites exhibited a high degree of spatial overlap with resident breeders in Delhi while maintaining distinctions in foraging and roosting areas. Roosting occurred preferentially in the safety of woodlots and parklands. Subadult Black-eared kites selected woodlots and pylons in the vicinity of landfills, which served as their primary foraging grounds, for roosting.

B. Estimating the kite population within the RDC area and the efficacy of experimental interventions.

Based on previous estimates of nesting densities, we calculated potential threat from 5384 ± 2106 breeding males within 2-kilometre of the RDC fly-path (89.74 ± 35.1 nests/km^2), under the assumption that female kites were confined to their nesting territories. For these many nests situated within the RDC region, we estimated that male birds provisioned ~1938.24 kilograms sourced from devout Muslims. This estimation assumes that each nest required 400 grams of meat and 90% of this dietary requirement was obtained through ritual feeding events. Moreover, for the RDC area, we approximated 7860 ± 4212 non-breeders from the indigenous population, based on the assumption that each territorial pair in Delhi produces approximately 0.73 fledglings, each fledgling has a 50% probability of surviving its first year, and raptors generally defer their participation in breeding by three to four years.

The trial sessions conducted before Republic Day 2023 ascertained that the kites' attraction to meat tossing persisted for <15 minutes, after which the numbers diminished until the emergence of a new flock. Given that the duration of aircraft flight formations extended to 30 minutes, we implemented a strategy of slow tossing of meat to attract the birds, subsequently transitioning to a more rapid rate of delivery for those birds that gathered the meat chunks on their wings. This process could be effectively managed by controlling the height of the tossed meat, with higher tosses ensuring the rapid acquisition of chunks by the birds, enabling them to swiftly depart from the area. From the trial sessions, we learnt that kites' attraction to experimental meat tossing was affected by visibility, depending on the weather in cold winter months. Winter fog/smog affected the flocking strength. Contrary to our anticipations, the Black-eared kites did not exhibit descending behaviour in response to the distribution of more than 120 kilograms of meat scraps on the rooftops where they habitually roost while opportunistically consuming chicken slaughter discards in the *Ghazipur* region.

C. Experimental Outcomes: Univariate comparison of kite density in aerospace

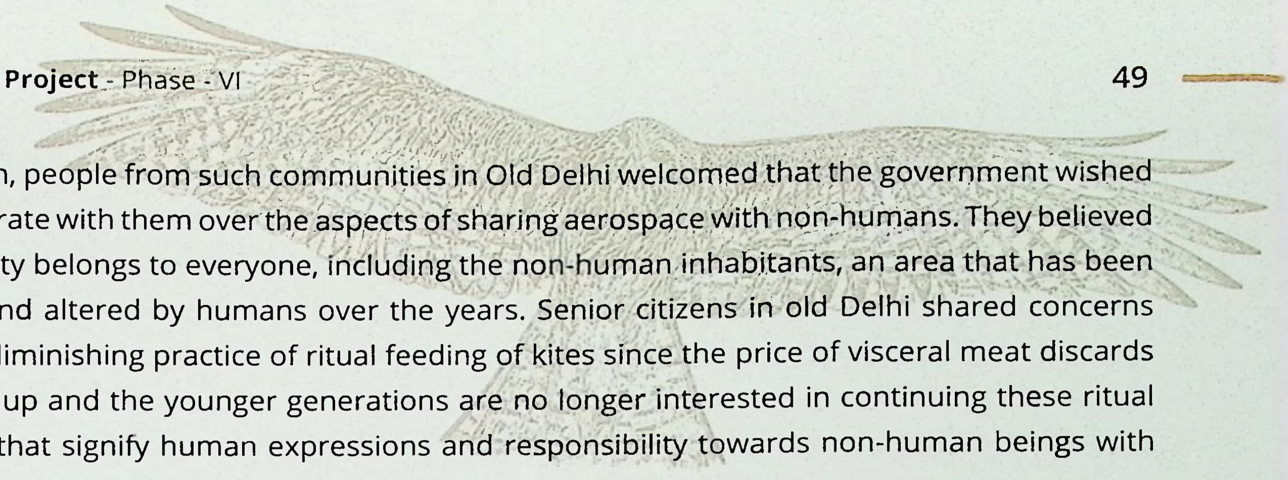
The trial sessions and final implementation during RDC on January 26th, 2023, provided evidence that tossing meat significantly diminished the concentration of kites near the flypast aerospace at the control sites. However, the effectiveness of this approach was affected on days when the weather conditions were not optimal, particularly when the sky was not clear (summarised in Appendix Table 2; Fig. 2). Following prior expectations, the kite counts conducted at *Idgah* and *Nizamuddin* in the vicinity of Old Delhi demonstrated substantial modifications in flock behaviour as a direct result of the act of tossing meat. In contrast, within zones designated for ritual feeding, such as *Jama Masjid* and the *Kamla Market* region (inclusive of the *Ram Leela* grounds), we observed a comparatively subdued reaction among congregating kites. This phenomenon can be attributed to inadequate collaboration with local communities, leading to the rapid dispersal of kite flocks to neighbouring areas, thus modifying their flocking patterns. Finally, despite the recognised limitations arising from insufficient strategic planning in response to weather-related changes to kite aeroecology, and the absence of collaboration with the local community, this experimental intervention effectively prevented >3000 kites from reaching the control sites on RDC. It significantly reduced the risk of birdstrikes, which would have escalated if the kites had not been contained within the nine experimental locations.

D. Potential for Community Support for Experimental Interventions

Our conversational ethnography revealed intriguing aspects of potential community engagement. The Muslim community was more responsive towards the aspect of keeping the birds safe from poorly justified actions. Respondents involved with regular meat tossing as part of their occupation expressed their concerns, since this ritual, much like other aspects of ritual feeding in the region, has generated enormous economic opportunities for people who process and sell visceral slaughter discards. One such respondent shared his concerns about the potential impact on birds, which he believed are just responding to how humans are dealing with nature. He stated:

> *"Sarkaar aur uske jahaaz ke surakhsha apni jagah zaroori hai, lekin main aapka saath isliye doonga kyonki mudda in bezubaan pakshiyon ko kisi galatfehmi se bachaane ka hai; agar aapke bataye tareekon ko amal nahi kiya gaya, to cheelon ko maara, pakda aur pareshan kiya jaa sakta hai".*

He meant that while the safety of the government and its aircraft is important, I will support you because the issue is about saving these voiceless birds from a misunderstanding; if your suggested methods are not implemented, kites could be killed, caught, and disturbed. This statement underscored the community's willingness to collaborate on keeping the military aircraft safe from potential birdstrike threats, but more importantly, to protect the kites.



In addition, people from such communities in Old Delhi welcomed that the government wished to collaborate with them over the aspects of sharing aerospace with non-humans. They believed that the city belongs to everyone, including the non-human inhabitants, an area that has been claimed and altered by humans over the years. Senior citizens in old Delhi shared concerns over the diminishing practice of ritual feeding of kites since the price of visceral meat discards had gone up and the younger generations are no longer interested in continuing these ritual practices that signify human expressions and responsibility towards non-human beings with whom they share their life and city.

4. DISCUSSIONS

Our two-year investigation uncovered intricate dynamics surrounding urban wildlife management and human-animal conflict resolution. This study has furthered our understanding of complex social-ecological aspects of urban ecosystems (see Chester et al., 2023) by elucidating challenges encountered in conflict resolution that involve species inextricably entangled with people in tropical regions. In this case, ecological applications for birdstrike mitigation were derived from long-term ecological and behavioural studies of an opportunistic raptor species; the mitigation approach further benefited from integrating suggestions from biologists and practitioners who represented various stakeholder groups.

We recorded behavioural distinctions between resident and migratory kites in urban environments. Nonetheless, the interplay between life history traits and behaviour in synurbic species, such as Black kites, is a fascinating but poorly explored aspect of urban ecology (Galbreath et al., 2014; Luniak, 2004; Parker & Nilon, 2012; Santini et al., 2019). Such species or population-specific exploitation of anthropogenic resources mediated by life history traits indicates distinct ways the seemingly homogeneous human niche can support multiple species and populations (reviewed in Hulme-Beaman et al., 2016). Numerous facultative scavengers benefitting from anthropogenic food subsidies further gain from companionship ascribed via long-drawn coexistence with humans (Kumar, 2019). The applied ecological problem we addressed exemplified how human-induced rapid environmental change (HIREC; Sih et al., 2011) may expose synurbic animals that constantly adjust to risks associated with urban infrastructure. Frequently, extraordinary demographic success in synurbic environments can result in various negative consequences, such as electrocution (Dwyer & Mannan, 2007), birdstrikes (Baxter et al., 2003.; Blackwell et al., 2009; Sodhi, 2002), physiological distress (Bernat-Ponce et al., 2023; Cummings et al., 2020; Wilcoxen et al., 2015), and collisions with buildings (Van Doren et al., 2021). While these incidents are frequent, in certain conflict situations, synurbic success can also lead to persecution by humans (Jones, 1972; Soulsbury & White, 2015). Despite the observed disparities in conflict dynamics generated by adult birds of the resident and migratory kite populations, it is noteworthy that non-breeding kites of both these populations exhibited a high propensity to roost close to food subsidy locations. Field observations revealed that such behaviour, which is possibly a result of evolutionary traps, could potentially expose these inexperienced kites to relatively elevated vulnerabilities and conflict risks (see Robertson & Blumstein, 2019; Schlaepfer et al., 2002).

Identifying and exploiting anthropogenic resources by facultative scavengers like kites is a complex process of adjusting to novel cues (see Kane & Kendall, 2017; López-López et al., 2013; Moleón et al., 2014), potentially influenced by life stages. However, researchers have yet to explore links between urban ecology, behaviour, and life history stages underscoring the need for a more nuanced appreciation of evolutionary and ecological traps (Alberti, 2008; Gardner et al., 2018; McDonnell, 2011; Mortier & Bonte, 2020). In light of HIREC in urban environments, these habitats are undergoing continuous transformation, posing unprecedented challenges to animal behavioural strategies (Bermúdez-Cuamatzin et al., 2009; Evans et al., 2010; Lowry et al., 2013). Consequently, we posit that evolutionary/ecological traps are unavoidable in the initial inexperienced life stages of long-lived synurbic species at the upper end of the synurbisation spectrum (Greggor et al., 2019; Robertson et al., 2013). We discuss and examine the outcomes to explore the ramifications of systematic interventions for birdstrike mitigation through multifaceted approaches.

I. Spatio-temporal planning of conflict mitigation

Incorporating food subsidies' appeal in managing facultative scavengers to mitigate birdstrikes at the RDC demanded meticulous planning to avoid adverse effects. Kumar, et al., (2019) suggested in the absence of significant predation pressure in urban environments, birds of prey with facultative scavenging behaviours are constrained by suitable nesting/roosting territories, with kites exhibiting a preference for trees (Kumar, 2019). Therefore, in contrast to the sustained feeding of kites at experimental sites, which could have altered habitat suitability criteria and intensified their presence at the RDC, we kept our interventions stochastic. Furthermore, once a tossing region was finalised, we selected the actual meat tossing sites near a parkland/ woodlot, in agreement with Kumar, et al., (2019b), since trees constrained the level of resource-tracking by the kites and their potential ecosystem service. This successfully served as a tool for temporarily managing kite density in aerospace, considering they usually perch and consume the meat chunks grabbed on wings.

Our approach to establishing a network of experimental intervention sites was effective, strategically incorporating both traditional locations and previously unexplored areas. This strategy successfully attracted more kites to meat-tossing locations than could have been achieved at individual sites. However, our study was limited by a lack of comprehensive understanding of the spatially explicit impact of these interventions (see Macdonald & Johnson, 2015), particularly concerning nest density within the RDC. Future research should adopt more nuanced approaches, especially considering the sensitivity of these interventions to environmental factors such as inclement weather and pollution/smog, which can significantly impact visibility in aerospace and consequently, the reactions of the kites.

II. Behavioural implications of experimental interventions to manage synurbic species.

While concerns always existed regarding the local impacts of experimentally feeding meat to kites, the uncertainty surrounding the temporary cessation of food availability at municipal waste locations and transient roadside refuse accumulations during the peak of the breeding season is of greater concern (Kumar, 2013; Kumar et al., 2014; Kumar, Singh, et al., 2019; Salemdeeb et al., 2017). Given the temporal alignment of the RDC with the peak of breeding activities, any intervention aimed at altering food availability in urban areas, which arguably host the world's densest kite breeding colonies, could lead to unintended consequences if ecological considerations are overlooked. For example, the abrupt implementation of month-long or similar restrictions on kites' access to garbage from smaller dump sites could likely alter kite visitation patterns. Nonetheless, understanding the breeding habitat selection of kites, as evidenced by the research conducted by Kumar, Gupta, et al. (2018a), suggests that such an intervention may increase the likelihood of introducing information-cue misalignment, thereby disrupting the established cognitive ecological patterns associated with recognising and obtaining food supplements. This informational noise and its cascading behavioural effects have the potential to undermine the success of birdstrike mitigation efforts. In support of this, our previous home range studies have revealed that female kites are confined to their nests during December and January. During this period, male kites exhibit highly efficient provisioning behaviour, returning with food items, typically consisting of meat chunks, within minutes of leaving their nests (unpublished data).

On the other hand, non-breeding kites, often inexperienced, have been observed to maintain proximity to predictable but low-quality foraging locations. This behaviour exposes them to risks as they wait for opportunities to seize a morsel on their wings. Such behaviour suggests a naivety in assessing risk-benefit trade-offs, indicating that ecological setting, life stage, and experience significantly mediate the response of kites to sudden changes in refuse availability (see Greggor et al., 2019). Inexperienced kites, in particular, tend to have a poor understanding of the threats associated with foraging near human-dominated systems. These kites are often observed to be emaciated; their health compromised by their propensity to continue feeding on poor quality but highly predictable resources (NS & MS *pers comms*). This behaviour potentially increases their susceptibility to potential strikes with aircraft. Evidence exists that avian specimens not in optimal physiological condition, or those afflicted with disease or injuries, exhibit an increased propensity for conflict with aircraft or human beings (Kempf & Hüppop, 1998.). This observation underscores the need for comprehensive strategies that consider the health and behavioural implications of interventions, aiming for coexistence that benefits both wildlife and urban communities (McMahon et al., 2024; Nkansah-Dwamena, 2023; Nyhus, 2016; Torres et al., 2018).

III. Community engagement and conflict resolution in social-ecological systems.

Through extensive observation and analysis of over 30 million camera trap images from more than 150 kite nests, we found that maximum provisioning occurred during the early morning hours, specifically between 6 am and 10 am (unpublished data). In Delhi, the year-round ritual activity of meat tossing intensifies on Tuesdays and Thursdays. Typically, this activity takes place after the first two Muslim prayers of the day, *Fajr* at 5:30 am and *Duha* at 6:50 am, although variations exist based on personal working hours (unpublished data; see Kumar et al., 2019b).

The coordination of meat-tossing activities with local citizens requires careful spatiotemporal planning. Without large-scale coordination, people in traditional meat tossing locations will continue to feed kites during their customary hours, primarily before 10 am daily. While we currently lack a precise daily estimate of the total quantity of ritually tossed meat for kites in Delhi, interviews with individual meat sellers provided valuable insights. We found that on Tuesdays and Thursdays, they sell approximately 150-300 kg of meat, with a daily average of around 50 kg (unpublished data).

These quantities suggest that the kites in the RDC area will be well-fed, soaring in the airspace around the ceremonial flypast path, actively exploring breeding opportunities and utilising air thermals between 10 am and 12 pm. Our statistical evaluations indicated that the experimental tossing (<200 kg), in addition to deviating from the targeted time frame by approximately four hours, constituted less than 10% of the daily meat consumption by kites in the region of RDC. This makes it evident that strategic planning and synchronised implementation of meat tossing are essential for success, which can only be achieved through collaborative efforts with the local community. Our mitigation approach respects and leverages the long-standing traditions and practices that have shaped human-avian relationships in Delhi. Such coordination, in terms of both timing and location, shall foster harmonious coexistence between aircraft operations and avian species, ultimately reducing the risks of birdstrikes (Hoare, 2012; India, 2023; Mukherjee et al., 2015).

Implications of feeding rituals on kite ecology and birdstrike threats

Within the urban environment, birds exhibiting long lifespans, e.g., kites with a potential lifespan exceeding twenty years in their natural habitat, have adapted to the predictable availability of human-generated waste and other subsidies (Barua & Sinha, 2022; Beatley, 2020; Strohbach et al., 2014). Despite this, the intricate relationships between life history parameters, behavioural strategies, and migration patterns — in the case of wintering avifauna — remain poorly understood (see Martin, 1995; Newton, 1979, 2010). The disparities observed in the responses of the two kite subspecies to the ritual feed highlight the need for in-depth cognitive-ecological investigations, which fall outside the scope of this manuscript. Nevertheless, through a comparative analysis of juvenile individuals from both subspecies and a contrast of the distinctive approaches adopted by adult individuals in exploiting urban foraging opportunities, we underscored the interplay between life history traits and age as shaping influences on behavioural strategies (Buss & Hawley, 2010). Resident kites, in contrast to their migratory counterparts, were successful in seizing meat chunks, mid-air, on their wings. Despite the allure of this supplementary food source, the wintering birds merely hovered in circular patterns, unable to descend swiftly and seize the food. This was probably because resident kites are smaller and lighter (see, e.g., Ferguson et al., 2023). It remains to be determined how Smith's, (1952) hypothesis regarding stalling speed affects the success of smaller urban scavengers in contrast to larger wintering kites that are predominantly found in open areas (Kumar, 2019).

Considering that the principles of aerodynamics governing machines are essentially analogous to the long-standing success of soaring birds, which have evolved in response to abiotic aspects of flight, it is unsurprising that the migratory routes of Black-eared Kites and air force stations coincide both spatially and temporally (Dhawan, 1991; Nourani et al., 2021). This situation becomes problematic when certain opportunistic populations of relatively large-sized birds, such as kites, exploit human waste and exhibit demographic responses and an affinity for human-dominated landscapes. Vultures, for similar reasons, were previously a primary concern until their near extinction at the turn of the century (see Blackwell & Wright, 2006; Satheesan & Satheesan, 2000).

Upon their arrival at the subcontinent, following their traversal of the *Himalayan Mountain Range*, Black-eared kites utilised an interconnected system of cities within the National Capital Region (NCR), all of which are situated within a radius of 200 kilometres from Delhi (Kumar et al., 2020). The consistent reliance of avian populations on human waste across these urbanised areas, a relatively recent phenomenon, necessitates an exploration of the potential implications of food subsidies on their survival and migratory patterns (see Newton, 2010). Kumar et al., (2020) demonstrated that kites wintering primarily within or near urban centres did not regularly frequent human-dominated landscapes during their breeding seasons in Central Asia. In light of changing environmental conditions, this raises questions regarding aerospace safety and whether breeding ecology or wintering ecology is a limiting factor for opportunistic migratory avifauna (see Faaborg et al., 2010). Further studies are required to elucidate how survivorship, influenced by interactions with urban areas, shapes migratory strategies and connectivity (Tryjanowski et al., 2013). Consequently, understanding the ecological dynamics of these species within urban environments is paramount for effective birdstrike mitigation and biodiversity conservation (Burak et al., 2018).

Implications of feeding rituals on urban ecology

Globally, feeding wildlife — a biophilic expression meditating human-animal coexistence — is rising (Dasgupta et al., 2021; Milner et al., 2014; Orams, 2002; West & Jones, 2022). Quite often, and especially in the Global South, the target organisms of directed feeding efforts are urban exploiters that originally benefited from food subsidies afforded by the pervasive problem of solid waste disposal in the region (Coogan et al., 2018). The issue of birdstrikes posed by kites that we addressed serves as an example of how uncontrolled and inadequately executed urban development provides suitable conditions for opportunistic scavengers, which may additionally profit from instances of deliberate feeding leading to conflicts. Similar problems exist in the case of compassionate or ritual feeding that causes aggressive interactions between humans and commensals like dogs (Saree et al., 2021), macaques (Hsu et al., 2009; Yeo & Neo, 2010), and magpies, etc. (review in Cox & Gaston, 2018). Mitigation measures frequently meet obstacles when various approaches adopted by individuals, society, and the state (top-down) are not aligned in terms of timing and location. This issue becomes increasingly complex in heterogeneously developed regions like South Asia. In such regions, human-animal conflicts and zoonotic diseases pose significant challenges to coexistence and sustainable development (Glidden et al., 2021; Nyhus, 2016; Torres et al., 2018).

The assessment of the outcomes of our RDC intervention, in the context of the urban behavioural spectrum of kites elucidated by Kumar et al. (2018b) and (2019a), emphasises the significance of recognising that the challenges and disparities associated with animal management often arise from a lack of understanding of the alignment between human and animal behavioural processes (Gifford et al., 2011; Mellor et al., 2020; Teel & Manfredo, 2010). The comparable and contrasting aspects of animals and human behaviour and social processes are frequently disregarded in animal management, fostering the erroneous notion that animals, as non-sentient entities, can be effortlessly "handled" (Boissy et al., 2007; Burgess-Cady, 2016; Dickman, 2010; Lunney, 2012). Numerous companion animal species have developed the capacity to recognise and manipulate individual humans or communities as sources of nourishment. These behaviours are intertwined with regional socio-cultural nuances, resulting in corresponding animal cultures of opportunism (Dasgupta et al., 2021; Greenberg, 2003; Griffin et al., 2017;

Steyaert et al., 2014; van Overveld et al., 2018; West & Jones, 2022). The persistently littered streets of cities such as Delhi act as catalysts for such intricate relationships (Kumar, Singh, et al., 2019). As we continue to coexist with these creatures, it becomes imperative to comprehend and address the ecological implications of our shared existence. This coexistence extends beyond mere space sharing; it encompasses a complex interplay of behaviours, resources, and socio-cultural expressions that shape our urban ecosystems.

Conclusions

In human-use landscapes, behavioural strategies are intrinsically linked with demographic outcomes, underpinned by social-ecological processes (Folke, 2006; Milner-Gulland, 2012). Driven mutually by humans and non-human agencies sharing spaces, the latter also form the basis of animal cultures in opportunistic species (Oro et al., 2013). Our research underscored that when conflict mitigation efforts disrupt animal population processes, we inadvertently introduce temporary noise in stimuli-cue links. This can potentially subject individuals to evolutionary/ecological traps, with significant physiological consequences. For instance, in the case of facultative scavenging birds not accustomed to feeding on carrion may need to make circumstantial decisions that alter their physiological profiles, making them more susceptible to bird strikes. Moreover, interventions that fail to consider the ecological processes that connect behavioural strategies and demographic outcomes in a spatiotemporal context are unlikely to yield positive results. In conclusion, understanding the eco-evolutionary dynamics of synurbic species in urban landscapes requires a multi-faceted approach. By considering individual life histories, behavioural adaptations, and the unique challenges posed by urban environments, we can gain valuable insights into urban avian ecology and inform effective conservation strategies.

APPENDIX

(Univariate comparison of changes in kite density within aeroscape because of experimental intervention)

The implementation of the meat tossing, as an experimental demonstration on 26.12.2022 at *Rajpath* successfully exhibited its impact in attracting Black kites (*Milvus migrans*) from the surrounding areas to the ceremonial path. However, the strength of attraction was found to be fainter than anticipated based on previous research conducted by the Wildlife Institute of India (WII). The observed decrease in kite counts on the areas surrounding the point location of meat tossing validated the hypothesis that in actual experiment, kites would be lured away from critical flight paths towards the meat tossing points. These results indicated the efficacy of the intervention in diverting kite activity away from areas of potential birdstrike hazards. The lower-than-expected strength of attraction can be attributed to two primary factors. ***Firstly***, due to the overcast sky and fog, the prevailing weather conditions during the study period were not favourable, which may have affected kite foraging behaviour and their responsiveness to the meat tossing ritual at the new location. Adverse weather conditions, which limited visibility, could have disrupted the normal foraging patterns of the kites. ***Secondly***, it is important to consider the behavioural adaptation of kites to feeding practices. As kites are habitual scavengers and opportunistic feeders, they may have developed preferences and familiarity with specific feeding locations and methods. The introduction of meat tossing at *Rajpath* as a novel feeding strategy may have initially caused some hesitation or caution among the kites, as they were not accustomed to being fed through this method in the new setting; technically, neophobia.

Experimental Outcomes: Univariate Comparison of kite numbers in aerospace

a) 17.01.2023

During observation (Table 1), the mean number of kites at Jama Masjid was 57.7 ± 9.4 and 140.3 ± 20.4, before and after meat tossing, respectively. Similarly, the numbers at Nizamuddin changed from 85 ± 8.0 to 267 ± 12.4 after the meat tossing. Meanwhile, at *Rajpath*, we saw a decrease from 47 ± 4.0 to 36.9 ± 1.0, likely driven by the simultaneous increase in nearby areas where coordinated meat tossing was carried out (Fig. 2). Univariate comparison of mean count estimates, where *Jama Masjid* and *Nizamuddin* were experimental sites, while *Rajpath* was the control, showed that meat tossing significantly reduced kite density from the flypast aerospace (summarised in Table 2; Fig. 2).

Table 2: *Summary of the paired differences tested by means of t-tests (Meat tossing event # 1) to illustrate the effect of meat tossing around the flypast in mitigating birdstike threat. Significance Symbols: * P < 0.05; ** P < 0.01; *** P < 0.001.*

Sl. No.	Locations pairs	Paired Differences			t	df	Sig.
		Mean difference	Std. Dev	SE			
Pair 1	Jama_Before -Jama_After(1)	80.9	33.2	12.6	6.4	6	***
Pair 2	NiZ_Before - Niz_After(1)	183.0	31.9	15.9	11.5	3	***
Pair 3	Rajpath_Before -Raj_After(1)	16.4	10.4	3.9	4.2	6	**

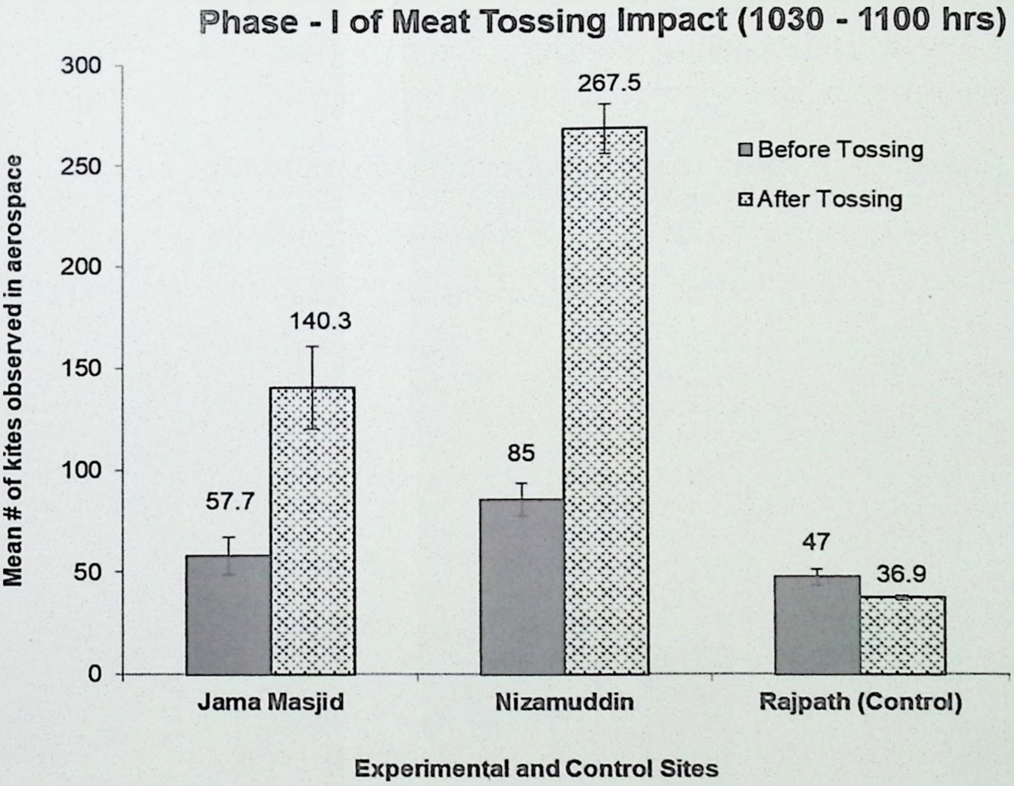


Fig. 2: *Phase - I of meat tossing on 17.01.2023 at Jama Masjid and Nizamuddin saw increase in mean kite numbers in visible aerospace, which most likely contributed to significant reduction in kite density at Rajpath's aerospace of concern. The error bars represent ± 1 SE.*

Further, when the task was repeated after a break of 20 minutes on 17.01.2023, impact of meat tossing at *Nizamuddin* fizzled out, with relatively poorer congregations. As a result, there was no significant change in the kite density at *Rajpath*, albeit kite density still increased at *Jama Masjid* (Table 3 and Fig. 3).

Table 3: *Summary of the paired differences tested by means of t-tests (Meat tossing event # 2) to illustrate the effect of meat tossing around the flypast in mitigating birdstike threat. Significance Symbols: * P < 0.05; ** P < 0.01; *** P < 0.001.*

Sl. No.	Locations pairs	Paired Differences			t	df	Sig.
		Mean difference	Std. Dev	SE			
Pair 1	Jama_Before -Jama_After(2)	97.6	19.3	8.6	11.3	4	***
Pair 2	NiZ_Before - Niz_After(2)	95.5	51.6	25.8	3.7	3	*
Pair 3	Rajpath_Before -Raj_After(2)	5	17.1	5.7	0.9	8	-

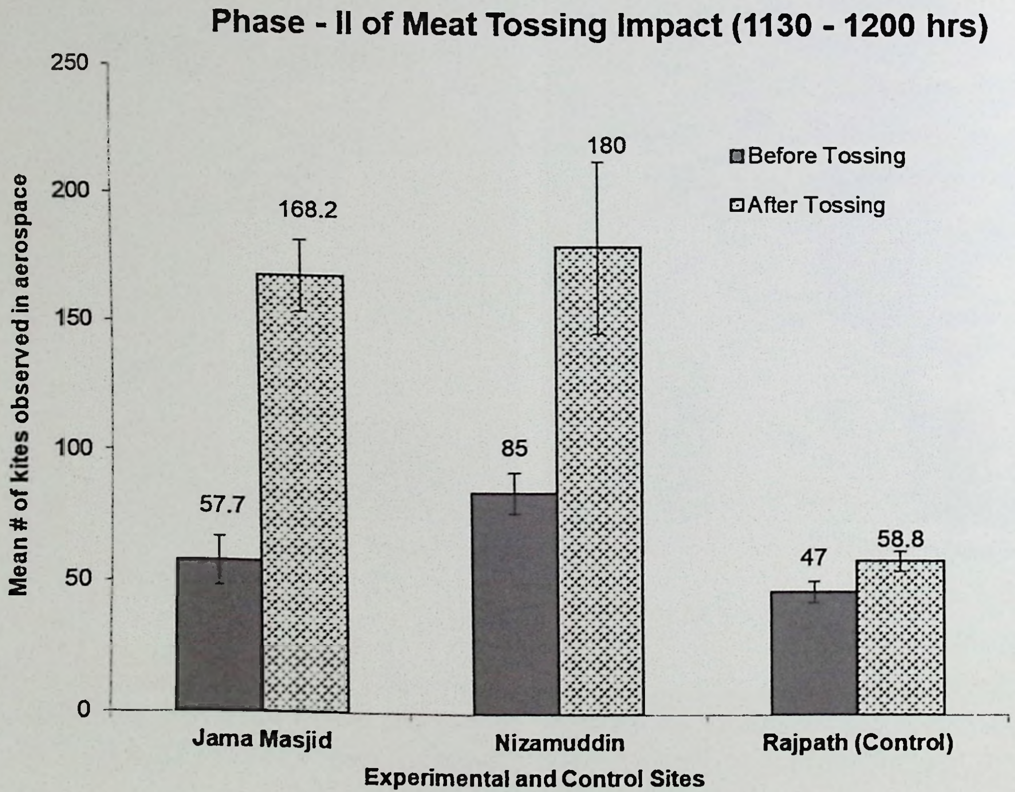


Fig. 3: *Phase - II of meat tossing on 17.01.2023 did not bring substantial change in kite density at Nizamuddin, while the effect stayed equally strong at Jama Masjid; albeit the latter is 4.2 km away from Rajpath. This may explain the trends contrary to the expectation, given that there was a slight increase in the mean kite numbers at Rajpath, during mid-day. However, this change was not significant. The error bars represent ± 1 SE.*

b) 20.01.2023

Univariate comparison of kite counts revealed statistically significant variations at the Golf course area, where no previous history of meat tossing existed (Table 4; Fig. 4). Similarly, there were notable changes in kite numbers observed at the ITO graveyard, which is not a customary site for ritual feeding of kites. As anticipated, the kite counts at the *Kamla Market* area (Ram Leela ground), in close proximity to old Delhi, exhibited significant alterations. However, contrary to expectations, the *Nizamuddin* area, a traditional site for ritual meat tossing, did not demonstrate a significant change in kite numbers throughout the duration of the tossing event. This outcome was attributed to a delayed start of the tossing experiment caused by a traffic jam, which hindered the timely delivery of meat. Moreover, no significant changes in kite numbers were observed at the *Rajpath/Buddha Jayanti Park* along the flight path, possibly due to inadequate coordination efforts across multiple sites. Similarly, the Pusa campus (IARI), located considerably far from the customary meat tossing areas in the capital, did not display a significant change in kite numbers. At the *Pusa* campus (IARI), kites were more invested in snatching the chunks away from each other and exhibited heightened aggression to snatch meat from other commensals such as street dogs, suggesting a sense of neophobia.

At *Ghazipur*, the Black-eared kites almost showed no attraction to the meat chunks and minced meat (120 kg) we provided, possibly due to neophobia. It highlighted the need for alternative strategies in birdstrike mitigation from the migratory populations of kites in the city.

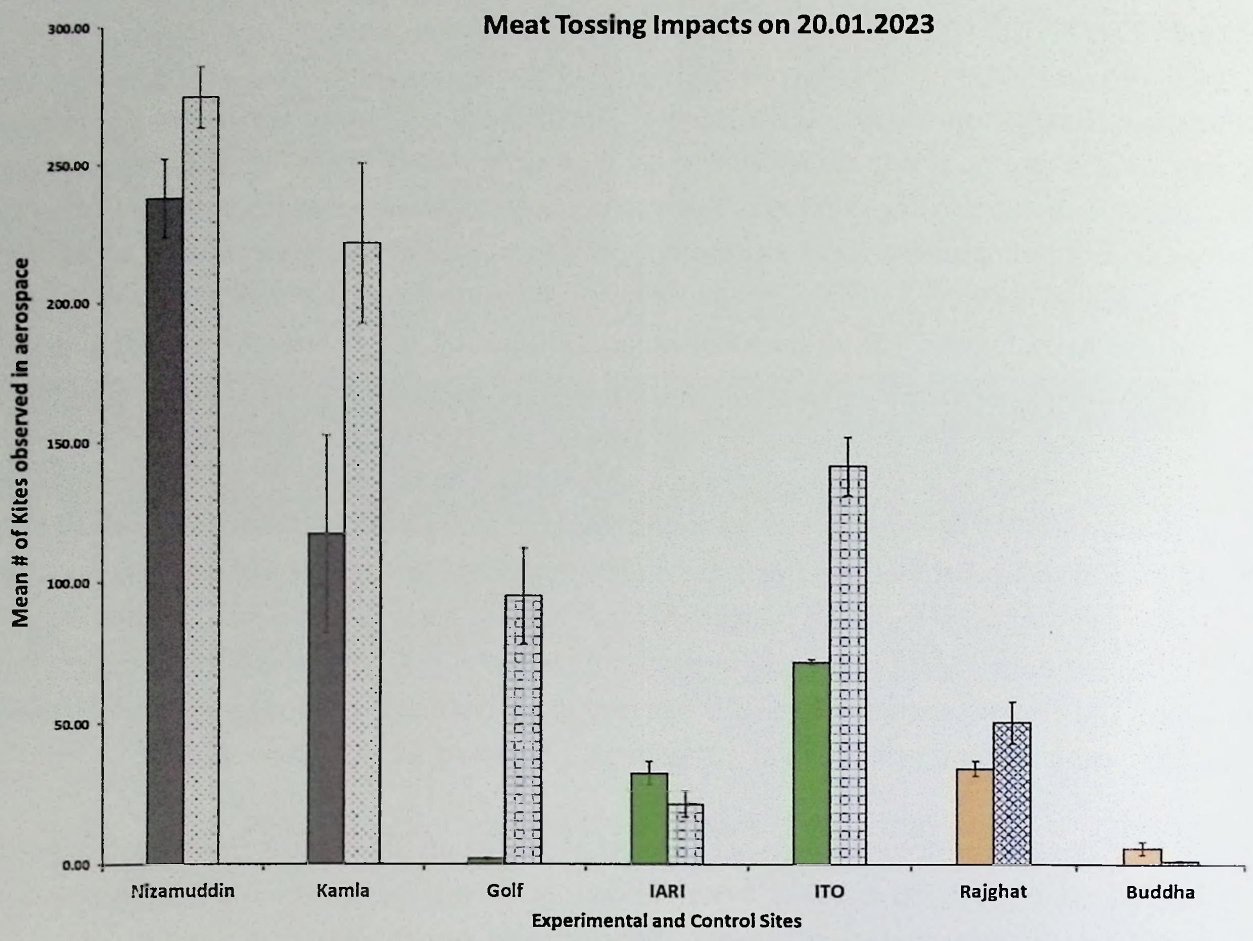


***Fig. 4:** Experimental meat tossing on 20.01.2023 at traditional locations (Grey bars: Kamla Market and Nizamuddin) saw significantly high increase in mean kite numbers in visible aerospace, which most likely contributed to significant reduction in kite density at Buddha Jayanti Park, albeit it did not bring the desired result at Rajpath's aerospace of concern (Orange bars). The change in kite numbers as experimental intervention at new locations (Green Bars). The textured bars represent the kite numbers during tossing. The error bars represent ± 1 SE.*

Table 4: *Summary of the paired differences tested by means of t-tests (Meat tossing events I & II) to illustrate the effect of meat tossing around the flypast in mitigating birdstike threat. Significance Symbols: * P < 0.05; ** P < 0.01; *** P < 0.001.*

Sl. No.	Paired Treatments	Paired Differences			t	df	Sig.
		Mean	Std. Dev	SE			
Pair 1	Niz_B - Niz_A	36.50	33.67	13.74	2.66	5.00	.
Pair 2	Golf_B - Golf_A	93.00	33.50	16.75	5.55	3.00	*
Pair 3	IARI_B1 - IARI_A1	11.00	5.57	3.21	3.42	2.00	-
Pair 4	Buddha_B - Buddha_A	4.75	4.50	2.25	2.11	3.00	-
Pair 5	Raj_B - Raj_A	16.33	9.29	5.36	3.04	2.00	-
Pair 6	ITO_B1 - ITO_A1	108.00	17.69	10.21	10.57	2.00	*
Pair 7	Kamla_B1 - Kamla_A1	104.00	17.35	10.02	10.38	2.00	*
Pair 8	ITO_B2 - ITO_A2	69.67	19.35	11.17	6.24	2.00	*

c) 23.01.2023

Univariate comparison of kite counts revealed statistically significant variations at the Golf course and *Mandir marg* area (Phase - II of meat tossing), where no previous history of meat tossing existed (Table 5; Fig. 5). Similarly, there were notable changes in kite numbers observed at the ITO graveyard, which is not a customary site for ritual feeding of kites. As anticipated, the kite counts at *Idgah* and *Nizamuddin* in close proximity to old Delhi, exhibited significant alterations. However, contrary to expectations, the *Jama Masjid*, and *Kamla Market* area (*Ram Leela* ground) areas, traditional sites for ritual meat tossing, did not demonstrate a significant change in kite numbers in the latter half of the tossing event. This outcome may be attributed to a poor coordination of meat tossing with citizens ritually feeding at these traditional sites, which quickly shifted the flocks in the nearby regions and altered flocking. Moreover, no significant changes in kite numbers were observed at the *Buddha Jayanti Park* along the flight path, possibly due to inadequate coordination efforts across multiple sites. At *Rajpath*, we surely found a significant reduction in kite numbers. Furthermore, the *Pusa* campus (IARI), located considerably far from the customary meat tossing areas in the capital, did not display a significant change in kite numbers. At the *Pusa* campus (IARI), kites were more invested in snatching the chunks away from each other and exhibited heightened aggression to snatch meat from other commensals such as street dogs, suggesting a sense of neophobia.

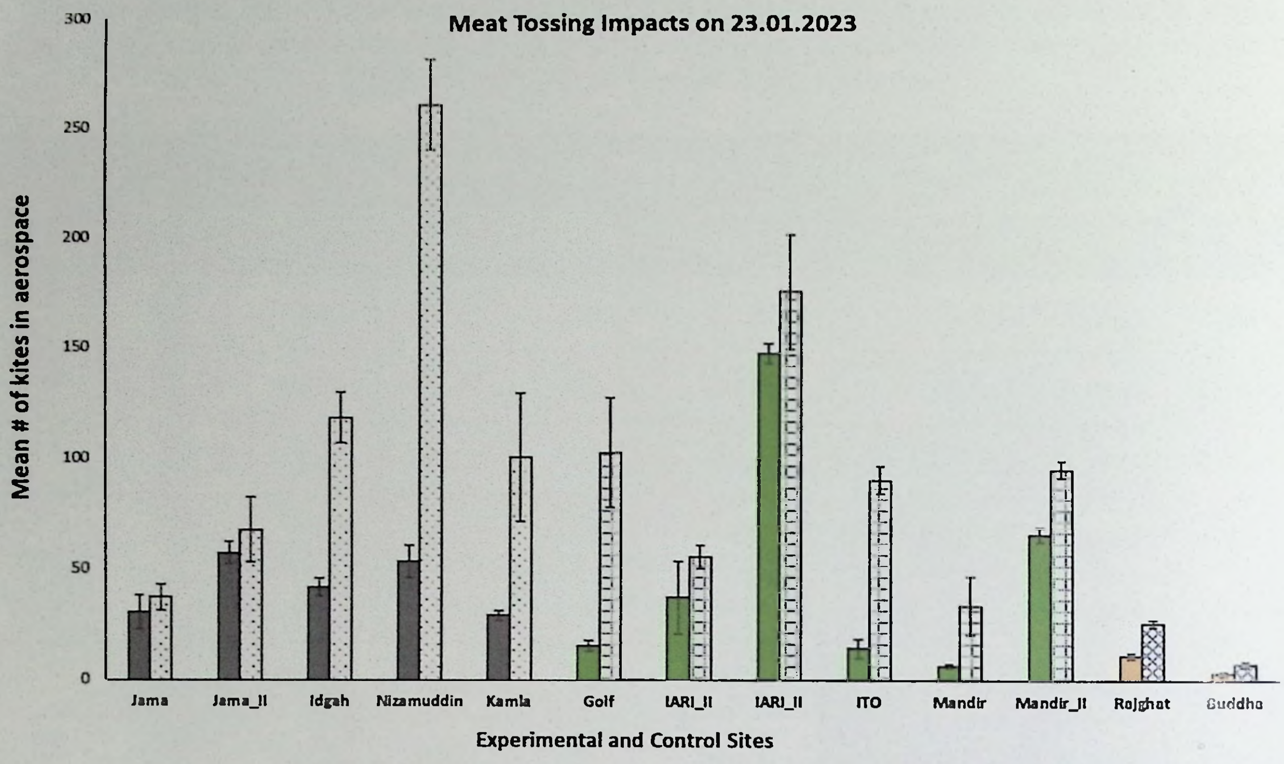


Fig. 5: *Experimental meat tossing on 23.01.2023 at traditional locations (Grey bars: Jama Masjid, Idgah, Kamla Market and Nizamuddin) saw significantly high increase in mean kite numbers in visible aerospace, which did not bring the desired result at Buddha Jayanti Park and Rajpath's, the aerospace of concern (Orange bars). The change in kite numbers as experimental intervention at new locations (Green Bars). The textured bars represent the kite numbers during tossing. The error bars represent ± 1 SE.*

***Table 5:** Summary of the paired differences tested by means of t-tests (Meat tossing events I & II) to illustrate the effect of meat tossing around the flypast in mitigating birdstike threat. Significance Symbols: * P < 0.05; ** P < 0.01; *** P < 0.001.*

Sl. No.	Paired Treatments	Paired Differences			t	df	Sig.
		Mean	Std. Dev	SE			
Pair 1	Niz_B - Niz_A	206.80	57.19	25.58	8.09	4.00	***
Pair 2	Golf_B - Golf_A	86.89	75.59	25.20	3.45	8.00	*
Pair 3	Jama_B - Jama_A	6.50	23.25	13.43	0.48	2.00	-
Pair 4	Idgah_B - Idgah_A	76.50	36.84	15.04	5.09	5.00	***
Pair 5	IARI_B1 - IARI_A1	18.33	25.74	14.86	1.23	2.00	-
Pair 6	IARI_B2 - IARI_A2	28.00	52.51	30.32	0.92	2.00	-
Pair 7	Mandir_B1 - Mandir_A1	27.00	21.07	12.17	2.22	2.00	-
Pair 8	Mandir_B2 - Mandir_A2	29.33	10.07	5.81	5.05	2.00	*
Pair 9	Buddha_B - Buddha_A	4.00	2.71	1.35	2.95	3.00	-
Pair 10	Raj_B - Raj_A	14.20	2.59	1.16	12.27	4.00	***
Pair 11	ITO_B1 - ITO_A1	75.58	13.62	6.81	11.10	3.00	***
Pair 12	Kamla_B1 - Kamla_A1	71.00	46.51	26.85	2.64	2.00	-
Pair 14	Jama_B2 - Jama_A2	10.33	25.42	14.68	0.70	2.00	-

d) 26.01.2023

Univariate comparison of kite counts revealed statistically significant variations at the Golf course area (Phase - II of meat tossing), where no previous history of meat tossing existed (Table 6; Fig. 6). Similarly, there were notable changes in kite numbers observed at the ITO graveyard (Phase - I), which is not a customary site for ritual feeding of kites. As anticipated, the kite counts at *Idgah* and *Nizamuddin* in close proximity to old Delhi, exhibited significant alterations. However, contrary to expectations, *Jama Masjid*, and *Kamla Market* area (*Ram Leela* ground) areas, traditional sites for ritual meat tossing, did not demonstrate a significant change in kite numbers throughout the duration of the tossing event. This outcome may be attributed to a poor coordination of meat tossing at these traditional sites, which quickly shifted the flocks in the nearby regions, thereby altering flocking patterns. Moreover, no significant changes in kite numbers were observed at the *Buddha Jayanti* Park along the flight path, possibly due to inadequate coordination efforts across multiple sites. Furthermore, the *Pusa* campus (IARI), located considerably far from the customary meat tossing areas in the capital, did not display a significant change in kite numbers. At the *Pusa* campus (IARI), kites were more invested in snatching the chunks away from each other and exhibited heightened aggression to snatch meat from other commensals such as street dogs, suggesting a sense of neophobia.

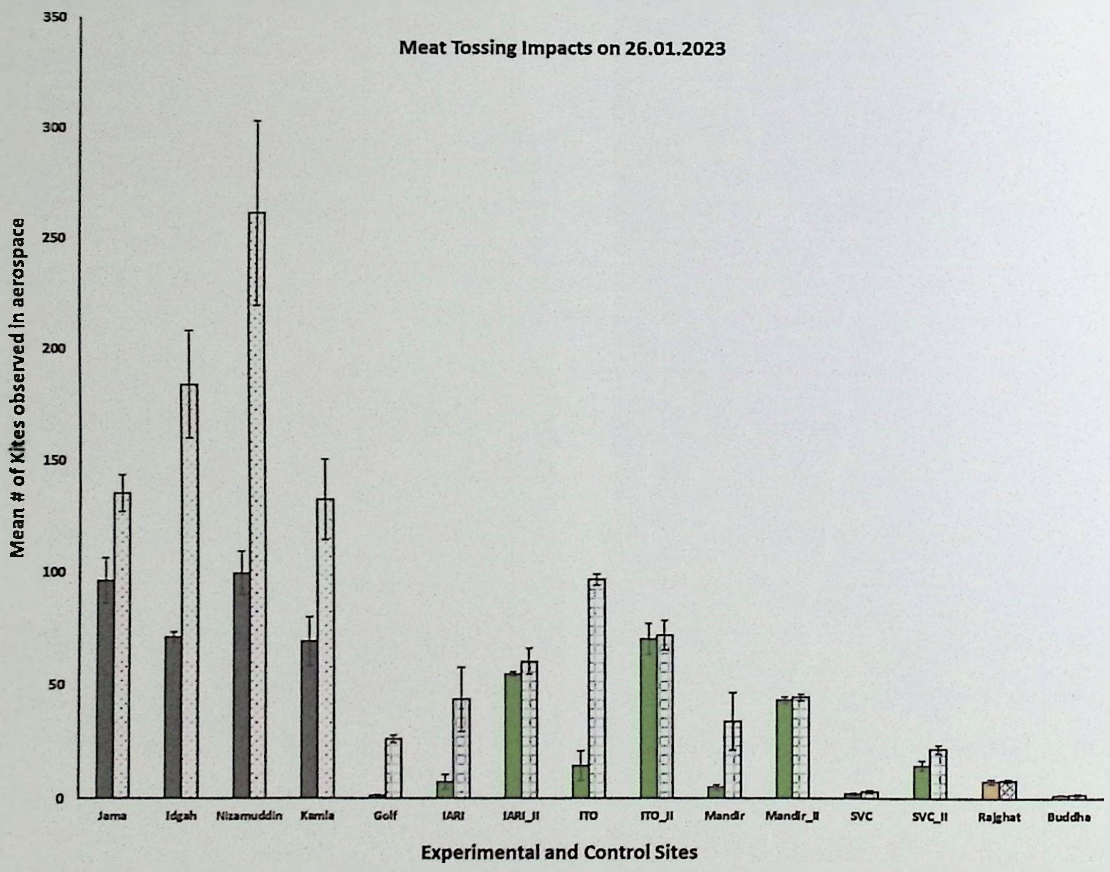


Fig. 6: *Experimental meat tossing on 26.01.2023 at traditional locaitons (Grey bars: Jama Masjid, Idgah, Kamla Market and Nizamuddin) saw significantly high increase in mean kite numbers in visible aerospace, which did not bring the desired result at Buddha Jayanti Park and Rajpath's, the aerospace of concern (Orange bars). The change in kite numbers as experimental intervention at new locaitons (Green Bars). The textured bars represent the kite numbers during tossing. The error bars represent ± 1 SE.*

Table 6: *Summary of the paired differences tested by means of t-tests (Meat tossing events I & II) to illustrate the effect of meat tossing around the flypast in mitigating birdstike threat. Significance Symbols:* $* P < 0.05$; $** P < 0.01$; $*** P < 0.001$.

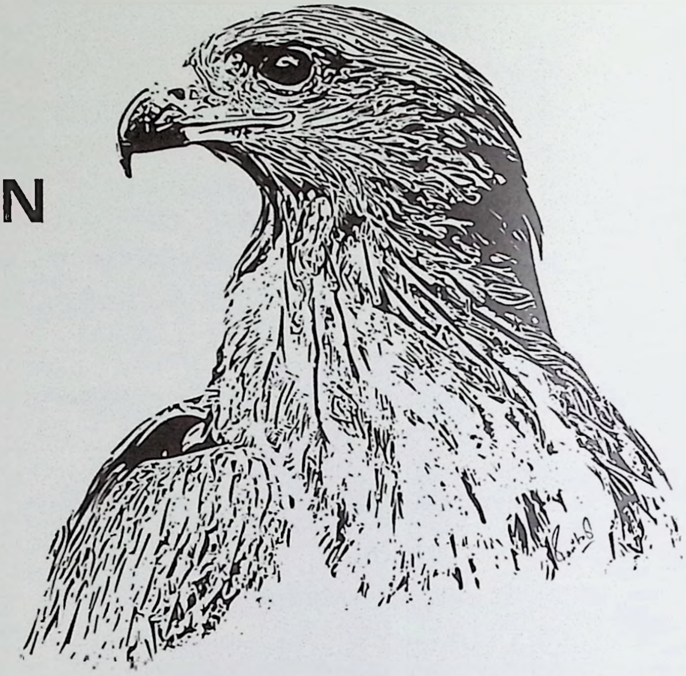
Sl. No.	Paired Treatments	Paired Differences			t	df	Sig.
		Mean	Std. Dev	SE			
Pair 1	Niz_B - Niz_A	-161.67	98.88	40.37	4.00	5.00	*
Pair 2	Golf_B - Golf_A	-25.00	3.46	2.00	12.50	2.00	*
Pair 3	Jama_B - Jama_A	-39.11	43.06	14.35	2.72	8.00	*
Pair 4	Idgah_B - Idgah_A	-113.00	64.03	22.64	4.99	7.00	***
Pair 5	IARI_B1 - IARI_A1	-36.57	19.43	11.22	3.26	2.00	-
Pair 6	IARI_B2 - IARI_A2	-5.67	8.62	4.98	1.14	2.00	-
Pair 7	Mandir_B1 - Mandir_A1	-29.33	20.03	11.57	2.54	2.00	-
Pair 8	Mandir_B2 - Mandir_A2	-1.33	2.08	1.20	1.11	2.00	-
Pair 9	Buddha_B - Buddha_A	-0.25	1.29	0.53	0.47	5.00	-
Pair 10	Raj_B - Raj_A	-0.32	1.78	0.73	0.44	5.00	-
Pair 11	SVC_B1 - SVC_A1	-1.00	1.73	1.00	1.00	2.00	-
Pair 12	SVC_B2 - SVC_A2	-7.33	3.51	2.03	3.62	2.00	-
Pair 13	ITO_B1 - ITO_A1	-83.00	5.66	4.00	20.75	1.00	*
Pair 14	ITO_B2 - ITO_A2	-1.67	18.77	10.84	0.15	2.00	-
Pair 15	Kamla_B - Kamla_A	-63.20	37.96	16.97	3.72	4.00	*

CHAPTER 3

- Nishant Kumar

ECOLOGICAL IMPACTS OF POULTRY WASTE ON URBAN RAPTORS:

conflicts, diseases, and climate change implications amidst pandemic threats



Abstract

The dramatic increase in poultry production and consumption (PPC) over the past decades has raised questions about its impacts on biodiversity, particularly in the Global South. This study focuses on the ecological and environmental impacts of PPC waste metabolism at Asia's largest livestock wet market, located next to the continent's largest landfill of Ghazipur in Delhi, which I have been monitoring since 2012.Daily processing of >100,000 poultry fowls at Ghazipur results in annual production of ~27,375 metric tonnes of poultry waste, attracting massive flocks of Black-eared kites, and migratory facultative scavengers that winter in South Asia. Approximately >33,600 kites foraged in the area every day and disposed of 8.83% of the total PPC slaughter remains produced during October-April. However, with their return migration to Central Asia, kite flocks over Ghazipur reduced by 90%, leading to a proportional decrease in scavenging services. The absence of kites from the larger, migratory race during May-September did not elicit any compensatory response from the small Indian kites, whose numbers over landfill remained unchanged. This raises vital questions about microclimate impacts by greenhouse gases (GHG) released from massive amounts of routine detritus. Bearing in mind the prevalence of ritual feeding of meat chunks to kites in Delhi, my research indicates how life-history traits (migratory vs. resident) enable the exploitation of specific anthropogenic resources, creating distinct kite-

niche(s). Other opportunistic scavengers, e.g., dogs, rats, cattle-egrets, several passerines, and livestock (fishes and pigs) also benefited from PPC waste. Public health and ethical concerns, including Avian-influenza outbreaks in 2018-21 and pandemic lockdowns from 2020-22 - that affected informal meat processing - reduced the flocking of kites at Ghazipur by altering spatial dispersion of PPC remains.

Waste-biomass driven cross-species associations can exacerbate zoonotic threats by putting humans and animals in close contact. The ecological impacts of waste-based biomass, as well as the aerospace conflicts caused by avian scavengers that cause birdstrikes, must factor in the integrated management of city waste. The quantity, type, dispersion, and accessibility of food waste for opportunistic urban fauna in tropical cities along avian migratory pathways are crucial for public health, and for the conservation of (facultative) migratory avian-scavengers like Eurasian Griffons and Steppe Eagles that are facing extinction threat

INTRODUCTION

Over the last six decades, the production and consumption of poultry have dramatically increased, leading to the current situation where the overall biomass of poultry-fowl now exceeds the combined value of all wild birds on Earth by more than 300% (Bar-On et al., 2018; Bennett et al., 2018). Despite the overwhelming evidence that modern global food systems are amongst the primary drivers of defaunation (Bennett et al., 2018; Tscharntke et al., 2012), the ecological impacts of poultry intensification on biodiversity remain largely overlooked, particularly in regions such as South Asia, Africa, and Southern China, where urbanisation is rapidly increasing, and per capita demand for poultry meat by 2030 is projected to rise by approximately 200% (FAO, 2022). While urbanisation has been associated with growth and innovation, and scaling in cities (Bettencourt et al., 2007), it is critical to monitor the massive ecological and environmental impacts of a global standing crop of >25 billion broiler-fowls beyond laboratory-centric studies that primarily focus on carbon footprint and antimicrobial resistance (Bennett et al., 2018). Ecologists are yet to fully examine the far-reaching consequences of poultry intensification on biodiversity, a knowledge gap that must be addressed in the interest of global food security, environmental health, and biosecurity (Gržinić et al., 2023; Tscharntke et al., 2012).

Public health concerns related to poultry production and consumption (PPC) often centre on bacterial or viral contamination of broiler birds (e.g., Hassell et al., 2019; Khan et al., 2020; Woolhouse et al., 2015). In developed regions, there is widespread adherence to scientifically informed poultry management practices that are incorporated from farm-to-pot, to address disease concerns emanating from industrialised PPC (see Thieme, 2013). However, ecological and, thereby, health implications of poultry intensification in developing regions remain poorly understood (Pattison, 2008; Vaarst et al., 2015). This knowledge gap is particularly concerning given the existing skew in the field of urban ecology, with most studies being based in western cities (e.g., review in Marzluff, 2017). Livestock-driven biosphere reconfiguration by humans is a significant challenge due to the ecological and environmental impacts of animal food production, as noted by Dopelt et al. (2019). To put the ecological impacts of more than 65% loss and wastage of food in the meat sector at the consumption stage in perspective (Karwowska et al., 2021), this study focused on the metabolism of food waste from the poultry sector in a developing world setting.

Studying the ecological and environmental consequences of meat-detritus is critical for several reasons. ***First***, developmental heterogeneity in many countries within the Global South affects the possibility to maintain uniform and widespread social rationality and planning for solid waste disposal. Therein, people frequently rely on informal channels to rid of waste, including non-human agencies (Statistica, 2023). Second, such developing countries are experiencing maximum urban growth, and most of the upcoming megacities will be in these regions (Bourdeau- Lepage & Huriot, 2007; UNO, 2018). Consequently, human refuse within urbanising tropics has seen exponential growth, e.g., India's national capital, Delhi, has the highest per capita production of waste in the country. The national capital has overseen a 300% increase in the amount of solid waste over the past 20 years (S. Kumar et al., 2017). The organic constituents of such enormous urban refuse that afford numerous commensals with vital food-subsidies are predictably dispersed within heterogeneously developed, poorly planned tropical cities. Such opportunistic food resources, whose access to urban animals are patterned in space and time (e.g., Griffin et al., 2017; Oro et al., 2013), are a significant ecological concern within a contested and finite city space (see Griffin et al., 2022; Kumar, Jhala, et al., 2019; Wheat et al., 2019; details in the methods section).

Third, a recent study by the National Family Health Survey, India (Paswan et al., 2016), found the growth in per capita income to be closely linked to progressive enhancement of per capita meat consumption by citizens (Roser, 2013; Satterthwaite et al., 2010). Among various Indian states, Delhi, reportedly, has registered the maximum increase in its per capita consumption of meat over the last decade. This rise in meat consumption can be attributed to the increase in the city's per capita income, which is more than thrice the national average (Devi et al., 2014; Paswan et al., 2016). ***Finally***, a combination of above factors, including concentrated poultry consumption in urban areas, creates a geography of opportunistic responses to the enormous slaughter-biomass by facultative scavengers like kites, crows, dogs, and rats often associated with meat-shops, garbage and abattoirs (Kumar et al., 2019). Despite the significance of how multiple human and non-human stakeholders interact with poultry, from production to consumption, and the overall culmination of food waste, only a few authors have incorporated human socio-economic factors as an integral component of their research (see Faraji Mahyari et al., 2021;

Gerber et al., 2008; Guèye, 2000; Mozhiarasi & Natarajan, 2022).

In recent years, numerous studies have focused on the impacts of human infrastructure, such as overhead transmission wires, wind energy farms, and artificial lights at night (ALAN), on migratory avifauna (Drewitt & Langston, 2008; Drewitt et al., 2021; Horton et al., 2019; Nilsson et al., 2021). However, few have explored how the availability of predictable foraging resources at garbage dumps, landfills or abattoirs affects the movement and behaviour of migratory bird populations (e.g., Gilbert et al., 2016; Kumar et al., 2020). This is particularly concerning given the massive growth of meat waste in tropical areas, and when cities/towns producing this waste are frequently located along migratory paths (Galbraith, Jones, Kirby & Mundkur, 2014). Additionally, we have a limited understanding about how the amount and spatial dispersion of urban refuse affects human-animal social-ecological relationships. Gangoso et al., (2013) described one such relationship between the people of Socotra, Yemen, and Egyptian vultures *Neophron percnopterus*, but we need more research to fully understand these complex interactions (see Kumar et al., 2019). Ultimately, the proliferation of poultry and other urban animals can significantly alter ecosystems and sanitary services, affecting human-animal coexistence. Despite such potential cascading eco-evolutionary effects, little research attention has been given to these issues (Oro et al., 2013).

Urban ecology - a discipline encompassing aforementioned issues - is a rapidly growing domain, but researchers have largely ignored the ecological impacts of waste-based biomass. While some recent studies have examined the effects of waste on wild birds and mammals frequenting garbage points and landfills, there is a notable lack of research on the topic (Gil- Fernández et al., 2020; Katlam et al., 2018; Plaza & Lambertucci, 2017; Prange et al., 2003; Vuorisalo et al., 2014). This may be due to the relatively organised solid waste management practices in many Western countries, where urban ecology research has been most prominent (Marzluff, 2017). Additionally, there is a lack of mechanistic explanations as to how access to waste-based food subsidies mediates ecology and behaviour of urban animals (see Kumar, Gupta, et al., 2018; Kumar, Qureshi, et al., 2018). Thus, the findings of my longitudinal study since 2012 on the ecology and metabolism of poultry waste in Delhi's *Ghazipur* - Asia's largest livestock wet market situated adjacent to the city's largest landfill - shed light on complex interplays between multiple organisms in urban environments, addressing important gaps. The study holds special relevance in the wake of recent political discourse surrounding the management of landfills in Delhi. Various political parties in their representations included the flattening of these waste units as part of their electoral mandates and agendas (BJP Manifesto, 2022; K. Sharma, 2022). However, it is crucial to recognise a significant oversight in treating these landfills merely as inert hills composed of garbage and construction waste. The organic matter present in these landfills, particularly the unsegregated waste containing meat detritus, plays a crucial role in supporting and sustaining a distinct community of opportunistic commensals, such as kites, dogs, rats, and even livestock that urban poor rely upon for their sustenance (see Hendrix et al., 1986).

In this study, I explored complex multi-organismic interactions that are driven by organic detritus in urban environments. By examining the chronology of seasonal, and 'gradual vs. stochastic' changes to the availability of meat waste, such as those caused by Avian influenza and COVID-19 pandemic lockdowns, I could afford quasi-experimental insights into how the biotic and abiotic components of landfill(s) represent a living ecosystem (Plaza & Lambertucci, 2017), wherein, fluctuations in food-subsidies may impact the movement and habitat choices of both resident and migratory fauna, e.g., kites in Delhi. The manuscript argues that a poor understanding of the ecological underpinnings of urban organic waste hinders progress in several areas, including the incorporation of ethical practices in poultry transport and processing at *Ghazipur*, municipal solid-waste management to prevent the release of GHG/the proposed flattening of landfills, zoonosis prophylaxis for public health issues, and wildlife management to ensure safe aerospace for both birds and aircraft.

MATERIALS AND METHODS

Study Area and the ecology of poultry waste

Delhi is a megacity of more than 29 million inhabitants, currently covering an area of 1500 km^2, which is overlooking constant, rapid infrastructural expansion (*Census 2011 India*, 2011; UNO, 2018). It is polycentric and heterogeneous, with a multitude of urban configurations, which make it difficult to establish a linear urban-rural gradient. The climate is semi-arid, with a mean annual precipitation of 640 mm, mainly concentrated in July and August during the monsoon season. Temperature ranges from a minimum mean value of 8.2°C in the winter to a maximum mean value of 39.6°C during the summer (IMD, 2022). The vegetation of the general region falls within the 'northern tropical thorn forest' category (Champion & Seth, 1968).

The poultry production and consumption (PPC) network, which encompasses poultry production, transport, and processing, before consumption, is intricately associated with select set(s) of people from a variety of socio-economic backgrounds, like farmers, butchers, transporters, traders and cleaners, and animals. I focused on PPC links within waste processing subsystems, that is composed of humans as well as non-human agencies. Delhi, as a representative city for South Asian urbanism (Shahmoradi, 2013), has three characteristic aspects that significantly shape PPC in the region. ***First***, like other solid waste disposal systems in the city, the informal handling and segregation of PPC waste generates informal livelihoods (see Kumar et al., 2019 for details). Garbage piles of varying sizes and contents, linked with informal labour as the primary agency for processing waste, generates spatially patterned and close interactions between urban poor and opportunistic commensals such as stray dogs, rats, cattle, and various facultative avian scavengers (kites, crows, egrets, and pigeons). Owing to their similarities in urban heterogeneity, tropical cities in the global south have widespread congruence over treatment of urban detritus. This detritus and associated animals in shared living spaces give such tropical cities, a representative visual and olfactory character. With urban poor at their core, such communities on city detritus collectively represent the stench and sensibilities of tropical urbanisation (Doron, 2021).

Second, PPC in Delhi and nearby regions is facing significant changes due to upheavals in human meat consumption that generate subsystems of animal waste. These changes are primarily driven by the collective impacts of demand-supply chains, urban planning, and poultry management on public health concerns (GoI, 2022; S. Kumar et al., 2017). As a result, the traditional practice of rearing poultry in sheds and backyards is being replaced by organised poultry cooperatives (GoI, 2019), which is affecting the number of country-breeds and homogenising the overall poultry germplasm (Bennett et al., 2018; Chatterjee & Rajkumar, 2015; M. Singh et al., 2022).

Third: aforementioned changes, however, are constrained by the increasing volumes of unsegregated waste, animal remains and excreta, and the lack of suitable new places for garbage disposal, leading to conflicts of management among various civic bodies. The Delhi Development Authority is responsible for making the city's Master Plan every 20 years, including spaces for waste, while municipal corporations are responsible for garbage collection and dumping spaces (Bettencourt et al., 2007; Talyan et al., 2008). The Department of forest and wildlife, under the Government of National Capital Territory of Delhi is addressing encroachment by unauthorised dumpers of waste, and animal welfare organisations advocate for improved management. However, the failure to find new sites has resulted in all three of Delhi's landfills continuing to function more than a decade after court orders for their decommissioning were passed. Additionally, several sub judice 'Public Interest Litigations' filed by animal welfare activists have enforced a complete ban on formal processing of poultry at *Ghazipur*, the largest market facility in Asia and the location of the continent's largest landfill. The location also receives offal from various livestock meat processing units in the vicinity. This ban has led to the decommissioning of poultry slaughter on the grounds of animal cruelty, which stochastically altered the spatial dispersion of PPC waste as food-subsidies to urban fauna since September 2018. Given the likelihood of further disruptions to where and how poultry can be reared and consumed, new regulations are already in place with respect to how landfill sites can be used for the disposal of slaughter remains (details in Kumar et al., 2019).

The ongoing political discussions regarding the flattening of landfills in Delhi have sparked competing agendas among different political parties, advocating for the repurposing of waste materials for road construction and electricity generation (BJP Manifesto, 2022; K. Sharma, 2022). This shift in focus on waste management has emerged as a significant aspect of election manifestos in the context of a tropical megacity. However, upon careful analysis of all available manifestos, a striking observation is the apparent absence of consideration for potential ecological implications and challenges associated with the rapid dismantling of landfill (BJP Manifesto, 2022; K. Sharma, 2022). While the concept of flattening mega landfills and utilising waste materials for construction and energy production holds promise in terms of reducing environmental burdens and generating

sustainable resources, it is imperative to approach these initiatives with caution. Therefore, for this manuscript, I attempted a comprehensive assessment of feasibility and potential risks from PPC and landfill detritus to avoid unintended ecological consequences. Specifically, I gave careful attention to the organic composition of the waste, encompassing various organic material and meat detritus from PPC/cattle/fish processing units, in order to mitigate potential direct and indirect impacts.

Human and urban parameters of poultry waste

This study is part of a comprehensive, ongoing research project on the ecology and ethno-zoology of urban scavengers in Delhi, which began in 2012 (Kumar et al., 2019). Through regular surveys at 32 sampling plots spanning approximately 1 km² in a stratified-random design, my field sampling has systematically covered a range of urban settings, from semi-natural to extremely built-up sites, including all three sanitary-landfills (for more information, see Kumar et al., 2019). Given that urbanisation is an ongoing process in Delhi, which has created a melting pot of cultures with people from across the Indian subcontinent (Bhagat & Mohanty, 2009), this study examined the ecology of non-human and urban parameters of poultry waste. In addition to monitoring the metabolism of poultry waste and ecology of opportunistic scavengers (Pickett et al., 2016), I employed a Delphi-like ethnographic approach to understand the range of stakeholders and their interactions with poultry waste and facultative scavengers (Esmail et al., 2020; Mukherjee et al., 2015).

Fig. 1: *Massive flocking of Black-eared kites Milvus migrans lineatus is typical for landfills within tropical cities across South Asia. This image from February 2013 depicts a beholding view of >10,000 kites that regularly congregate over and around the Ghazipur landfill spread over 70 acres. Kites and other commensals mostly capitalise over poultry processing waste at and from Shaheed Ashfaqullah Khan Chicken, Fish and Egg market (SAK) (Government of National Capital Territory of Delhi) in the vicinity. (Photo Credit: Fabrizio Sergio).*

During my field visits to Delhi's landfills, I conducted ethnographic research that involved interactions with an average of 27.03 new onlookers (SE: 2.31) within each of the three sampling units. These individuals willingly engaged in conversations about the impact of poultry detritus, and I employed various methods, including iterated surveys, facilitated discussions, structured elicitation, and aggregation of individual perceptions, to gather direct input on the importance of poultry-based food subsidies for opportunistic scavengers in the city. To address individual-level psychological biases, I interacted with new, randomly selected respondents from the same stakeholder unit, and thematically organised their responses to identify correlations in socio-cultural and professional backgrounds (Esmail et al., 2020). Additionally, I collected information as to how the prevalence of poultry detritus links with opportunistic scavengers, such as dogs, rats, other avian commensals, and livestock, under the purview that meat detritus could mediate prosocial or agonistic human and non-human animal interactions in shared spaces (see Moleón et al., 2014). These observations allowed me to understand how informal and state-driven human agencies formed complex but predictable spatio-temporal interactions with native and invasive animal agencies flourishing on waste (Kumar et al., 2019).

Urban scavenger's guild on landfill detritus: estimating the number of kites on the landfill. Black Kites are frequently seen flocking over landfill sites in South Asia, where they congregate in numbers ranging from a few hundred to several thousands, scavenging on detritus from kitchens, eateries, and slaughterhouses (Kumar et al., 2020; Fig. 1). At landfills like *Ghazipur*, it is almost impossible to visually estimate the number of kites in the region using conventional methods like point points, or through total counts from a single point location. Apart from hovering over the dump these huge kite flock also forage at multiple locations by perching on the garbage. Therefore, it is essential to count the number of birds in flight and those perched on the garbage to arrive at a realistic estimate. To estimate the number of these birds hovering over, and perched on the landfill, I conducted a systematic survey from ten vantage points with good visibility. These vantage points were selected using a systematic sampling method in 2012-13 that I describe below.

The number of kites in the region varies significantly throughout the day, depending on the behaviour of these soaring raptors, which utilise air thermals for flight and foraging. The human detritus found in the dump, primarily from poultry/livestock slaughter, attracts a wide range of avian and other scavengers, including opportunistic feeding of livestock by the urban poor from nearby informal establishments, like dairy farmers (Kumar et al., 2019; see Fig. 2 for a visual representation of on-ground situations and the strength of kite flocks). To determine the time of maximum congregations over a 24-hour diel cycle, I conducted repeated counts and photo shoots of the dump area from a fixed vantage point every hour between 0500 hours and 1830 hours (the end of daylight) from 2012-14. I used two steps to estimate the number of kites - total counts and the estimation method using an open access Java based ImageJ software (https://rsbweb.nih.gov/ij/), as described in detail by Kumar (2013). By obtaining the mean of the numerical estimates from the total counts at the vantage points, I arrived at an estimate for the number of birds in flight.

Subsequently, to obtain the mean value for the ratio of ***"kites perched on the dump: the kites in flight"***, I used Image J and manual counts to estimate kite numbers from the photographs that were clicked under a schematic, as described: I stationed 10 people, each with a camera, at previously chosen systematic locations in the regions during 2012-14 (Fig. 1 and 2). Each person first clicked the kites sitting on the dump followed by tilting the camera upwards to shoot the kites in flight (Figure 3). This was followed by a 60° turn and repeat of the earlier steps, while attempting to avoid overlaps with the previous frame. The concerned person at point 'X' continued this with successive 60° turns till s/he completed capturing kites in his/her 360° view through 5 replicates of the initial step. In the end, kites flying over his/her head were captured with an overhead shot. Thus, on an average, 6 clicks of kites perched in the region and the 7th click of the kites that were in flight afforded us the ratio of completed shooting of kites available for a person from a given point on dump. Rest nine persons also simultaneously followed the same steps at their respective points. This activity was synchronised using cellular phones to avoid double counts of birds as they change locations in a span of a few minutes. To estimate the minimum number of kites benefiting from the poultry detritus in a 24-hour period, I used telemetry data from GPS-tagged Black-eared kites (14 adults and five pre-adults) that were monitored between 2014 and 2018 (details in Kumar et al., 2020).

Calculating GHG emissions from landfilling of PPC waste.

Based on the estimate of waste that was not consumed by kites, which I assumed the SAK sent to the Ghazipur landfill (Singh, 2021), I used the Intergovernmental Panel on Climate Change (IPCC) methodology for estimating CH4 emissions from landfilling. These estimates are based on the first order decay (FOD) approach, which was applied with the default parameters and regional specific landfill data in the IPCC waste model, following Ghosh et al. (2019); Yu & Zhang, (2016). The paper shall present quantitative assessments for kite numbers at Ghazipur and qualitative assessments for the ethnographic surveys, involving multiple stakeholders in the region. All means are given ± 1 SE.

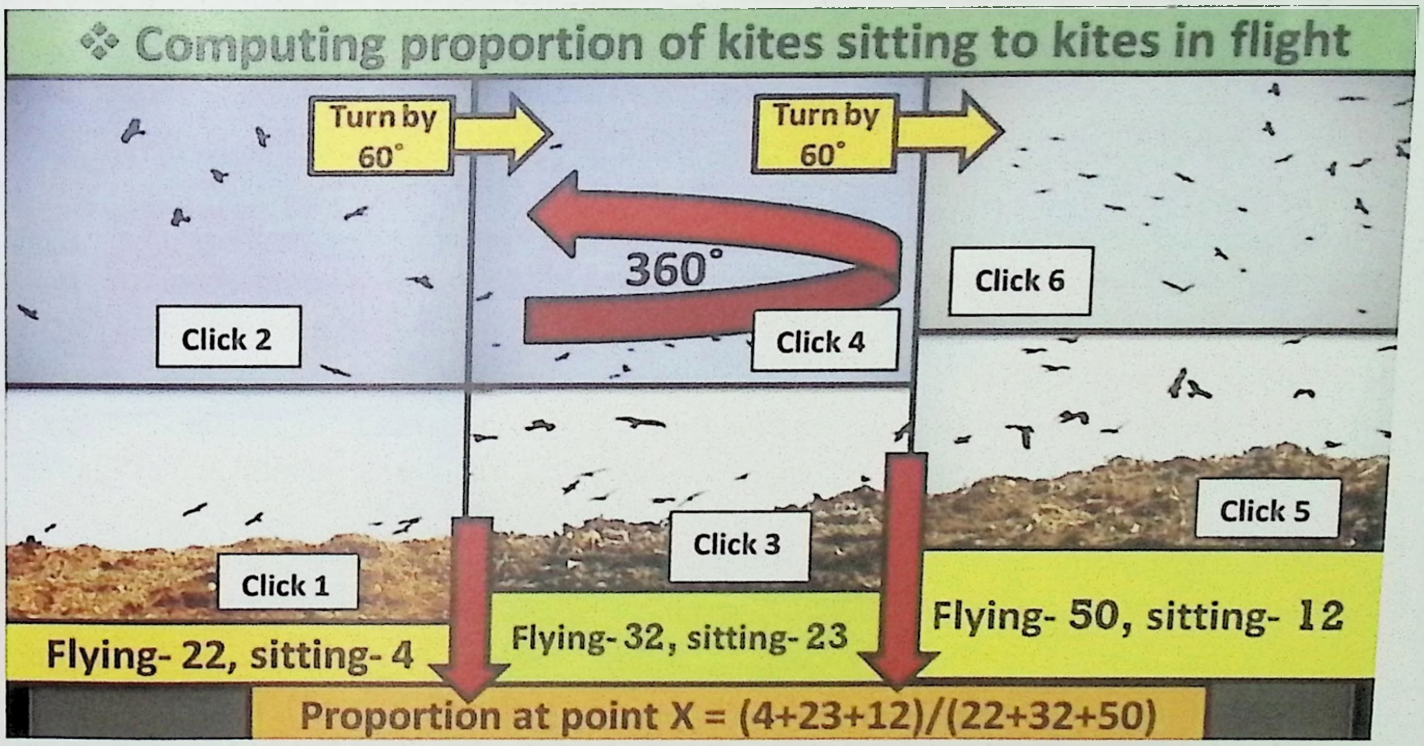


Fig. 2: *To count the black kites at Ghazipur, I stationed 10 people, each with a camera, at predetermined locations in the area during 2012-14 (Figures 1 and 2). Each person first took a picture of the kites sitting on the dump, then tilted the camera upwards to take a picture of the kites in flight (Figure 3). They then turned 60 degrees and repeated the steps, being careful not to overlap any of the previous frames. The person at point 'X' continued this process, turning 60 degrees each time, until they had captured a 360-degree view of the kites in five passes. Finally, they took an overhead shot of the kites flying overhead.*

Fig. 3: *Food scraps from poultry slaughter provide opportunities for interactions between humans and animals that scavenge on garbage piles. At landfill systems like Ghazipur that are associated with meat processing units, this creates systematic relationships between different species, which are poorly understood. The forms and functions of these guilds, which develop over urban food and foraging resources, affect how people view animals that live in cities and how animals adapt to the heterogeneous social environment of cities.*

RESULTS

Interviews with residents and the workers at *Ghazipur* revealed that the distribution of kites on the dump, and poultry processing and disposal facilities across Delhi underwent significant variations. Since 1992, with the establishment of the National Capital Territory of Delhi, the majority of these facilities have slowly been consolidated at *Ghazipur*, established near the landfill site by relocating livestock processing units from the densely populated areas of the city, including *Idgah* and *Jama Masjid*. The landfill at *Ghazipur* was created as part of preparations for the 1982 Asiad Games to accommodate the waste away from the main city. Similar international sporting events, such as the 2010 Commonwealth Games, have played a pivotal role in shaping Delhi's infrastructure development and spatial dispersion of waste in the city. In addition to these events, Delhi's infrastructural growth was also shaped by the central government's five-year plans and the Delhi Development Authority's 20-year master plans, which resulted in significant changes to the concept of waste and hygiene in the city, accompanying large-scale gentrification initiatives across the turn of the century.

Estimates for kite numbers within Ghazipur landfill area and their scavenging services.

Kite numbers in *Ghazipur* landfill area (1 km^2) underwent large scale variations, based on how these soaring raptors take advantage of air thermals for foraging and flight displays. My observations during 2012-14 to understand patterns in arrival/departure of flocks revealed that these flocks typically start building in numbers around 0800 hrs, with the first peak occurring at around 1000 hrs, when air thermals take effect. The second and third peaks occur around 1400 hrs and 1630 hrs, respectively (Fig. 2). Before kites build their flocks at *Ghazipur*, early in the morning (0530 - 0630 hrs), thousands of house crows *Corvus splendens*, egret spp., pigeons *Columba livia*, Red-naped ibis *Pseudibis papillosa*, Egyptian vultures, house swifts *Apus nipalensis*, and several small passerines (myna spp., wagtail spp., Rosy starlings *Pastor roseus*) also occupied the landfill, feeding on detritus/insects. The numbers of crows and pigeons dwindled with the increase in kite numbers, 0800 hrs onwards.

The GPS data showed that tagged kites spent an average of 3-4 hours in the landfill area. The time of day that the tagged birds (n=20) visited the landfill varied depending on the individual, age, and distance of the roosting sites from the landfill. In comparison to adult birds, all pre-adult GPS-tagged birds (n = 6) roosted in proximity of *Ghazipur* (χ^2= 7.01, P = 0.008). Since three peaks in kite congregations were observed within 24 hours in the region, it appears that multiple groups of kites from across Delhi visited the landfill(s) and foraged for about 3-4 hours before returning to their roosting locations. These observations were consistent throughout the sampling period, which the research team used to plan trapping of birds for GPS tagging. The team found that the birds congregated most often around 0930 hrs, 1330 hrs, and 1630 hrs. Multiple team members counted kites in flight at the nearby Ghazipur and *Shaheed Ashfaqullah Khan Chicken, Fish, and Egg market* (SAK) during peak congregation times.

Based on these repeated visual counts, I estimate that there are approximately 10,000 kites. Based on this number, I estimate that at least 33,600 kites feed on poultry detritus at *Ghazipur* landfill every day. I arrived at this figure by combining the total number of kites in flight with the number of birds perched on the landfill and nearby. The number of kites in flight was estimated by multiplying the number of major flying congregations (10,000) by 3. The number of perched birds was obtained from the overall ratio of 'birds in flight: birds perched' within *Ghazipur* area, using the equation from (N. Kumar, 2013). This gave a total of 33,600 kites.

At poultry shops within the SAK facility, procurement, processing, and slaughter detritus management practices were community-specific, associated with social factors such as religion, caste, and class. For instance, at the SAK facility in *Ghazipur*, the majority of workers who handled poultry waste, as well as allied staff and owners/workers at roadside eateries, came from Muzaffarpur, a district in the Indian state of Bihar. During the study period from 2013 to 2022, the SAK facility procured and processed more than 100,000 broiler chickens every year each day, which yielded approximately 400 metric tonnes of poultry meat for local consumption. Poultry fowls were sourced from farms/villages in neighbouring states, such as Haryana, Uttar Pradesh, Punjab, and Rajasthan, and transported to SAK on over 200 trucks/day. The processed meat was sold to local markets, restaurants, and also the aviation industry for use in in-flight meals.

The annual estimate for poultry waste from *Ghazipur*, which includes feathers, skin, heads, blood, and entrails, was approximately 27,375 metric tons. This estimate was based on an average of 250 grams of slaughter remains per kilogram of bird weight (mean weight estimated per fowl = 3 kg). During the winter migration period (October to March), migratory Black-eared kites from central Asia scavenged to dispose of about 8.83% of the slaughter detritus. However, during the April-September period, the birds that remained on or near the landfill (n <1000) could only scavenge and clear less than 0.03% of the total estimated 13,688 metric tons of slaughter detritus. In other words, the Black-eared kites were able to scavenge and clear a significant amount of poultry detritus during the winter migration period, but with their return migration, this ecosystem service decreased significantly during the April-September period. The absence of the larger, migratory kite species during May-August did not cause the smaller Indian kite species, *Milvus migrans govinda*, to increase in number within *Ghazipur* area. The number of birds over the landfill remained unchanged, with an overall bird count of less than 1000 during May-August.

Further, the number of kites in flocks at the other two landfills in Delhi was less than 1000, possibly because there are no livestock processing facilities at *Okhla* and *Bhalswa*. People from nearby slums collected poultry slaughter refuse from SAK for their own consumption, while farmers used it as feed in nearby pisciculture units within states bordering Delhi. Strong ties between informal and private initiatives helped to ensure that a significant portion of the remaining poultry waste was metabolised through the use of poultry waste in fish farming.

Large trucks transported fish from Kolkata (a metropolitan city on the eastern coast of India, 1600 km from Delhi) to SAK, and on their return journey, they loaded poultry waste, which was a major source of food for fish farming in the region, primarily for desi mangur *Clarias batrachus*, an invasive catfish in Asia (Fig. 5). However, these waste transport links between Delhi and Kolkata via circular economic channels only operated during the winter season (November-March), due to the limited lifespan of waste transported by road, which could rot and cause problems. The journey from Delhi to Kolkata took 2-3 days, during which, drivers of transporting trucks faced hostility from local residents along the journey if rotting detritus spread foul smell from the vehicles. The amount of time that waste could be stored before it began to decompose was limited by the amount of time that ice sheets could cover the waste in containers, the reasons it was impossible to move poultry waste to large distances during the summer. During April-October, this waste was either put on landfill or informally collected by regional fish farmers (Fig. 4). In April-May 2018, the government of West Bengal imposed a ban on the entry of poultry detritus from Delhi's *Ghazipur*.

As a result, meat waste from over 100,000 chickens per day was piled up at *Ghazipur* for more than 1.5 months, resulting in more than six-foot-high rotting biomass spread over an area half the size of a football field (Fig. 4). The ban was imposed because of the outbreak of diseases in the fish farms of Kolkata, which was linked with use of Delhi's detritus as feed. This event highlights the challenges and intricacies of managing food waste and its potential impact on the environment, animals, and public health. The interaction between poultry and fish trade, and their detritus, linked with urban commensals in complex ways. These ecologies of PPC and its detritus, illustrated in Fig. 5, are poorly explored for their implications on human, animal, and environmental health.

Environmental impacts of meat/organic detritus from Ghazipur landfill: GHG and wastewater

If all PPC waste that is not consumed by kites ends up rotting in landfills (which may not be the case, as dogs, rats, humans, and other animals may scavenge on it), then according to IPCC models, such detritus would produce 17.04 Gg of methane per year. Regardless of how PPC is metabolized (through scavenging, pisciculture, or landfilling), the amount of waste warrants serious consideration from the Municipal Corporation of Delhi. In case we take the landfilled biomass moving from SAK, as estimated by Singh, (2021), then such detritus would produce 2.68 Gg of methane per year.

Furthermore, the wastewater from the poultry slaughterhouse was discharged directly, untreated, into municipal wastewater by formal and informal traders in the region. Such effluents have a high Biochemical Oxygen Demand (BOD) that can harm aquatic fauna. Further, open dumping practices that are prevalent at *Ghazipur* lead to emission of enormous amounts of methane into the atmosphere. The East Delhi Municipal Corporation, in collaboration with the Gas Authority of India Limited and the Indian Institute of Technology, Bombay, launched a pilot program in 2012- 13 to harvest methane from the anaerobic decomposition of waste using 40% of the area of the *Ghazipur* landfill. However, the unit was shut down immediately after it began operating. The main reason for this was that the methane harvest was suboptimal due to the mixed nature of the solid waste on top of the landfill.

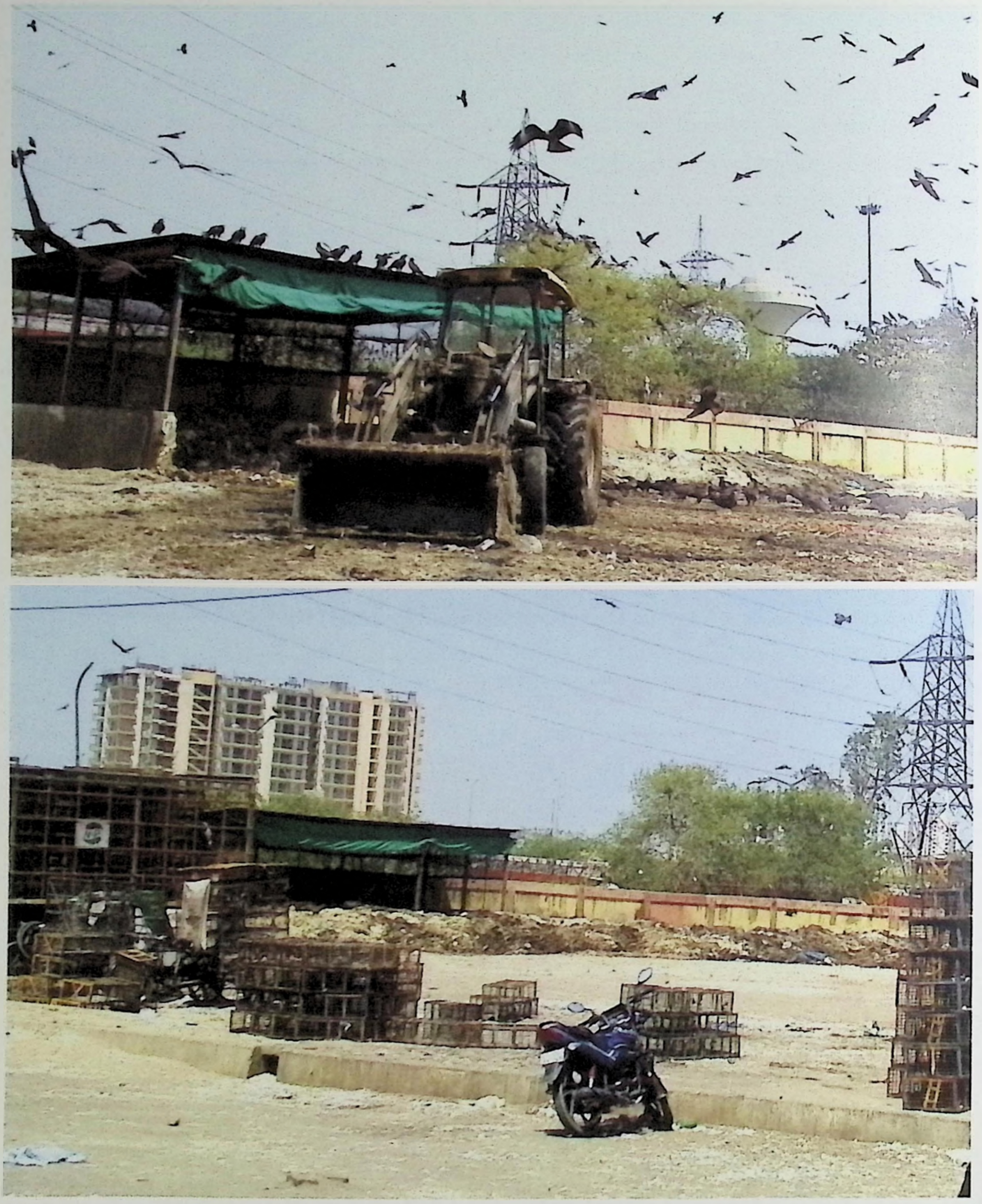


Fig. 4: *In April 2018, West Bengal's state government refused to accept poultry waste from Ghazipur for its fish farms due to the risk of disease transmission. The waste-to-value chain was disrupted. The pictures show how meat waste from over 100,000 chickens per day was piled up at Ghazipur for 1.5 months, resulting in a six-foot-high rotting biomass spread over an area half the size of a football field.*

Poultry detritus presented a significant opportunity for multi-species interactions between native and exotic (migratory) species at *Ghazipur*. During the study, the urban detritus community experienced several changes due to stochastic impacts, such as multiple Avian influenza outbreaks/prophylaxis between 2018 and 2021, ethical and legal issues with PPC in 2018, and the COVID-19 pandemic from 2020 to 2022. In addition, many Hindus refrain from eating meat during the Indian month of *Śrāvana*, which coincides with the monsoon rains in July and August, for cultural reasons. This leads to a regular fluctuation in the availability of PPC detritus. One of the respondents at *Ghazipur* explained:

"Śrāvana is a time of natural renewal, when the Earth regenerates its vegetation, and the animal kingdom also undergoes reproductive rituals. As a result, Hindus abstain from killing animals for meat, a traditional practice that predates modern animal husbandry and is still practised today."

Additionally, in Hinduism, it is a common practice to abstain from eating meat on certain days of the week as part of religious observance. Tuesdays, Thursdays, and Saturdays are traditionally considered to be days when meat consumption is prohibited. The availability of poultry waste was affected by monthly and yearly trends, which also had a negative impact on poultry meat sellers, particularly small informal shops, who did poor business during *Śrāvana* or on specific weekdays. Additionally, the Government of the National Capital Territory of Delhi took several preventive measures between 2012 and 2021 by restricting poultry trade in response to avian influenza, further impacting the availability of poultry waste. Improper disposal of carcasses after large-scale culling drives benefited urban scavengers like stray dogs and rats. Tracking kites with GPS tags helped to understand the effects of stochastic changes (such as a ban on chicken slaughter, pandemic lockdown, and avian influenza) on the distribution of food subsidies. However, due to the lack of tagged individuals, it was not possible to assess how food subsidies for rats at *Ghazipur* could be linked to AMR (Fig. 5), despite the existing public health concerns associated with urban rodents.

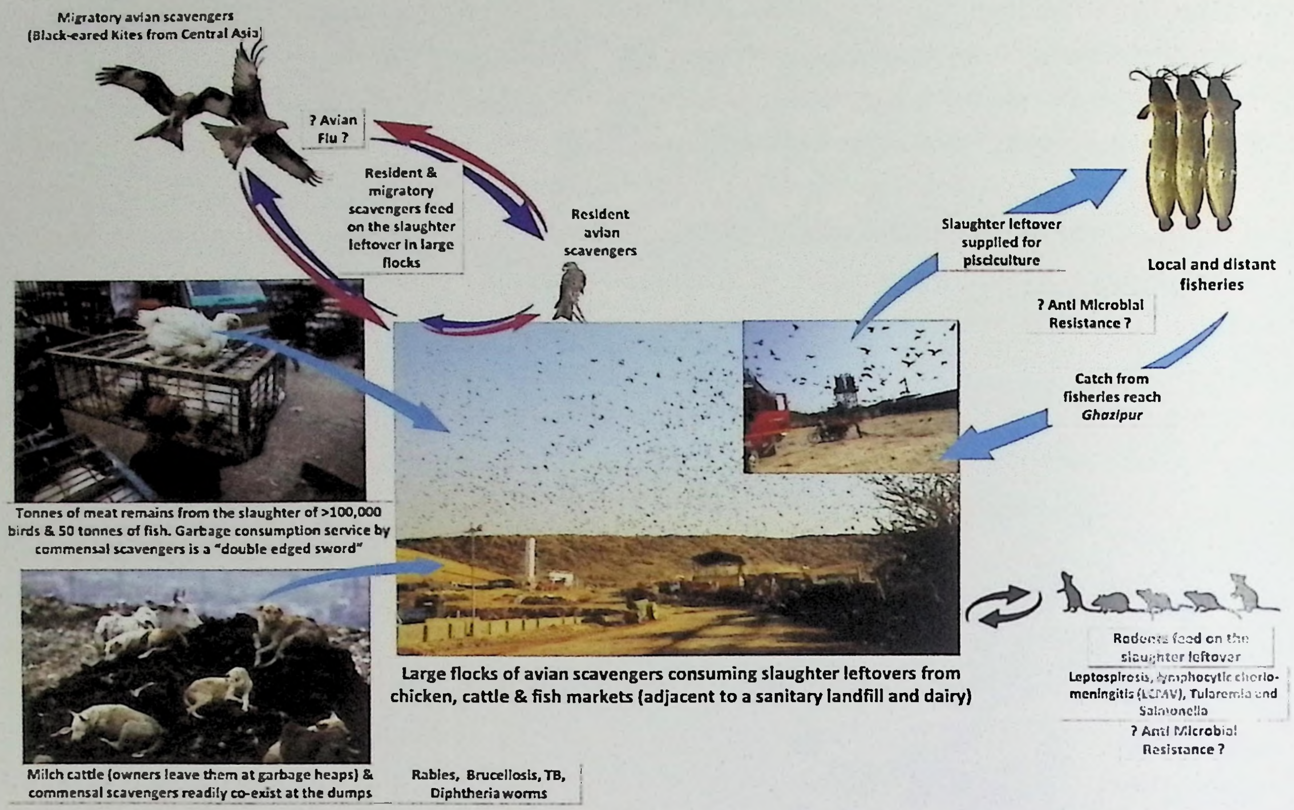
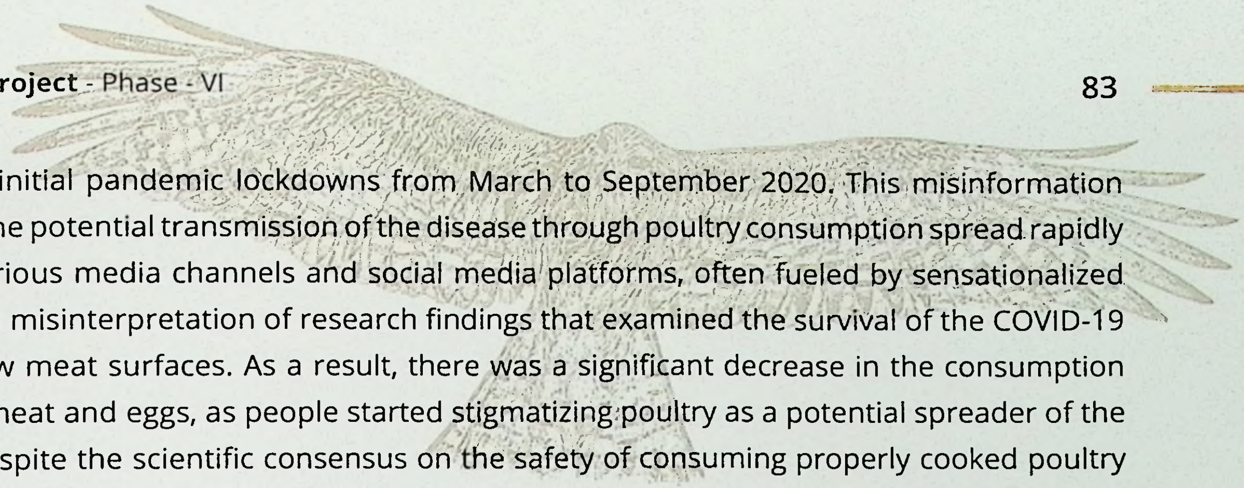


Fig. 5: *What goes around, comes around: the figure shows how people, animals, and waste interact in tropical megacities. It highlights the potential risks of informal handling of meat processing waste, such as bioaccumulation and biomagnification of toxic elements, antimicrobial resistance, and zoonotic diseases. These relationships and their implications are important for understanding the ecological and social dynamics of rapidly changing, human-dominated environments.*

The decision to ban poultry slaughter at SAK in September 2018 had a significant impact on the point location availability of poultry detritus at *Ghazipur*, which subsequently affected the number of kites congregating on the landfill. Since poultry waste was only available from around 20 informal shops in the SAK area, kites began to congregate at the nearby fish market, as well as on offal found at the landfill and throughout the rest of the city. Counting kites from high points showed that the overall flock size during the peak wintering season was reduced to about one-third of the previous estimate of around 10,000 birds. GPS-tagged kite data also revealed that avian scavengers likely dispersed throughout Delhi after the decentralisation of chicken slaughter in the city, which also caused the dispersion of slaughter waste.

Interviews conducted during prophylactic containment to prevent the spread of bird flu revealed that during the COVID-19 pandemic, a significant amount of misinformation circulated regarding the potential transmission of the disease through poultry consumption, leading to a decline in the consumption of poultry meat and eggs. Thus, poultry was sold at very low prices



during the initial pandemic lockdowns from March to September 2020. This misinformation regarding the potential transmission of the disease through poultry consumption spread rapidly through various media channels and social media platforms, often fueled by sensationalized reports and misinterpretation of research findings that examined the survival of the COVID-19 virus on raw meat surfaces. As a result, there was a significant decrease in the consumption of poultry meat and eggs, as people started stigmatizing poultry as a potential spreader of the disease. Despite the scientific consensus on the safety of consuming properly cooked poultry products, the misinformation surrounding poultry as a potential spreader of COVID-19 had a tangible impact on consumer behaviour. According to my interviewees, during the pandemic, consumers opted for alternative protein sources from plant origin. This decline not only affected the poultry industry at *Ghazipur* but also disrupted supply chains and posed economic challenges for farmers, informal workers, and businesses involved in poultry production and distribution. The pandemic also led to the creation of satirical songs in regional languages that mocked the situation and spread misinformation surrounding poultry as a potential spreader of the virus. One such song, *"Murga Badnaam Hua Corona Tere Liye,"* means "The rooster has earned a bad name for itself due to COVID-19" (see MCRS Music, 2020).

Market disruption caused the price of chicken and eggs to drop by up to 80% (general drop was at 20%), as people believed that poultry was a potential carrier of the virus. Since major lockdowns in 2020 (April - June) and 2021 (late April -May) coincided with the breeding time of Black-eared kites, when they are in northern Central Asian latitudes, I could not register the impacts of reduced poultry sale on the kite-movements at *Ghazipur*. These changes led to positive shifts in meat consumption by the urban poor who typically cannot afford it. In contrast to Western countries, socio-economic status influenced who consumed the most desirable parts of poultry. For example, the tarsii, skin, head, gizzard, etc., which are typically discarded during broiler processing, were available for Rs. 20/kg (i.e., at 10% of the price of broiler meat) and were typically purchased by people of lower socioeconomic status.

This study provides a clear example of the ecosystem-level impacts of cultivated non- human detritus. This detritus acts as a pollutant and food source, affecting both feral and wild species. Due to human reconfiguration of the biosphere by broiler chickens and other poultry, tropical urban cities like Delhi link society and biota at multiple spatial and temporal scales as an ecological formation. The findings underscore the need to comprehend how animal husbandry activities and practices in developing regions like South Asia connect with socio-cultural, economic, and ecological processes. In most tropical cities, the increasing disposal of solid waste creates enormous foraging opportunities for urban wildlife. However, despite the regional to global impacts of cultivated animal detritus that were discovered in the surveys, its conceptualization has largely been overlooked by conventional approaches to ecological assessments in cities.

The response of avian scavengers to food subsidies, space, infrastructure heterogeneity, and human agencies showed how these factors interact to create a mosaic of homogenized urban biota. For cities like Delhi, without a rethinking of how the dispersion of poultry detritus is mediated by urban infrastructure and socio-economic factors, investigating its importance as a predictable resource for opportunistic scavengers would have been overlooked. Below, I discuss the implications of these interactions for human, animal, and environmental health. The following are the implications of these interactions for human, animal, and environmental health:

- ***Human health***: Avian scavengers can spread diseases to humans through contact with their droppings or by eating contaminated food.
- ***Animal health***: Avian scavengers can also spread diseases to animals, such as poultry.
- ***Environmental health***: Avian scavengers can contribute to the spread of pollution and the decline of biodiversity.

DISCUSSION

The article highlights the ecological distinctions between traditional methods of poultry rearing/ consumption and modern practices, particularly in the context of rapidly urbanising tropical systems like Delhi. These contrasting aspects underscore the challenges of meeting the growing demand for poultry products in urban areas, while also maintaining traditional production practices that are often associated with rural areas. Furthermore, the article notes that poultry rearing has seen the highest rate of increase amongst all livestock items over the last 50 years (Bennett et al., 2018). However, the majority of poultry reared in South/South-east Asia still happens in relatively rural areas, where backyard farming is a common practice (Gilbert et al., 2015). These findings suggest that there may be an opportunity to promote more sustainable and equitable poultry rearing practices in urban areas, where demand for poultry products is high (Chatterjee & Rajkumar, 2015; Gilbert et al., 2015; Thieme, 2013; Wong et al., 2017).

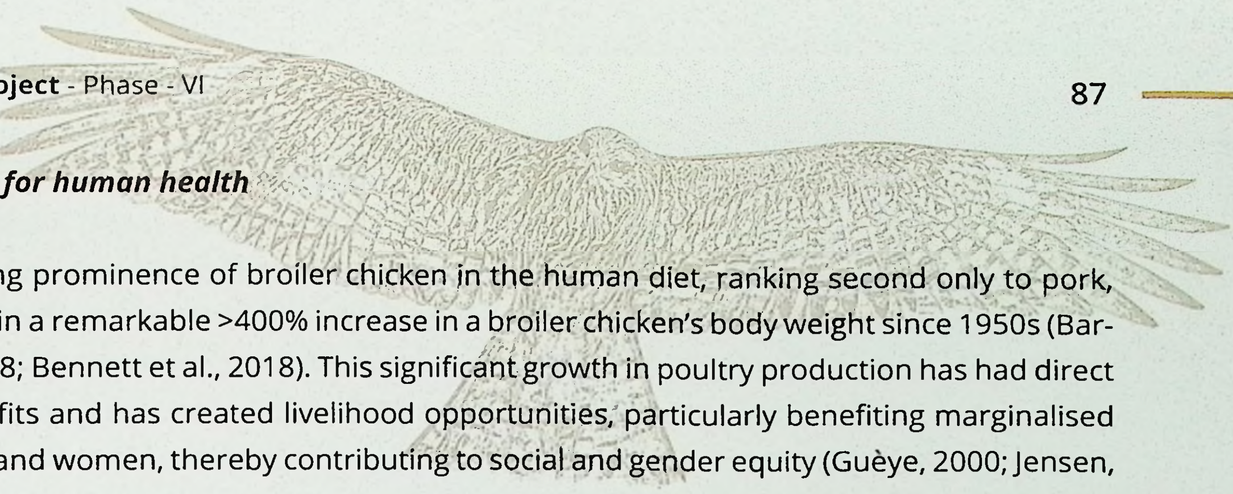
In addition, field observations pointed out disproportionately higher participation of women in backyard poultry rearing in tropical countries, unlike the distribution and processing networks that are male dominated (noted by FAO, 2019; Njuki et al., 2013; Rota, 2023; Samanta et al., 2018). This gender imbalance along the poultry value chain has important implications for equity, gender-mediated susceptibility to diseases spread by handling poultry, and the economic empowerment of women, and/or poor and oppressed people. Efforts to promote more sustainable and equitable poultry production practices in urban areas must take into account these gender- specific concerns at various stages of PPC value chain (Guèye, 2000; Jensen, 2022; Njuki et al., 2013; Rota, 2023).

My observations provide compelling examples for the ecosystem-level impacts of human detritus that affects the environment directly as a pollutant, while also indirectly mediating ecological responses from feral and wild species (Barua & Sinha, 2022; Kumar et al., 2019). The reconfiguration of the regional biosphere by poultry and other livestock in tropical urban areas such as Delhi have created an ecological formation that links society and biota across multiple spatiotemporal scales (e.g., see Kumar, Gupta, et al., 2018, 2019). In most tropical cities, increasing solid waste that is disposed of informally creates enormous foraging opportunities for urban fauna (Gutberlet, 2017). These steps involved in creation and culmination of organic biomass from waste highlight the need to better understand how animal husbandry activities in developing regions like South Asia intersect with socio-cultural, economic, and ecological processes. This case study at *Ghazipur* illustrated how animal-detritus has regional impacts on resident urban fauna, but also global effects on migratory avifauna (see Barua & Sinha, 2022). The largest landfill in New Delhi before the establishment of *Ghazipur* landfill in 1982 was located at *Indraprastha*, next to the National Zoological Park. Malhotra (2012) estimated that there were more than 40,000 Black-eared kites roosting in and around the zoo, unaware of Kumar et al.'s, (2020) study on the communal roosting habits of migratory Black-eared kites in Delhi. Since 1970s, the nesting density at Delhi's Zoo has quadrupled (~100 nests/km2: Kumar et al., 2019), and the roosting Black-eared kites' numbers are usually less than 2000. It is also worth noting that even after the return of larger migratory kites, the number of resident breeding birds remained unchanged in *Ghazipur*, which highlights the variation in the significance of the site for the birds from two races. This finding supports the interesting fact discovered by Kumar et al., (2018) that the distance to a landfill does not influence the choice of breeding habitat by kite pairs in Delhi. These findings highlight major distinctions in the niches of resident vs. migratory kites, as well as breeding vs. non-breeding birds, suggesting potential areas of research on how life-history characteristics (migratory vs. resident) as well as individual life histories (young vs. old bird) shape and determine the exploitation of specific anthropogenic resources by urban commensals (Burnside et al., 2012; Hulme-Beaman et al., 2016; Seress & Liker, 2015). This highlights why poorly managed waste continues to have unpredictable and negative ecological consequences for human, animal, and environmental health across scales (Bettencourt et al., 2007; Grimm et al., 2008; Pickett et al., 2016).

The way that birds and other animals that eat dead things react to food from poultry farms, how infrastructure is built and changed in *Ghazipur* and SAK, and what people do - including how they relate to birds and the laws they make - all have an impact on how different types of plants and animals live together in cities (Barua, 2020). These communities are changing quickly and becoming more similar to each other (Fig. 5, 7) (Barua & Sinha, 2022; N. Kumar, Gupta, et al., 2018). It is critical to rethink the distribution of poultry waste and how it is influenced by urban infrastructure and socioeconomic factors. Furthermore, if we consider the estimates for GHG emissions, then the landfilled biomass from SAK constitutes anywhere between 4.23%

to 26.81% of the annual methane (63.56 Gg/year) produced by landfilled biomass at *Ghazipur* in 2015, based on prior estimates by Ghosh et al., (2019). This shall enable recognition of its importance as a predictable foraging resource for both resident and migratory scavengers in cities like Delhi (see Fig. 6), which would have otherwise been overlooked. I discuss these further under specific headings (also see Kumar et al., 2019).

Fig. 6: *This aerial view shows the Shaheed Ashfaqullah Khan SAK, the largest poultry market in Asia. The poultry waste, produced by the daily trade of over 100,000 chickens, is an important food source for many opportunistic scavengers. In September 2018, the slaughter of poultry was halted following an order from the Delhi High Court, and a new processing facility has been under construction since then. The barricaded area that was previously used to collect poultry waste before it was loaded onto trucks (see Figures 2 and 3) also attracted a significant number of migratory kites. However, following the cessation of formal poultry slaughter (informal practices still ongoing), the number of kites has decreased to less than a third of the total congregated birds, resulting in a visible reduction to the kites' photo captures (birds in flight), in comparison to the skyline in Fig. 1, 2 and 3.*



Implications for human health

The increasing prominence of broiler chicken in the human diet, ranking second only to pork, has resulted in a remarkable >400% increase in a broiler chicken's body weight since 1950s (Bar-On et al., 2018; Bennett et al., 2018). This significant growth in poultry production has had direct dietary benefits and has created livelihood opportunities, particularly benefiting marginalised populations and women, thereby contributing to social and gender equity (Guèye, 2000; Jensen, 2022). However, my findings reveal that inadequate disposal mechanisms for poultry waste in developing countries disproportionately impact urban poor communities, leading to caste and class-specific relationships with poultry waste, which can be classified as environmental racism (Gladkova, 2020; Pellow, 2004). Improper waste management practices have caused a multitude of ecological impacts, affecting the community of opportunistic scavengers in urban areas and resulting in direct conflicts with humans and other cohabiting species. A prime example of such conflicts is the burden of human-dog conflicts (bite), estimated to occur every two seconds in India by Menezes in 2008; these disproportionately affect the urban poor (Reporter, 2021). Issues of human-animal conflicts that are mediated by spatial dispersion of urban meat detritus highlight the global challenges of sharing living spaces with commensal species (Aiyedun & Olugasa, 2012; Gogtay et al., 2014; Hampson et al., 2015).

Existing interventions aimed at mitigating the implications of waste-mediated human- animal interfaces in shared spaces have proven inadequate. For instance, these interventions include selective neutering/translocation of stray dogs (Jackman & Rowan, 2007; Reese, 2005), managing monkey troops (Ganguly et al., 2018), implementing effective vaccination strategies against potential zoonotic diseases, culling of poultry and swine to prevent zoonotic influenza (Barua, 2020), and rehabilitating slums (Dupont & Gowda, 2020), and decommissioning landfills and abattoirs (Kumar et al., 2019). However, these approaches have not effectively addressed the ecological and behavioural relationships associated with waste and other forms of human food subsidies that enable certain animals to thrive in urban environments (S. Kumar et al., 2017; Schell et al., 2020; B. B. M. Wong & Candolin, 2015). A noteworthy organisational feature of PPC is its heavy reliance on precarious backyard farmers and workers that are urban immigrants. Based on the results of our semi-structured interviews, it is important to note how pandemic threats such as Avian Influenza and COVID-19 created a situation of virtual virulence in Delhi and beyond. Access to misinformation, such as WhatsApp forwards, devastated India's poultry industry, which incurred losses in tune of $21 million/day in lockdown-I (Barua, 2020).

Telemetry data collected on kites (Kumar et al., 2020) and observations conducted at SAK have provided insights into how food subsidies influence the utilisation of airspace by both native and migratory bird species (Barua & Sinha, 2022). It is well-established that both native and exotic animal species thriving on poultry waste are associated with zoonotic concerns, thereby contributing to the perpetuation of antimicrobial resistance (AMR) pathways through the scavenger guild (Sharma et al., 2018). Notably, the interactions between rodents and kites over poultry and fish slaughter detritus are of particular concern, as they contribute to the imminent burden of AMR, which is predicted to experience the greatest growth in South Asia (Becker et al., 2018; Hassell et al., 2019; Khan et al., 2020; Woolhouse et al., 2015). In the Figure number 5, I illustrated the local and global impacts of the dominance of broiler chicken. These impacts, however, are often overlooked by the public health experts. It is important to note that socio- economic status within the Indian subcontinent plays a significant role in determining which parts of the chicken are consumed. Relatively wealthier individuals tend to discard the tarsii, skin, head and entrails, while in China, these parts are incorporated into highly regarded cuisines that are commonly consumed across caste and class lines (*pers. obs*). Understanding these dynamics is crucial for addressing the issue of AMR, taking into account the caste and class-specific consumption patterns associated with specific parts of poultry fowls in India (see Thieme, 2013, page. 20, for the contribution of each stage of the slaughter process to bacterial contamination).

The change in avian scavenger communities in South Asia following the decline of vulture populations is one aspect that has received little attention (Prakash et al., 2003). The rapid growth of the aviation industry in recent decades has resulted in an increase in the number of "aviation mega-cities" globally, projected to reach 91 by 2033, accompanied by an approximately 5% annual growth in air-passenger traffic over the next 20 years (Airbus, 2014). This expansion in air traffic, coupled with the preparations about utilisation of manned and unmanned drones for goods delivery and other purposes, creates a scenario where opportunistic birds and aircraft come into conflict within limited airspace. According to estimates provided by the Indian Air Force, birdstrikes affect approximately 1500 military and civilian aircraft annually in the region, leading to substantial financial losses and endangering human lives (IAF, *pers. comms.*). Among birds, avian scavengers, particularly Black Kites (*Milvus migrans*), pose the greatest threat in terms of birdstrike hazards, accounting for over 62% of all cases causing aircraft damage (IAF, *pers. comms.*). These conflicts would be less frequent if effective management strategies were employed for the disposal of poultry and other animal waste, highlighting the urgent need for novel approaches to wildlife management and conservation (Ditchkoff et al., 2006).

Implications for animal health

Waste plays a significant role in shaping human-animal relationships, as it is often utilised as a direct and indirect food source for livestock and by opportunistic scavengers (Cavé, 2014; Kumar et al., 2019; Kumar et al., 2017; Sorathiya et al., 2014). In the context of Delhi, the availability of poultry waste is influenced by urban food habits, planning, and human beliefs and practices, with infrastructure playing a mediating role in determining access (Kumar et al., 2019). Through this research, I have revealed that the impact of poultry detritus on trophic dynamics exhibits high variability, dependent on the interplay between urban configuration and species-specific tolerance towards human proximity (see Kumar et al., 2019). For instance, the successful colonisation of detritus units by thousands of migratory kites in and around *Ghazipur* is contingent upon broader social perceptions of non-human life. Animals access anthropogenic resources such as poultry detritus, through species-specific movement patterns in response to built-up features like roads and overhead transmission wires they must negotiate (Criffield et al., 2018). The impacts of poultry detritus on trophic dynamics exhibit a high degree of geographic variability, which is contingent upon the spatially explicit coupling of urban configuration and species-specific tolerance towards human proximity (Kumar et al., 2019). The relationship between humans and animals is affected by a variety of factors, including the environment in which they live (extrinsic factors), the culture of the people involved, and the animals' own characteristics (intrinsic factors). These factors can influence whether interactions between humans and animals are friendly, neutral, or hostile, and can also affect the way animals interact with each other (Sumasgutner et al., 2021). For instance, the wintering of thousands of Black-eared kites in and around the *Ghazipur* area is not only dependent on people's social perceptions of non-human life in general, but also on the correlation between extrinsic urban habitat features within heterogeneously developed urban pockets and cultural geographies, combined with the intrinsic demographic factors of the animals (Kumar et al., 2019).

Furthermore, urbanisation, which offers predictable food subsidies, has likely impacted threatened migratory facultative scavengers such as Steppe Eagles and Eurasian Griffon vultures that congregate at landfills and carcass dumping sites (*pers obs.*). Despite its impact on biodiversity, urban expansion is an inevitable outcome of development. The rise of cities along the migratory flyways not only offers novel anthropogenic-opportunities to avian scavengers, but also multiple threats from overhead transmission wires, wind energy farms, buildings, artificial-lights at night, etc. (A. L. Drewitt & Langston, 2008; E. J. A. Drewitt et al., 2021; Horton et al., 2019; N. Kumar et al., 2020; Nilsson et al., 2021). But development is still a work in progress for vast tropical landscapes. It offers opportunities to allow incorporation of wireless technology in planning 'green' and 'smart' infrastructure in the Global South that can support long-term coexistence of birdlife and people linked through ecosystem services, e.g., safe disposal of human-refuse by opportunistic avian migrants and scavengers, and their cultural reverence (Natuhara, 2018). In tropical countries, migratory birds and humans often coexist in urban settings for long periods of time. This is because the birds interact with anthropogenic resources that are shaped by sociocultural and economic factors. These dynamic nature-culture relationships also lead to unique model systems for ecological and ethno-ornithological studies (Colin A. Galbraith, Tim Jones, Jeff Kirby and Taej Mundkur, 2014; Mikula et al., 2023; Newton, 2010). The results of this study and observations from carcass dumping sites like *Jorbeer* (Rajasthan) (Khatri, 2013) and several areas in Uttar Pradesh (Jha, 2015) suggest that migratory avian scavengers have the potential to have a significant impact on conservation and public awareness of science. For instance, they can lead to

revenue-generating models from bird-watching tourism and small industries (e.g., bovine-leather and bone-meal fertilisers near carcass-dumping grounds) (MOEF&CC, 2020; Sinha, 1986). Regarding ethnic-philosophy that is well known to support and care non-human lives in South Asia, Indian-scriptures mention "non-violence as the ultimate duty" *Ahimsa- Parmo-Dharma*) and teach to "respect and honour guests as God" (*Atithi-Devo- Bhava*) (Dave, 2005). Currently, these ethnic principles are threatened by the simultaneous loss of biodiversity and cultures in urbanising tropical cities (N. Kumar, Gupta, et al., 2018).

It is worth highlighting an incident that occurred in April 2017, which exemplifies the phenomenon of "empathic reinforcement" between daily-waged immigrant butchers/cleaners and kites at SAK in Delhi (Fig. 3-6). Upon observing the migration routes of kites between Delhi and Central Asia on Google Maps, members of the community demonstrated compassion by providing care to 15-20 Black-eared kites that were in a moribund state after a dust-storm. They offered these birds food, water, and temporary shelter. This response stemmed from the innate love for living creatures, often referred to as biophilia, which finds expression in religious beliefs prevalent in South Asia (Pinault, 2008; Taneja, 2015). Both Muslims and Hindus hold reverence for kites, albeit with different perspectives. For Muslims, kites are regarded as "winged emissaries" that carry away sins, worries, or prayers-messages, symbolized by the act of offering meat to these birds during ritual feeding near mosques. On the other hand, Hindus perceive interconnectedness among all life forms, viewing animal species as holy beings or even solutions to astrological problems, thus displaying tolerance towards usual inconvenience caused by aggressive animal parents, e.g., kites, dogs, and macaques (Kumar et al., 2019; Pinault, 2008; Taneja, 2015).

Delhi residents are sympathetic towards aggressive co-inhabiting animals because of the mutualism derived from animals' parenting behaviour and from the realisation that urbanisation has destroyed and degraded the natural habitats of wildlife. Interviews revealed that residents were well aware of the useful "scavenging ecosystem services" provided to their neighbourhood by kites and other animals which consume poultry and other detritus (see Kumar at al., 2019).

Therefore, unintended ecological consequences of landfill flattening can manifest in various ways, including the hazards posed to bird populations due to increased birdstrike incidents, movement, migration and/or dispersal of animals in search of new resources, and the potential contamination of soil and water resources used by various life forms (Ahluwalia & Patel, 2018; Plaza & Lambertucci, 2017; Poore & Nemecek, 2018). While it is beyond the scope of this manuscript, by thoroughly considering and addressing these factors, we can minimise negative ecological impacts on humans/animals and ensure the sustainable management of waste materials during landfill flattening. In summary, while the current political discussions surrounding landfill flattening in Delhi highlight a progressive approach to waste management, it is imperative to conduct a comprehensive evaluation of the ecological implications and challenges associated with these initiatives. By carefully considering the organic composition of waste materials and implementing appropriate mitigation strategies, we can mitigate potential environmental risks and contribute to sustainable waste management practices in the context of a tropical megacity (Ahluwalia & Patel, 2018; Pellow, 2004; Shahmoradi, 2013).

Implications for environmental health.

Six percent of global greenhouse emissions come from food losses and waste (Poore & Nemecek, 2018). This study found that a large amount of poultry waste is left to decompose in open spaces or drains because of the lack of proper disposal methods, especially during the threat of avian influenza (Gržinić et al., 2023). The traditional approach of relying on scavenging services provided by commensal animals that works on small village-town scales (see Kumar et al., 2019) has been found to create conflicts and contribute to the spread of diseases (Nyhus, 2016; Schwarzenbach et al., 2010; Scoones, 2016; Vergara & Tchobanoglous, 2012). Although this paper does not directly address the issue, large-scale poultry production raises environmental concerns, such as the high carbon footprint of chicken feed and the high nitrogen content of chicken manure (Gržinić et al., 2023). Suggestions have been made to address the environmental impact of global poultry dominance, including the production of biodiesel, biogas, organic manure, and compost (Faraji Mahyari et al., 2021; Gerber et al., 2008; Wang et al., 2014). In cities like Delhi, the problem of poorly managed poultry waste is not only spatial but also seasonal. The absence of Black-eared kites, which primarily scavenge on such remains at *Ghazipur*, during the six summer months increases the risk of disease transmission from decaying carrion, especially given the proliferation of insect vectors during warm and humid weather conditions (Krystosik et al., 2020). There lies a significant global challenge in optimising these tropical urban spaces to support PPC activities while minimising the health risks associated with cohabiting with animals that have adapted to urban environments (Council, 2001).

Human socio-cultural factors play a significant role in determining the settlement patterns of both people and animals around poultry waste, which can lead to physical conflicts between humans and wildlife or the transmission of zoonotic diseases (Krystosik et al., 2020; N. Kumar et al., 2020; N. Kumar, Jhala, et al., 2019; Olson et al., 2016; Onen & Bassey, 2017). Migratory birds, such as waterfowl, are known carriers of avian influenza. They have been observed roosting in close proximity to each other, posing a risk of spreading infectious diseases to poultry, livestock, humans, and even endangered wildlife (Bobiec et al., 2021; Bradley et al., 2020; Grace et al., 2012; N. Kumar et al., 2020; Xu et al., 2016). The environmental burden associated with poultry waste is influenced by the geography of human religious practices, hygiene practices, and poverty. More often than not, in tropical cities that have heterogeneously developed pockets, gentrification drives result in concentrated waste accumulation at the outskirts of the city. In addition, *Ghazipur* in Delhi has become a prime example of how a lack of foresight about systemic linkages in health and hygiene, and informal to formal eco-commercial linkages can create a variety of problems affecting humans and other living things (Ferronato & Torretta, 2019; Gutberlet, 2017; S. Kumar et al., 2017; Talyan et al., 2008). Consequently, the process of landfill flattening, and waste repurposing should be carried out with caution to protect the environmental and social well-being of the surrounding ecological communities supported by and centred on humans. Appropriate measures should be taken to address potential issues, such as the release of harmful GHG and pathogens from decomposing waste, which can cause air, land, and water pollution (Krystosik et al., 2020).

The predictable distribution of food waste from humans has been shown to affect the behaviour of urban animals such as kites (see Kumar et al., 2018, 2019). Kites tolerated humans at close range when feeding on carrion but will attack if provoked near the nests (Kumar, Jhala, et al., 2019; N. Kumar, Qureshi, et al., 2018). This was not observed for the birds from the migratory *lineatus* race that fled on approach, much like the behaviour of the resident *govinda* kites when not breeding (*unpiblished data*). Such "coupled-systems" in which humans and non-human species interact and shape each other's socio-ecological space through repeated interactions highlights the impact of urbanisation on ethno-zoological domains in megacities (see Kumar et al., 2019). The age-old human-scavenger relationships highlighted by this study for a megacity are facing a growing threat from the progressive lack of appreciation by younger generations of the value of intangible benefits provided by wildlife to humans (Curtin & Kragh, 2014). It is critical to educate younger generations about the importance of wildlife so that these relationships can be maintained. This human-nature disconnect has alienated people through the "extinction of experience," with simultaneous consequences for human, animal, and environmental health (Kumar et al., 2019). Addressing this issue necessitates focused research and public policy on documenting and promoting biocultural awareness and research about the human-nature disconnect and develop public policies to address it (Soga & Gaston, 2016).

CONCLUSION

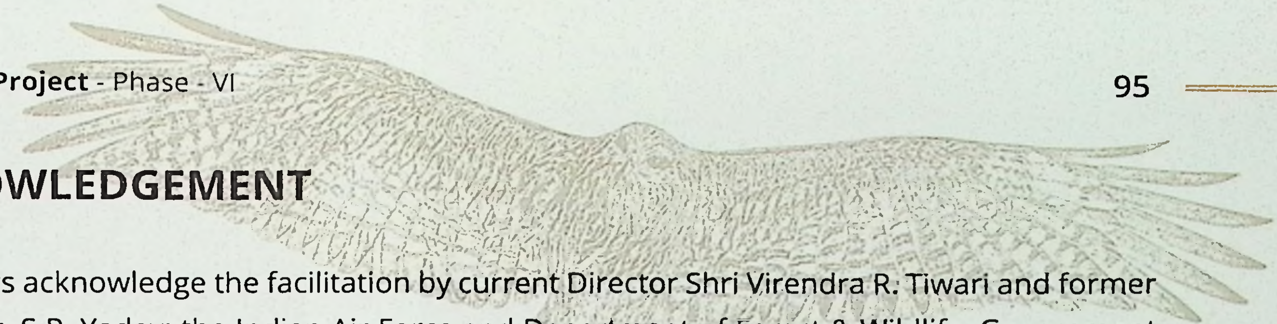
This study has provided valuable insights into the management of poultry detritus in Delhi, highlighting its significant implications for environmental and public health (Dunn et al., 2006; Gržinić et al., 2023). The traditional practice of benefitting from scavenging services of animals that help dispose of waste at the scales of villages and towns is undergoing rapid change, often leading to human-animal conflicts that contribute to the spread of zoonotic diseases. The geographic dispersion of anthropogenic food subsidies in the region, which is influenced by human socio-cultural factors such as religion, hygiene, and poverty, plays a significant role in determining the distribution of environmental burdens. The interconnected relationship between humans and non-human taxa, as observed in this study, emphasises the impact of urbanisation on ethno- zoological domains in megacities. Understanding and addressing this coupled-system, where humans and wildlife mutually shape each other's social-ecological space through repeated interactions, is essential in mitigating conflicts and promoting harmonious coexistence. It is anticipated that conflicts arising from close exposure to humans will increase as growing economies and urban populations worldwide attract predatory vertebrates with similar subsidies. To effectively manage urban wildlife and minimise conflicts, it is crucial to incorporate ethno- zoological insights into ecological considerations. In addition, relying solely on waste-to-value chains that use human waste as food subsidies for non-human species may not be ecologically sustainable. It is important to carefully examine its impacts on human, animal, and environmental health, particularly the release of GHG, zoonosis, and antimicrobial resistance.

If food waste were a country, its capacity to produce geen house gases would globally rank third, after the USA and China (FAO, 2023). Therefore, as tropical regions like India prepare to urbanise and accommodate more than 2.5 billion citizens in the coming decades, it becomes imperative to optimise urban spaces for humans, solid waste management, and human-animal coexistence. A holistic approach that considers ecological and socio-cultural factors is needed for effective management of waste from animal processing for food, e.g., poultry. In summary, this study underscores the importance of adopting a comprehensive approach to poultry detritus management, considering the ecological and socio-cultural dynamics that shape the urban landscape. As cities expand and human-wildlife interactions become more prevalent, promoting biocultural awareness, and integrating ecological insights can foster the development of sustainable and "waste wise" urban ecosystems (Becker et al., 2015, 2018).

CONCLUDING REMARKS: BLACK KITE PROJECT PHASE – VI

The sixth phase of Black Kite Project has broadened views of urban ecology, making it more inclusive of patterns and processes that better characterize tropical non-western cities. In particular, all our results stress the overriding importance of incorporating human socio-cultural factors into urban ecological studies. Our research suggests that rapid-changes to cultural geography by urbanisation affect and shape urban colonisation by opportunistic commensals, and the forms and functions of integrated humans-animal units within the finitude of tropical urban spaces (Kumar, Singh, et al., 2019).

Over the long-term, Delhi and other rapidly developing tropical megacities are likely to repeat the past and current development trajectories of western megacities like London. Their rapid socio-economic development in coming decades will largely manifest in terms of changes in internal structure, management, and culture, with expected improvements in sanitary infrastructures and refuse disposal. Analogous to the unfortunate, human-led decline of their congeneric Red Kites *Milvus milvus* in the United Kingdom, infrastructural developments, economic change, and the already visible cultural shifts in younger generations will imply major alterations in resource availability and predictability for many synurbic species (Kumar, 2013). Such unique systems of human-animal coexistence and its impending conundrums on human-wildlife conflicts and zoonotic diseases, caused by modernisation, will bring challenges to urban societies. The results of Phase VI of this study suggest that, after centuries of urban colonisation and of co-existence by kites with humans, their ecology and behaviour is finely tuned on spatial variations caused by the historical chain of events, contextualising human religion, hygiene, and poverty. Further research is needed on synurbic animals in their mature stage of adaptation to an urban life in rapidly urbanising tropical megacities, to understand the fine-grained adjustments to urban structure and human culture.



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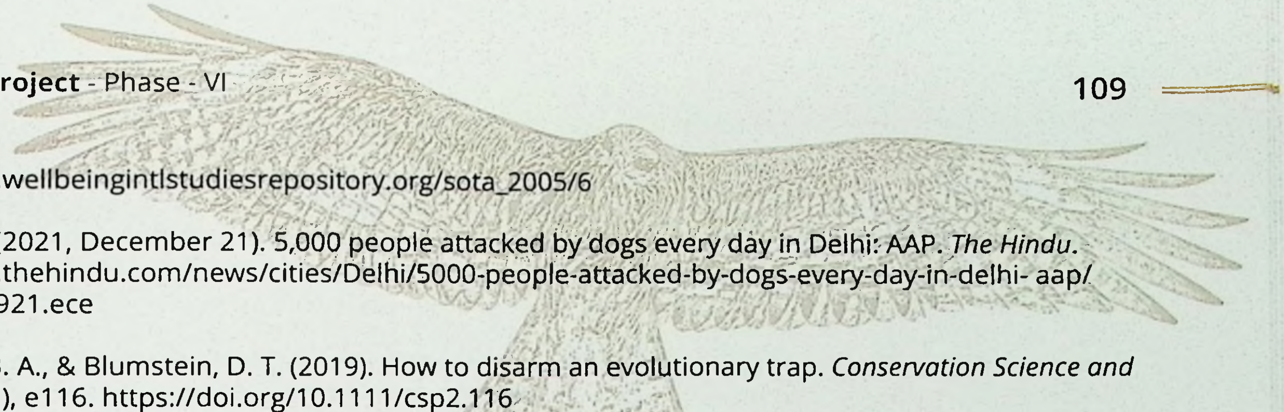

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ANNEXURE

(Additional papers published/communicated during Phase - VI)

1. Ethno-Ornithology and Conservation (Special Issue: *Ornithological Applications*) Feathers, Folklore, and Eco-Literacy: Stories ascribe cultural keystone status to avian scavengers in South Asian cities **[Urvi's M.Sc. Thesis]**

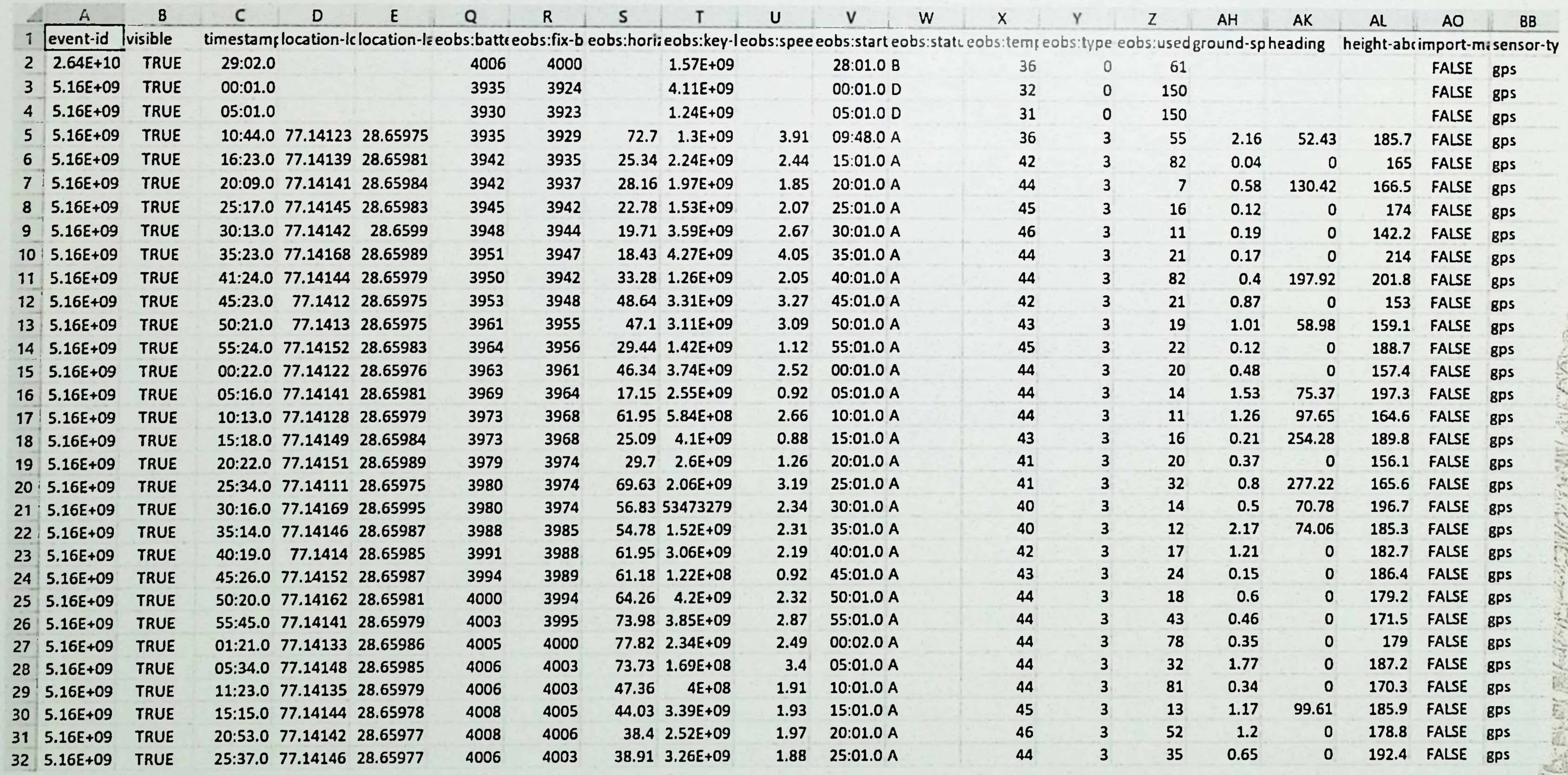
2. Ethno-Ornithology and Conservation (Special Issue: *Ornithological Applications*) Decolonizing bird knowledge: More-than-Western bird–human relations. Bastian Thomsen et al. (2024) 126, 1–13 https://doi.org/10.1093/ornithapp/duad053

3. **Book - Chapter**: Kumar, N. "The Conference of the birds" and people in tropical megacities. In Ali Kazim: Suspended in Time. Ashmolean Museum of Art and Archaeology. Oxford University. (2022).

4. **Book - Chapter**: Kumar, N et al. "People, animals and waste form systemic links within tropical cities: the case of an urban raptor in Delhi, India". *In* Ecology of Tropical Cities: Natural and Social Sciences Applied to the Conservation of Urban Biodiversity. Springer Nature. (2024).

APPENDIX 1

Example screenshot of Raw dataset for Tag ID- 6242)



	A	B	C	D	E	Q	R	S	T	U	V	W	X	Y	Z	AH	AK	AL	AO	BB
1	event-id	visible	timestamp	location-lc	location-la	eobs:batte	eobs:fix-b	eobs:hori:	eobs:key-l	eobs:spee	eobs:start	eobs:statu	eobs:temp	eobs:type	eobs:used	ground-sp	heading	height-abo	import-ma	sensor-ty
2	2.64E+10	TRUE	29:02.0			4006	4000		1.57E+09		28:01.0	B	36	0	61				FALSE	gps
3	5.16E+09	TRUE	00:01.0			3935	3924		4.11E+09		00:01.0	D	32	0	150				FALSE	gps
4	5.16E+09	TRUE	05:01.0			3930	3923		1.24E+09		05:01.0	D	31	0	150				FALSE	gps
5	5.16E+09	TRUE	10:44.0	77.14123	28.65975	3935	3929	72.7	1.3E+09	3.91	09:48.0	A	36	3	55	2.16	52.43	185.7	FALSE	gps
6	5.16E+09	TRUE	16:23.0	77.14139	28.65981	3942	3935	25.34	2.24E+09	2.44	15:01.0	A	42	3	82	0.04	0	165	FALSE	gps
7	5.16E+09	TRUE	20:09.0	77.14141	28.65984	3942	3937	28.16	1.97E+09	1.85	20:01.0	A	44	3	7	0.58	130.42	166.5	FALSE	gps
8	5.16E+09	TRUE	25:17.0	77.14145	28.65983	3945	3942	22.78	1.53E+09	2.07	25:01.0	A	45	3	16	0.12	0	174	FALSE	gps
9	5.16E+09	TRUE	30:13.0	77.14142	28.6599	3948	3944	19.71	3.59E+09	2.67	30:01.0	A	46	3	11	0.19	0	142.2	FALSE	gps
10	5.16E+09	TRUE	35:23.0	77.14168	28.65989	3951	3947	18.43	4.27E+09	4.05	35:01.0	A	44	3	21	0.17	0	214	FALSE	gps
11	5.16E+09	TRUE	41:24.0	77.14144	28.65979	3950	3942	33.28	1.26E+09	2.05	40:01.0	A	44	3	82	0.4	197.92	201.8	FALSE	gps
12	5.16E+09	TRUE	45:23.0	77.1412	28.65975	3953	3948	48.64	3.31E+09	3.27	45:01.0	A	42	3	21	0.87	0	153	FALSE	gps
13	5.16E+09	TRUE	50:21.0	77.1413	28.65975	3961	3955	47.1	3.11E+09	3.09	50:01.0	A	43	3	19	1.01	58.98	159.1	FALSE	gps
14	5.16E+09	TRUE	55:24.0	77.14152	28.65983	3964	3956	29.44	1.42E+09	1.12	55:01.0	A	45	3	22	0.12	0	188.7	FALSE	gps
15	5.16E+09	TRUE	00:22.0	77.14122	28.65976	3963	3961	46.34	3.74E+09	2.52	00:01.0	A	44	3	20	0.48	0	157.4	FALSE	gps
16	5.16E+09	TRUE	05:16.0	77.14141	28.65981	3969	3964	17.15	2.55E+09	0.92	05:01.0	A	44	3	14	1.53	75.37	197.3	FALSE	gps
17	5.16E+09	TRUE	10:13.0	77.14128	28.65979	3973	3968	61.95	5.84E+08	2.66	10:01.0	A	44	3	11	1.26	97.65	164.6	FALSE	gps
18	5.16E+09	TRUE	15:18.0	77.14149	28.65984	3973	3968	25.09	4.1E+09	0.88	15:01.0	A	43	3	16	0.21	254.28	189.8	FALSE	gps
19	5.16E+09	TRUE	20:22.0	77.14151	28.65989	3979	3974	29.7	2.6E+09	1.26	20:01.0	A	41	3	20	0.37	0	156.1	FALSE	gps
20	5.16E+09	TRUE	25:34.0	77.14111	28.65975	3980	3974	69.63	2.06E+09	3.19	25:01.0	A	41	3	32	0.8	277.22	165.6	FALSE	gps
21	5.16E+09	TRUE	30:16.0	77.14169	28.65995	3980	3974	56.83	53473279	2.34	30:01.0	A	40	3	14	0.5	70.78	196.7	FALSE	gps
22	5.16E+09	TRUE	35:14.0	77.14146	28.65987	3988	3985	54.78	1.52E+09	2.31	35:01.0	A	40	3	12	2.17	74.06	185.3	FALSE	gps
23	5.16E+09	TRUE	40:19.0	77.1414	28.65985	3991	3988	61.95	3.06E+09	2.19	40:01.0	A	42	3	17	1.21	0	182.7	FALSE	gps
24	5.16E+09	TRUE	45:26.0	77.14152	28.65987	3994	3989	61.18	1.22E+08	0.92	45:01.0	A	43	3	24	0.15	0	186.4	FALSE	gps
25	5.16E+09	TRUE	50:20.0	77.14162	28.65981	4000	3994	64.26	4.2E+09	2.32	50:01.0	A	44	3	18	0.6	0	179.2	FALSE	gps
26	5.16E+09	TRUE	55:45.0	77.14141	28.65979	4003	3995	73.98	3.85E+09	2.87	55:01.0	A	44	3	43	0.46	0	171.5	FALSE	gps
27	5.16E+09	TRUE	01:21.0	77.14133	28.65986	4005	4000	77.82	2.34E+09	2.49	00:02.0	A	44	3	78	0.35	0	179	FALSE	gps
28	5.16E+09	TRUE	05:34.0	77.14148	28.65985	4006	4003	73.73	1.69E+08	3.4	05:01.0	A	44	3	32	1.77	0	187.2	FALSE	gps
29	5.16E+09	TRUE	11:23.0	77.14135	28.65979	4006	4003	47.36	4E+08	1.91	10:01.0	A	44	3	81	0.34	0	170.3	FALSE	gps
30	5.16E+09	TRUE	15:15.0	77.14144	28.65978	4008	4005	44.03	3.39E+09	1.93	15:01.0	A	45	3	13	1.17	99.61	185.9	FALSE	gps
31	5.16E+09	TRUE	20:53.0	77.14142	28.65977	4008	4006	38.4	2.52E+09	1.97	20:01.0	A	46	3	52	1.2	0	178.8	FALSE	gps
32	5.16E+09	TRUE	25:37.0	77.14146	28.65977	4006	4003	38.91	3.26E+09	1.88	25:01.0	A	44	3	35	0.65	0	192.4	FALSE	gps

BB	BD	BF	BG	BH	BI	BJ	BK
sensor-typ	tag-local-i	study-name	utm-easting	utm-northing	utm-zone	study-timezone	study-local-timestamp
gps	6242	WII Black Kite Nishant Kumar Delhi				India Standard Time	59:02.0
gps	6242	WII Black Kite Nishant Kumar Delhi				India Standard Time	30:01.0
gps	6242	WII Black Kite Nishant Kumar Delhi				India Standard Time	35:01.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709261.3085	3172165.596	43N	India Standard Time	40:44.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709277.3452	3172172.147	43N	India Standard Time	46:23.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709279.2025	3172176.548	43N	India Standard Time	50:09.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709282.6064	3172175.401	43N	India Standard Time	55:17.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709279.4903	3172182.307	43N	India Standard Time	00:13.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709305.6511	3172181.59	43N	India Standard Time	05:23.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709281.8067	3172170.919	43N	India Standard Time	11:24.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709258.8333	3172165.662	43N	India Standard Time	15:23.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709268.5677	3172165.947	43N	India Standard Time	20:21.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709290.0283	3172174.858	43N	India Standard Time	25:24.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709260.6551	3172167.136	43N	India Standard Time	30:22.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709278.9997	3172173.13	43N	India Standard Time	35:16.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709266.7356	3172170.504	43N	India Standard Time	40:13.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709286.696	3172176.372	43N	India Standard Time	45:18.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709288.9028	3172181.999	43N	India Standard Time	50:22.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709249.4731	3172165.782	43N	India Standard Time	55:34.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709305.7377	3172188.21	43N	India Standard Time	00:16.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709283.2716	3172179.204	43N	India Standard Time	05:14.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709277.9042	3172177.512	43N	India Standard Time	10:19.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709289.7254	3172179.209	43N	India Standard Time	15:26.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709299.3276	3172172.685	43N	India Standard Time	20:20.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709278.7606	3172170.654	43N	India Standard Time	25:45.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709271.4207	3172178.072	43N	India Standard Time	31:21.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709285.2673	3172177.522	43N	India Standard Time	35:34.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709272.8036	3172170.757	43N	India Standard Time	41:23.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709281.9543	3172169.78	43N	India Standard Time	45:15.0
gps	6242	WII Black Kite Nishant Kumar Delhi	709280.3646	3172168.454	43N	India Standard Time	50:53.0
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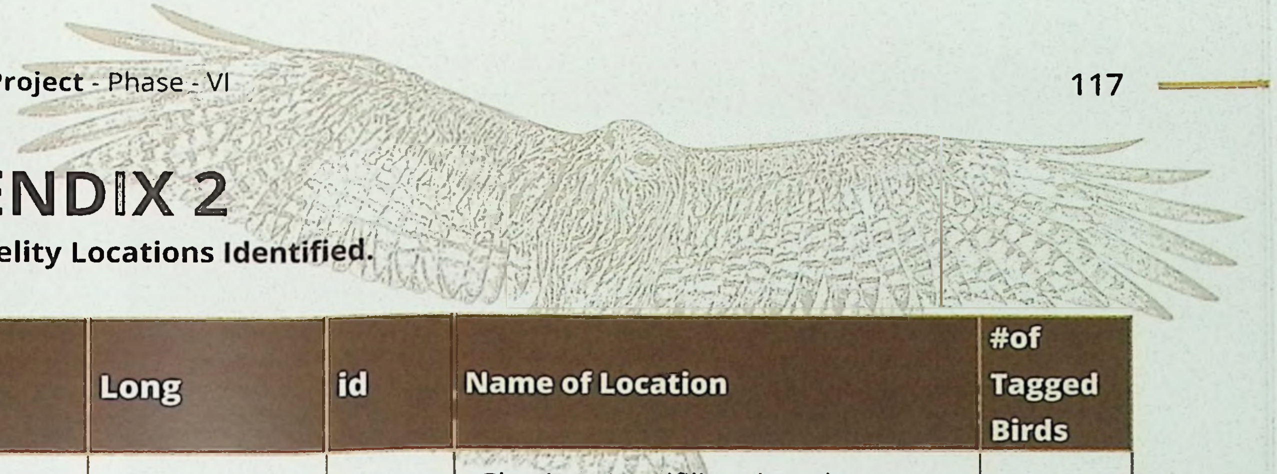


APPENDIX 2

All Site-fidelity Locations Identified.

Lat	Long	id	Name of Location	#of Tagged Birds
28.62479168	77.32758758	1	Ghazipur Landfill and Poultry Market	20
28.65551706	77.33624403	2	Bharat Electronics Campus	18
30.72220707	76.76195831	61	Chandigarh	9
28.558643	77.27965082	7	Jamia Campus	7
28.74095418	77.15726754	8	Bhalswa Landfill	7
28.51118192	77.28395201	9	Okhla Landfill	6
28.60334992	77.24725566	10	Zoo	6
28.40772004	77.32111854	14	Faridabad Along Mathura Road & Nala Stretch	5
27.86465093	78.04842582	62	Aligarh	5
29.38122178	76.88244692	63	Panipat	5
28.59344685	77.28228253	4	Flood Plains Near Okhla Bird Sanctuary	4
28.59665464	77.24770749	11	Sunder Nursery	4
28.43443045	77.254588	12	Asola Bhati Wildlife Sanctuary	4
28.40261379	77.1716528	13	Bhandwari Landfill	4
28.49769135	76.9410538	15	Najafgarh Jheel	4
28.33089518	77.26993556	16	SaroorPur Near Faridabad	4
28.65568255	77.24676343	17	Vijay Ghat	4
28.54230207	77.31658166	3	Kalindi Kunj Ghat	3
28.66933186	77.40578857	5	Harit Vatika HIndon	3
28.63908717	77.39381096	6	Sajwan Nagar Ghaziabad	3

Lat	Long	id	Name of Location	#of Tagged Birds
28.4015087	77.25688946	24	Regional Centre for Biotech Faridabad Gurgaon Highway	3
28.71638487	77.15196876	25	Shalimar Bagh	3
30.51387895	76.9812917	64	Barwala Near Chandigarh	3
28.9302101	77.73341097	65	Meerut	3
28.71745777	77.77406407	70	Hapur	3
28.45285278	77.12435715	18	Gurgaon Ridge near Golf club	2
28.78283449	77.1069358	26	Khera Khurd Village	2
28.66880158	77.03666628	27	Near Mundka Village	2
28.72414287	77.56910982	28	Noorpur	2
28.65303156	77.00833171	29	Nirmal Vihar	2
31.42486323	75.78181184	66	Adampur Airforce Station	2
30.34330518	76.85109913	67	Ambala	2
33.7368375	75.1488211	68	Anantnag	2
33.43912546	75.19056961	69	Banihal	2
31.30116637	75.62335181	71	Jalandhar	2
29.99163001	77.12868643	72	Jandhera	2
29.39023125	77.21322116	73	Kairana	2
30.88684887	75.88996203	74	Ludhiana	2
29.98641729	76.96045746	96	Mathana Near Kurukshetra	2
28.41161779	77.10434564	19	Ireo City Gurugram	1
28.45834009	77.44335396	20	Kambakashpur_2	1
28.43212929	77.43092064	21	Kambakashpur_1	1
28.48203062	77.45561927	22	NOIDA sec 125	1
28.62464854	77.36438772	23	NOIDA sec 62	1

Lat	Long	id	Name of Location	#of Tagged Birds
28.64349086	77.30403747	30	Anand Vihar Terminal	1
28.56358622	77.31852817	31	Botanical Garden	1
28.70392263	76.85857382	32	Saidpur Near Bahadurgarh	1
28.29251944	77.27602695	33	Bhanakpur	1
28.8202838	77.17929841	34	Bhaktawarpur	1
28.33145651	77.3142692	35	Ballabhgarh	1
28.50937336	77.3118053	36	Badarpur Thermal Power Station	1
28.73051772	77.15389984	37	DMRC_Mukarba Chowk	1
28.82727592	77.01349514	38	Daryapur Kalan	1
28.65466608	77.3790293	39	Kanawani	1
28.78578347	77.31222879	40	Loni Dehat	1
28.68470654	77.10903788	41	Mongolpuri	1
28.69436125	77.08502716	42	Mongolpuri Khurd	1
28.80713216	77.29017858	43	Mandaula	1
28.71607068	77.04078964	44	Near Madanpur Dabas	1
28.67833351	77.53950566	45	Masuri	1
28.66302839	77.07709006	46	Nihal Vihar Park	1
28.35483617	77.22893568	47	Nekpur	1
28.75740673	77.02582286	48	Chandpur Narela	1
28.65283961	77.24322043	49	Red Fort	1
28.64743016	77.25130904	50	Raj Ghat	1
28.1954189	77.07157341	51	Sohna	1
28.54771741	77.28211457	52	Seewage Treatment Plant Okhla	1
28.60598816	77.32486169	53	Kondli Tretment Plant	1
28.51990375	77.27452877	54	Tughlaqabad Forest	1

Lat	Long	id	Name of Location	#of Tagged Birds
28.65565786	77.3165272	55	Vigyan Lok	1
28.52668454	77.33889443	56	Yamuna Bank Near NOIDA	1
28.64815063	77.23228323	57	Chandani Chowk	1
28.6950449	77.14718285	58	Near District Park Pitampura	1
28.71880697	77.12348784	59	Near Swarna Jayanti park Rohini	1
28.65767727	77.2067325	60	Sadar Bazaar	1
29.55779628	76.64473723	75	Asandh	1
28.92667513	77.39968964	76	Baghpat	1
28.38780351	77.86792062	77	Bulandsahar	1
30.34961256	76.54982238	78	Bhat Majra	1
28.2377847	77.25310693	79	Chaprola	1
29.6883423	77.66435225	80	Deoband	1
28.67144834	77.67774789	81	Near Dhaulana UP	1
33.14803316	75.52649755	82	Doda_Kashmir	1
31.44116296	76.43749138	83	Gobind Sagar	1
29.75633081	77.2670404	84	Gangoh	1
28.25030103	77.20302494	85	Ghangola	1
29.37261234	77.69478309	86	Ghazipura_muzzaffarnagar	1
28.81997046	76.88289199	87	Hassangarh Haryana	1
29.86598689	77.1005589	88	Ghadhpur Khalsa Near Indri	1
29.78117607	76.96486966	89	Shamgarh Near Karnal	1
29.76215973	76.98197705	90	Korali	1
28.26289912	77.86111715	91	Khurja	1
28.29993939	77.29765801	92	Khandawli Near NH44	1
28.77188349	76.94434339	93	Khairpur Haryana	1

Lat	Long	id	Name of Location	#of Tagged Birds
28.86619332	76.92048368	94	Kharkhoda	1
32.14628816	76.25791097	95	Near Kangra Airport	1
33.31143979	75.78050531	97	Kishtwar Kashmir	1
30.86387746	76.55636976	98	Mughal Majra	1
27.8854447	77.55540336	99	Musmana Khadar Naujhil	1
29.6437162	77.57373691	100	Nanhera Kalan Muzaffarnagar	1
29.34742546	79.04506696	101	Piru Madara	1
29.39520879	79.06558625	102	Ramanagar	1
31.53290996	76.18379148	103	Panoh	1
33.51578472	75.16140347	104	Ramban Kashmir	1
28.75504768	77.29189906	105	Rameshwar Park	1
30.47881571	76.60972359	106	Rajpura	1
30.5360295	77.07321259	107	Rajpur Rani Panchkula	1
28.60176281	78.61841943	108	Sambhal	1
30.32960457	77.20768527	109	Sadhuara	1
30.40729518	77.35407371	110	Sultanpur	1
34.12619484	74.78396668	111	Srinagar Landfill	1
28.98535376	77.04797393	112	Sonipat	1
29.9758486	77.5200807	113	Saharanpur	1
27.69557564	74.46818324	114	Sujangarh	1
28.69276171	77.078108	115	SultanPur Majra	1

APPENDIX 3

Stratified Site-fidelity point location for Ground Truthing Exercise

Location ID for DELHI NCR	Count of Clusters Observed
GL	20
MP	18
YFP	10
GZ	7
JMI	7
BL	7
OL	6
ZOO	6
SN	4
ABWS	4
BSWMP	4
FRBD	5
NJ	4
SRP	4
VG	4
GGM	3
NOIDA	3
RCBT	3
SHB	3
KK	2
CGH	9
AL	5
PPT	5
BRWL	3
MT	3
ADM	2
AMBL	2
ANTK	2
BK	2
HP	2
JLDHR	2
JNR	2
KR	2
KRNL	2
LDH	2
ASN	1
BGHPT	1
BLNDSHR	1
BMP	1
CHP	1
KMBKP	2
MNDK	2
NRP	2
NV	2
AG	1
AVT	1
BG	1
BH	1
BHP	1
BKTWRPR	1
BLBG	1
BTPS	1
DMRCMC	1
DRPK	1
KNWN	1
LNDH	1
MGP	1
ML	1
MPD	1
MSURI	1

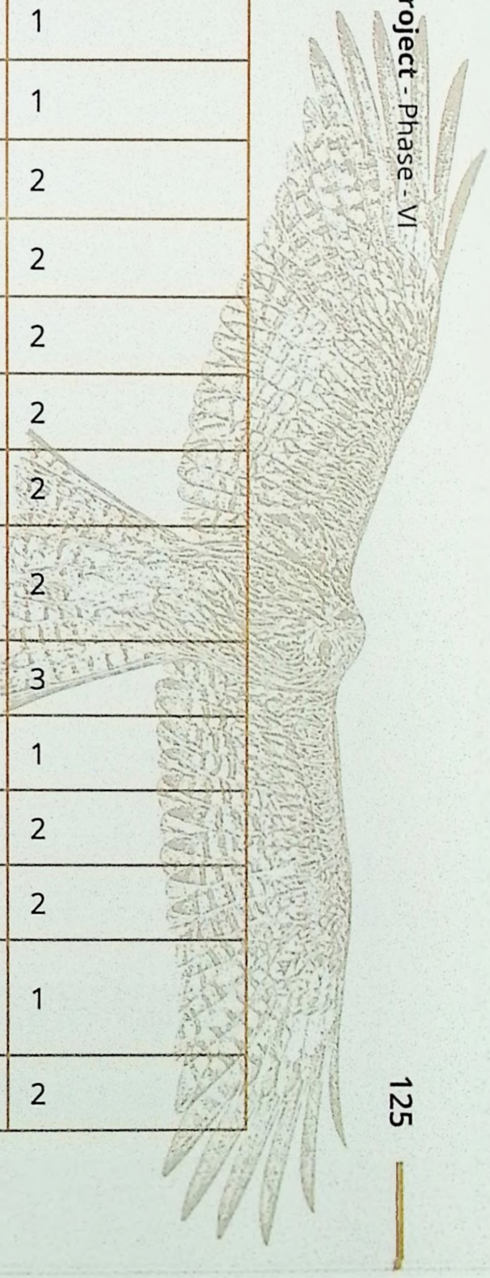
Location ID for DELHI NCR	Count of Clusters Observed
NHV	1
NKP	1
NRL	1
RF	1
DBND	1
DHLN	1
DKSH	1
GBSG	1
GGH	1
GHG	1
GHMZNG	1
HSH	1
INDRI	1
Kh	1
KHD	1
KHH	1
KKHd	1
KNGRA	1
KRK	1
KRL	1
KSHTK	1
MgHM	1
MKN	1
MTHNA	1
MZ	1
MZP	1
PM	1
PNH	1
RG	1
SHN	1
STOP	1
STPK	1
TGLQF	1
VLAV	1
YNOIDA	1
CC	1
MKH	1
PM	1
RN	1
SDBZ	1
RKSH	1
RMNG	1
RMSHP	1
RP	1
RRPKL	1
SB	1
SDHURA	1
SH	1
SLM	1
SNGK	1
SNP	1
SP	1
SUGH	1

APPENDIX 4

Final selected Site-Fidelity points & Habitat Correlates data for each Point.

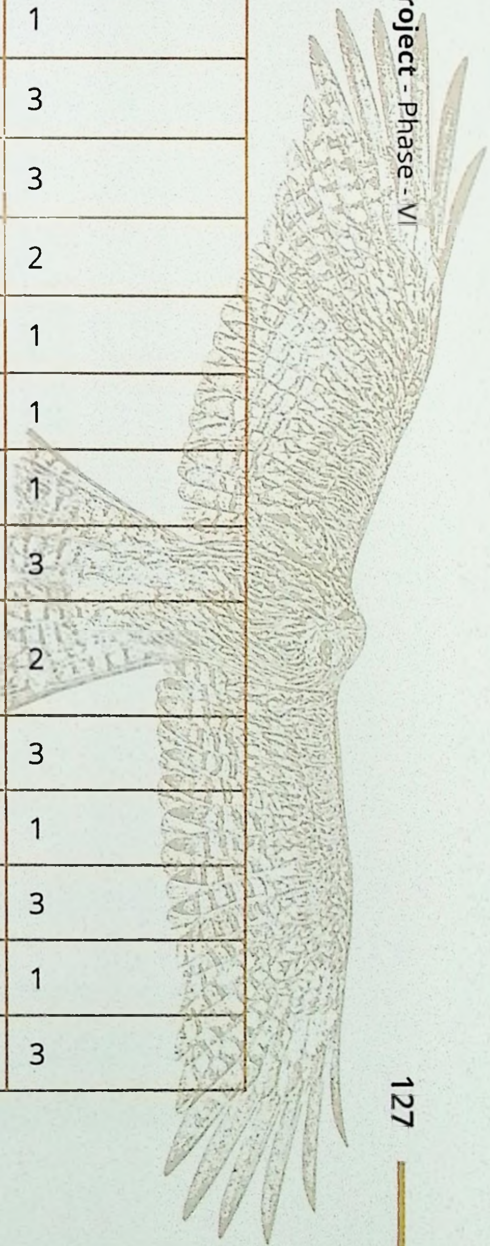
Point Name	Number_of_ Kites_track_ confluence	Distance_ to_Nearest_ Dumpsite	Distance_ to_Nearest_ RoostingSite	Distance_ to_Nearest_ WaterBody	Open_ Area	Urbanisation_ gradient
Ghazipur Landfill and Poultry Market	20	0	3.51	0.283	1	3
Bharat Electronics Campus	18	3.51	0	0.482	0	3
Chandigarh	9	4.371	4.798	4.348	1	2
Jamia Campus	7	1.234	0	1.359	1	2
Bhalswa Landfill	7	0	2.77	0.456	1	3
Okhla Landfill	6	0	1.325	2.758	1	2
Zoo	6	2.761	0	1.088	1	2
Faridabad Along Mathura Road & Nala Stretch	5	3.908	1.295	1.344	1	3
Aligarh	5	0.23	0.777	0.09	1	2
Panipat	5	0.281	5.006	0.133	1	1
Flood Plains Near Okhla Bird Sanctuary	4	0.114	3.296	0.632	1	2
Sunder Nursery	4	3.417	0	1.358	1	2
Asola Bhati Wildlife Sanctuary	4	0.072	0	1.962	1	1

Point Name	Number_of_ Kites_track_ confluence	Distance_ to_Nearest_ Dumpsite	Distance_ to_Nearest_ RoostingSite	Distance_ to_Nearest_ WaterBody	Open_ Area	Urbanisation_ gradient
Bhandwari Landfill	4	0	7.188	4.251	1	1
Najafgarh Jheel	4	0.223	5.203	0	1	1
SaroorPur Near Faridabad	4	4.377	0.283	0.264	1	2
Vijay Ghat	4	1.635	0	0.686	1	2
Kalindi Kunj Ghat	3	0	0.227	0.199	1	2
Harit Vatika HIndon	3	0.785	0	0.493	0	2
Sajwan Nagar Ghaziabad	3	0	0.103	0.299	1	2
Regional Centre for Biotech Faridabad Gurgaon Highway	3	0	0	2.427	1	2
Shalimar Bagh	3	2.778	0	1.562	1	3
Barwala Near Chandigarh	3	0	0.46	0	1	1
Meerut	3	0	2.432	4.204	1	2
Hapur	3	0	0	0.468	1	2
Gurgaon Ridge near Golf club	2	7.236	0	0.989	1	1
Khera Khurd Village	2	6.772	1.497	0	1	2

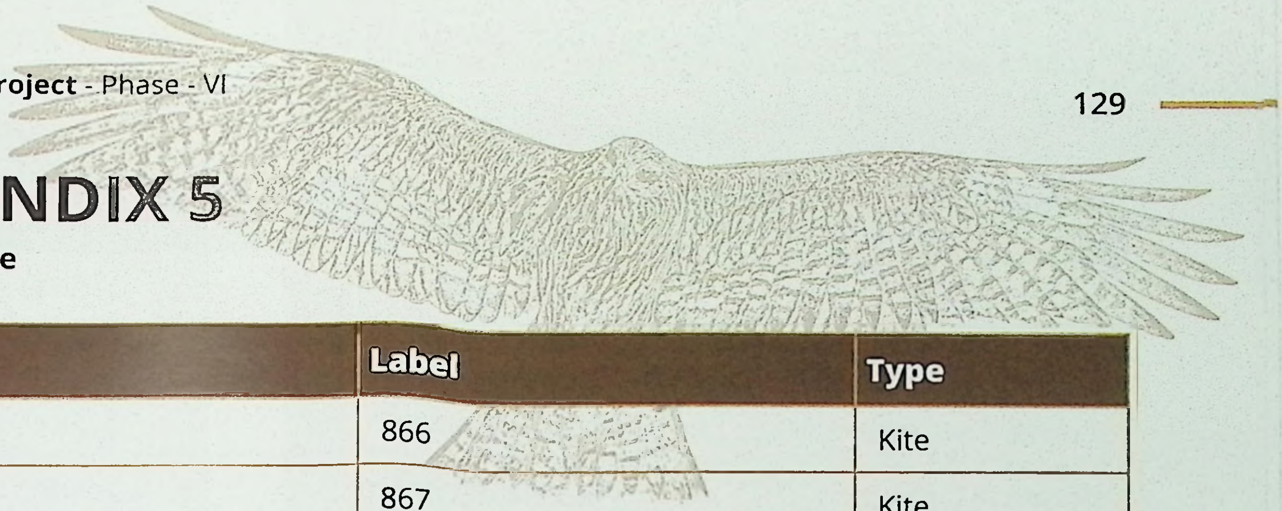


Point Name	Number_of_ Kites_track_ confluence	Distance_ to_Nearest_ Dumpsite	Distance_ to_Nearest_ RoostingSite	Distance_ to_Nearest_ WaterBody	Open_ Area	Urbanisation_ gradient
Near Mundka Village	2	0.133	0.496	1.516	1	2
Noorpur	2	3.639	1.012	0.151	1	1
Nirmal Vihar	2	3.159	0	0	1	2
Adampur Airforce Station	2	3.019	0	3.019	1	1
Ambala	2	1.521	0	0.711	0	2
Anantnag	2	2.852	2.638	2.852	1	2
Banihal	2	0	0.632	0	1	1
Jalandhar	2	0.895	0.147	0.444	0	3
Jandhera	2	0.33	0	0	1	1
Kairana	2	0.497	0.401	0.258	1	2
Ludhiana	2	0	0.085	0.24	0	3
Mathana Near Kurukshetra	2	0.293	0.397	0.187	1	1
Ireo City Gurugram	1	0.048	0.166	0.695	1	2
Kambakashpur_2	1	0.623	0.828	0.664	1	1
Kambakashpur_1	1	2.713	2.835	1.87	1	1

Point Name	Number_of_ Kites_track_ confluence	Distance_ to_Nearest_ Dumpsite	Distance_ to_Nearest_ RoostingSite	Distance_ to_Nearest_ WaterBody	Open_ Area	Urbanisation_ gradient
NOIDA sec 145	1	0	0.181	0.998	1	1
NOIDA sec 62	1	1.182	0	2.608	0	3
Anand Vihar Terminal	1	0.112	0.285	0.322	0	3
Botanical Garden	1	1.862	0	1.806	0	2
Saidpur Near Bahadurgarh	1	0.812	2.479	0.724	1	1
Bhanakpur	1	2.307	0	0.304	1	1
Bhaktawarpur	1	9.115	0.19	0	1	1
Ballabhgarh	1	0.032	1.036	2.997	0	3
Badarpur Thermal Power Station	1	2.689	0	0.153	0	2
DMRC_Mukarba Chowk	1	1.206	0	0.792	0	3
Daryapur Kalan	1	1.685	0.214	0.172	1	1
Kanawani	1	0.077	0.537	0.313	0	3
Loni Dehat	1	3.222	3.533	0.663	1	1
Mongolpuri	1	7.704	0	3.155	0	3



Point Name	Number_of_ Kites_track_ confluence	Distance_ to_Nearest_ Dumpsite	Distance_ to_Nearest_ RoostingSite	Distance_ to_Nearest_ WaterBody	Open_ Area	Urbanisation_ gradient
Mongolpuri Khurd	1	8.717	2.58	0.59	0	3
Mandaula	1	5.82	5.307	0.215	1	1
Near Madanpur Dabas	1	11.715	3.893	0	1	2
Masuri	1	0.131	0	2.2	1	2
Nihal Vihar Park	1	2.65	0	0.1	0	3
Nekpur	1	0.856	1.773	0.133	1	1
Chandpur Narela	1	0.06	1.805	0.036	1	1
Red Fort	1	8.82	0	2.172	1	2
Raj Ghat	1	7.883	0	1.265	1	2
Sohna	1	0.557	11.439	1.537	1	2
Seewage Treatment Plant Okhla	1	4.129	0	2.899	1	3
Kondli Tretment Plant	1	2.109	0.181	0.94	0	3
Tughlaqabad Forest	1	1.338	0	3.207	1	2



APPENDIX 5

Nodes Table

Id	Label	Type
866	866	Kite
867	867	Kite
868	868	Kite
869	869	Kite
6242	6242	Kite
6243	6243	Kite
6244	6244	Kite
6245	6245	Kite
6246	6246	Kite
6247	6247	Kite
6248	6248	Kite
6251	6251	Kite
6252	6252	Kite
6253	6253	Kite
6256	6256	Kite
6257	6257	Kite
6259	6259	Kite
128729	128729	Kite
138245	138245	Kite
Asola_bhatti_wildlife Sanctuary	Asola_bhatti_wildlife Sanctuary	Site
Adampur_airforcestation	Adampur_airforcestation	Site
Arjan_garh_Ridge	Arjan_garh_Ridge	Site
Aligarh	Aligarh	Site
Ambala	Ambala	Site

Id	Label	Type
Anantnag	Anantnag	Site
Asandh	Asandh	Site
Anand_vihar_terminal	Anand_vihar_terminal	Site
Botanical Garden	Botanical Garden	Site
Baghpat	Baghpat	Site
Near_bahdurgarh	Near_bahdurgarh	Site
Bhanak_pur	Bhanak_pur	Site
Banihal_kashmir	Banihal_kashmir	Site
Bhakhtwarpur	Bhakhtwarpur	Site
Bhalswa_landfill	Bhalswa_landfill	Site
Ballabgarh_mathuraRoad	Ballabgarh_mathuraRoad	Site
Bulandsahar	Bulandsahar	Site
Bhat_majra_Punjab	Bhat_majra_Punjab	Site
Mauli	Mauli	Site
Bandhwari_SWMP	Bandhwari_SWMP	Site
Badarpur_thermal_power_station	Badarpur_thermal_power_ station	Site
Chandani Chowk	Chandani Chowk	Site
Diff areas Chandigarh	Diff areas Chandigarh	Site
Chaprola	Chaprola	Site
Deoband	Deoband	Site
Dhaulana	Dhaulana	Site
Doda_Kashmir	Doda_Kashmir	Site
DMRC_mukarbaChowk	DMRC mukarbaChowk	Site
Daryapur Kalan	Daryapur Kalan	Site
Diff areas_Faridabad	Diff areas_Faridabad	Site

Id	Label	Type
GobindSagar	GobindSagar	Site
Gangoh	Gangoh	Site
Gurugram	Gurugram	Site
Ghangola	Ghangola	Site
Ghasipura_muzzafarnagar	Ghasipura_muzzafarnagar	Site
Ghazipur Landfill & Poultry Market	Ghazipur Landfill & Poultry Market	Site
SajwanNagar_Ghaziabad	SajwanNagar_Ghaziabad	Site
Ghaziabad	Ghaziabad	Site
Hapur	Hapur	Site
Hassangarh_Haryana	Hassangarh_Haryana	Site
GarhpurKhalsa_nearIndri	GarhpurKhalsa_nearIndri	Site
Jalandhar	Jalandhar	Site
Jamia Milia Islamia	Jamia Milia Islamia	Site
Jandhera_radaur	Jandhera_radaur	Site
Khurja	Khurja	Site
NH44Near_khandawli	NH44Near_khandawli	Site
Khairpur_Haryana	Khairpur_Haryana	Site
Khera khurd village	Khera khurd village	Site
Kharkhoda	Kharkhoda	Site
Kalanoo_Kashmir	Kalanoo_Kashmir	Site
Kambakashpur1	Kambakashpur1	Site
Near_kangra_Airport	Near_kangra_Airport	Site
Kanawani	Kanawani	Site
Kairana	Kairana	Site
Kurukshetra	Kurukshetra	Site

Id	**Label**	**Type**
Korali	Korali	Site
Shamgadh_near_karnal	Shamgadh_near_karnal	Site
Kishtwar_Kashmir	Kishtwar_Kashmir	Site
Ludhiana	Ludhiana	Site
Loni_dehat	Loni_dehat	Site
MahadevDesaiSeniorSecSchool_Faridabad	MahadevDesaiSeniorSecSchool_Faridabad	Site
Mugalmajra	Mugalmajra	Site
Mongolpuri	Mongolpuri	Site
Mongolpuri_khurd	Mongolpuri_khurd	Site
Musmana_khadar_Naujhil	Musmana_khadar_Naujhil	Site
Mandaula	Mandaula	Site
Near_mundka	Near_mundka	Site
Maharjpur	Maharjpur	Site
Near MadanPur Dabas	Near MadanPur Dabas	Site
Masuri	Masuri	Site
Meerut	Meerut	Site
Mathana	Mathana	Site
Nanhera_kalan_Muzzaffarnagar	Nanhera_kalan_Muzzaffarnagar	Site
Mirzapur	Mirzapur	Site
Nihal_vihar_park	Nihal_vihar_park	Site
Najafgarh_Jheel	Najafgarh_Jheel	Site
Nekpur	Nekpur	Site
NOIDA_Sec-62	NOIDA_Sec-62	Site
Near_chandpur_narela	Near_chandpur_narela	Site
Noorpur	Noorpur	Site

Id	Label	Type
Nirmal_Vihar	Nirmal_Vihar	Site
Okhla_landfill	Okhla_landfill	Site
Piru_Madara	Piru_Madara	Site
Pitampura	Pitampura	Site
Panoh	Panoh	Site
Panipat	Panipat	Site
Regional_centreForBiotech	Regional_centreForBiotech	Site
Red_fort	Red_fort	Site
Raj_ghat	Raj_ghat	Site
Ramban_Kashmir	Ramban_Kashmir	Site
Ramanagar	Ramanagar	Site
Rameshwar_Park	Rameshwar_Park	Site
Rohini	Rohini	Site
Rajpura	Rajpura	Site
Near_RajpurRani_panchkula	Near_RajpurRani_panchkula	Site
Sambhal	Sambhal	Site
Sadar Bazaar	Sadar Bazaar	Site
Near_sadhuara	Near_sadhuara	Site
Sultanpur_haryana	Sultanpur_haryana	Site
Shalimar_bagh	Shalimar_bagh	Site
Sohna	Sohna	Site
Sultanpur_majra	Sultanpur_majra	Site
Sunder_nursery	Sunder_nursery	Site
Srinagar_Landfill	Srinagar_Landfill	Site
Sonipat	Sonipat	Site
SaharanPur	SaharanPur	Site

Id	Label	Type
Near_saroorpur	Near_saroorpur	Site
Sewage_treatment_plant_okhla	Sewage_treatment_plant_okhla	Site
Kondli_Tretment_plant	Kondli_Tretment_plant	Site
Sujangarh	Sujangarh	Site
Tughlaqabad_forest	Tughlaqabad_forest	Site
Vijay_ghat	Vijay_ghat	Site
Vigyan_lok_near_anand_vihar	Vigyan_lok_near_anand_vihar	Site
Yamuna_Flood_Plains	Yamuna_Flood_Plains	Site
Yamuna_NearNOIDA	Yamuna_NearNOIDA	Site
National Zoological Garden	National Zoological Garden	Site

Edges Table

Source	Target
866	Bhalswa landfill
866	Ghazipur Landfill & Poultry Market
866	Khera khurd village
866	Mandaula
866	Maharjpur
866	Maharjpur
866	Maharjpur
866	Nanhera_kalan_Muzzaffarnagar
866	Najafgarh_Jheel
866	Najafgarh_Jheel

Source	Target
866	Red_fort
866	Raj_ghat
866	Rajpura
866	Sultanpur_haryana
866	Sunder_nursery
866	Vijay_ghat
866	Yamuna_Flood_Plains
866	National Zoological Garden
867	Botanical Garden
867	Bandhwari_SWMP
867	Ghazipur Landfill & Poultry Market

Source	Target
867	Hapur
867	Maharjpur
867	Meerut
867	Vijay_ghat
867	National Zoological Garden
868	Aligarh
868	Aligarh
868	Banihal_kashmir
868	Ghazipur Landfill & Poultry Market
868	SajwanNagar_Ghaziabad
868	Hapur
868	Khurja
868	Kairana
868	Musmana_khadar_Naujhil
868	Maharjpur
868	Sambhal
869	Bhalswa_landfill
869	Chandani Chowk
869	Ghazipur Landfill & Poultry Market
869	Mongolpuri_khurd
869	Pitampura
869	Rohini
869	Sadar Bazaar
869	Sunder_nursery
869	Sujangarh
869	Vijay_ghat
6242	Banihal_kashmir
6242	Bhalswa_landfill
6242	Bandhwari_SWMP
6242	Diff areas_Faridabad
6242	Diff areas_Faridabad
6242	Diff areas_Faridabad
6242	Diff areas_Faridabad
6242	Ghazipur Landfill & Poultry Market
6242	Jalandhar
6242	Jamia Milia Islamia
6242	Kambakashpur1
6242	Kambakashpur1
6242	Mahadev Desai Senior Sec School_Faridabad
6242	Maharjpur
6242	Masuri
6242	Mirzapur
6242	Nekpur
6242	NOIDA_Sec-62
6242	Okhla_landfill
6242	Panoh
6242	Rameshwar_Park
6242	Srinagar_Landfill

Source	Target
6242	Sonipat
6242	Near_saroorpur
6242	Yamuna_Flood_Plains
6243	Badarpur_thermal_power_station
6243	GobindSagar
6243	Ghazipur Landfill & Poultry Market
6243	Ghazipur Landfill & Poultry Market
6243	Jamia Milia Islamia
6243	Okhla_landfill
6243	Tughlaqabad_forest
6243	Yamuna_NearNOIDA
6243	National Zoological Garden
6244	Adampur_airforcestation
6244	Adampur_airforcestation
6244	Aligarh
6244	Aligarh
6244	Aligarh
6244	Ambala
6244	Anantnag
6244	Ghazipur Landfill & Poultry Market
6244	Maharjpur
6244	Panipat
6244	Near_sadhuara

Source	Target
6245	Asola_bhatti_wildlife Sanctuary
6245	Ambala
6245	Anantnag
6245	Bhalswa_landfill
6245	Bandhwari_SWMP
6245	Diff areas_Chandigarh
6245	Diff areas_Chandigarh
6245	Dhaulana
6245	Ghazipur Landfill & Poultry Market
6245	Hapur
6245	Jamia Milia Islamia
6245	Near_kangra_Airport
6245	Kurukshetra
6245	Ludhiana
6245	Noorpur
6245	Okhla_landfill
6245	Sunder_nursery
6245	Yamuna_Flood_Plains
6245	Yamuna_Flood_Plains
6245	Yamuna_Flood_Plains
6246	Bhalswa_landfill
6246	Mauli
6246	Diff areas_Chandigarh
6246	Diff areas_Chandigarh

Source	Target
6246	Gangoh
6246	Ghazipur Landfill & Poultry Market
6246	GarhpurKhalsa_nearIndri
6246	Jandhera_radaur
6246	Korali
6246	Shamgadh_near_karnal
6246	Shamgadh_near_karnal
6246	Kishtwar_Kashmir
6246	Maharjpur
6246	Meerut
6246	Panipat
6246	Panipat
6246	Shalimar_bagh
6246	Yamuna_Flood_Plains
6246	National Zoological Garden
6247	Bhakhtwarpur
6247	DMRC_mukarbaChowk
6247	Daryapur Kalan
6247	Ghazipur Landfill & Poultry Market
6247	Jandhera_radaur
6247	Kairana
6247	Near_mundka
6247	Maharjpur
6247	Mathana
6247	Shalimar_bagh
6248	Baghpat
6248	Bulandsahar
6248	Ghazipur Landfill & Poultry Market
6248	Ghaziabad
6248	Kalanoo_Kashmir
6248	Noorpur
6248	Near_RajpurRani_panchkula
6251	Diff areas_Chandigarh
6251	Ghazipur Landfill & Poultry Market
6251	Ghaziabad
6251	Maharjpur
6251	Maharjpur
6252	Anand_vihar_terminal
6252	BHanak_pur
6252	Ballabgarh_mathuraRoad
6252	Diff areas_Chandigarh
6252	Chaprola
6252	Doda_Kashmir
6252	Ghangola
6252	Ghazipur Landfill & Poultry Market
6252	Jamia Milia Islamia
6252	NH44Near_khandawli
6252	Maharjpur

Source	Target
6252	Najafgarh_Jheel
6252	Okhla_landfill
6252	Regional_centreForBiotech
6252	Ramban_Kashmir
6252	Near_saroorpur
6252	Vigyan_lok_near_anand_vihar
6252	Yamuna_Flood_Plains
6253	Asola_bhatti_wildlife Sanctuary
6253	Bhalswa_landfill
6253	Mauli
6253	Diff areas_Chandigarh
6253	Gurugram
6253	Ghazipur Landfill & Poultry Market
6253	Ghaziabad
6253	Jamia Milia Islamia
6253	Maharjpur
6253	Meerut
6253	Okhla_landfill
6253	Regional_centreForBiotech
6253	Sohna
6253	Near_saroorpur
6253	Sewage_treatment_plant_okhla
6253	Kondli_Tretment_plant
6253	Yamuna_Flood_Plains

Source	Target
6253	Yamuna_Flood_Plains
6256	Mauli
6256	Ghasipura_muzzafarnagar
6256	Ghazipur Landfill & Poultry Market
6256	SajwanNagar_Ghaziabad
6256	Jalandhar
6256	Kanawani
6256	Ludhiana
6256	Loni_dehat
6256	Maharjpur
6256	Piru_Madara
6256	Ramanagar
6257	Asola_bhatti_wildlife Sanctuary
6257	Bandhwari_SWMP
6257	Diff areas_Chandigarh
6257	Ghazipur Landfill & Poultry Market
6257	Ghaziabad
6257	Mugalmajra
6257	Maharjpur
6257	Okhla_landfill
6257	Regional_centreForBiotech
6257	Sunder_nursery
6257	SaharanPur
6257	Near_saroorpur

Source	Target
6257	Yamuna_Flood_Plains
6259	Asandh
6259	Near_bahdurgarh
6259	Bhalswa_landfill
6259	Bhat_majra_Punjab
6259	Ghazipur Landfill & Poultry Market
6259	Hassangarh_Haryana
6259	Khairpur_Haryana
6259	Khera khurd village
6259	Mongolpuri
6259	Near_mundka
6259	Maharjpur
6259	Near MadanPur Dabas
6259	Nihal_vihar_park
6259	Near_chandpur_narela
6259	Nirmal_Vihar
6259	Panipat
6259	Panipat
6259	Shalimar_bagh
6259	Sultanpur_majra
6259	National Zoological Garden
128729	Asola_bhatti_wildlife Sanctuary
128729	Gurugram
128729	Gurugram
128729	Ghazipur Landfill & Poultry Market
128729	Ghaziabad
128729	Jamia Milia Islamia
128729	Kharkhoda
128729	Maharjpur
128729	Najafgarh_Jheel
128729	NOIDA_Sec-62
128729	NOIDA_Sec-62
128729	Nirmal_Vihar
128729	Sunder_nursery
128729	Vijay ghat
138245	Arjan_garh_Ridge
138245	Diff areas_Chandigarh
138245	Deoband
138245	Ghazipur Landfill & Poultry Market
138245	Jamia Milia Islamia
138245	Maharajpur

APPENDIX 6

R -Script

```
getwd()
setwd(“C:/Users/lenovo/Documents/AUD_MAED/Dissertation/R files”)
getwd()
install.packages(“lme4”)
library(lme4)
data <- read.csv(“GLMM_Covariates.csv”)
head(data)
summary(data)
# Fit the Poisson GLM
model <- glm(Number_of_Kites_track_confluence ~ Distance_to_Nearest_Dumpsite +
          Distance_to_Nearest_RoostingSite +
          Distance_to_Nearest_WaterBody +
          Open_Area +
          Urbanisation_gradient,
         data = data, family = poisson)
summary(model)
library(nlme)
library(lme4)
hist(data$Distance_to_Nearest_Dumpsite)
hist(data$Distance_to_Nearest_RoostingSite)
hist(data$Distance_to_Nearest_WaterBody)
hist(data$Open_Area)
hist(data$Urbanisation_gradient)

Kitesnumber <- factor(Number_of_Kites_track_confluence)
dumpdistance <- factor(Distance_to_Nearest_Dumpsite)
```

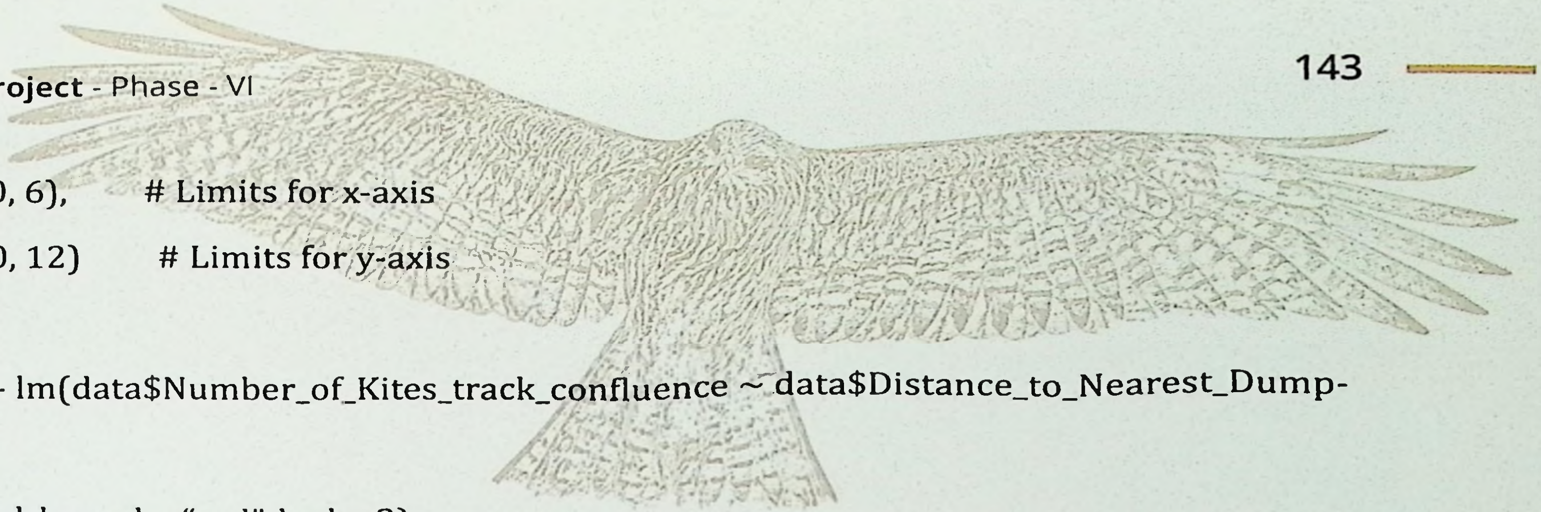
```
roostdistance <- factor(Distance_to_Nearest_RoostingSite)
waterdistance <- factor(Distance_to_Nearest_WaterBody)

install.packages(“car”)
library(car)
model.1 <- lm(Number_of_Kites_track_confluence ~ Distance_to_Nearest_Dumpsite +
          Distance_to_Nearest_RoostingSite +
          Distance_to_Nearest_WaterBody +
          Open_Area +
          Urbanisation_gradient)
vif(model.1)
plot(model.1, which=4, cook.levels=cutoff)
vif_values <- vif(model.1)
print(vif_values)
install.packages(“lattice”)
shapiro.test(data)
str(data)
shapiro.test(data$Number_of_Kites_track_confluence)
shapiro.test(data$Distance_to_Nearest_Dumpsite)
shapiro.test(data$Distance_to_Nearest_RoostingSite)
shapiro.test(data$Distance_to_Nearest_WaterBody)
shapiro.test(data$Open_Area)
shapiro.test(data$Urbanisation_gradient)

library(dplyr)
numeric_data <- data %>% select_if(is.numeric)
standardized_data <- as.data.frame(scale(numeric_data))
standardized_data <- cbind(standardized_data, data %>% select(Number_of_Kites_track_confluence(names(numeric_data))
```

```
library(car)
model.2 <- lm(Number_of_Kites_track_confluence ~ Distance_to_Nearest_Dumpsite +
           Distance_to_Nearest_RoostingSite +
           Distance_to_Nearest_WaterBody +
           Open_Area +
           Urbanisation_gradient)
vif_values2 <- vif(standardized_data)
print(vif_values)
install.packages("corrplot")
library(corrplot)
cor_matrix <- cor(standardized_data)
corrplot(cor_matrix, method = "circle", type = "upper",
       tl.col = "black", tl.srt = 45,
       addCoef.col = "black", number.cex = 0.7)
cor_matrix2 <- cor(numeric_data)
corrplot(cor_matrix2, method = "circle", type = "upper",
       tl.col = "black", tl.srt = 45,
       addCoef.col = "black", number.cex = 0.7)

pairs(numeric_data)
pairs(standardized_data)
library(ggplot2)
plot(data$Distance_to_Nearest_Dumpsite, data$Number_of_Kites_track_confluence,
   main = "Scatter Plot",  # Title of the plot
   xlab = "Distance to Nearest Dumpsite",  # Label for the x-axis
   ylab = "Number of Tagged Kites",  # Label for the y-axis
   col = "blue",         # Color of points
   pch = 16,             # Type of point (16 is solid circle)
```



```
  xlim = c(0, 6),        # Limits for x-axis
  ylim = c(0, 12)        # Limits for y-axis
)
model_lm <- lm(data$Number_of_Kites_track_confluence ~ data$Distance_to_Nearest_Dumpsite)
abline(model_lm, col = “red”, lwd = 2)
ggplot(data, aes(x = Urbanisation_gradient, y = Number_of_Kites_track_confluence)) +
 geom_point(color = “blue”, shape = 16, size = 3) +
 geom_smooth(method = “lm”, se = FALSE, color = “red”, linetype = “solid”) +
 labs (title = “Scatter Plot”, x = “Percentage of Urbanisation”, y = “Number of Tagged Kite”)
```

BlacK Kite Project

Phase - VI