



Original Research Paper

Artificial Intelligence Analysis of Household Waste Effects on Urban Wildlife Encounters

Dr. Abhishek Kumar Gupta^{1*}, Dr. Anand Trivedi²

^{1*}Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.
Email: ku.abhishekkumargupta@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0001-5653-9932>

²Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.
Email: ku.anandtrivedi@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0007-8240-391X>

Key Words

Abstract

Artificial intelligence, Urban ecology, Synanthropic behavior, Household waste, Human-wildlife interface, Predictive modeling.

The urban matrix has intensified so quickly that household waste can no longer be considered a by-product of domestic life, but as a high-density ecological resource, seen as an integrated system. This paper builds a conceptual framework to understand how household waste can be considered as an anthropogenic resource subsidy that alters the behavior of urban-tolerant wildlife and how artificial intelligence (AI) is not just 'computational add-on' but also a theoretical tool to understand the multi-variable and non-linear dynamics of the human-wildlife interface. Often, traditional wildlife ecology models assume that the distribution of waste is constant and the spatial location of waste is fixed, which masks the complex interactions and feedback among municipal waste collection systems, household waste disposal practices and synanthropic foraging strategies. The paper draws on the concepts of resource landscape theory, chrono disruption research, and pattern-recognition paradigms from machine learning to conceptualize how AI-informed spatial-temporal modeling can be used to identify high-risk interface areas, predict threshold moments of encounter rates, and drive proactive rather than reactive governance. This analysis also includes socio-economic influences on waste production both in terms of containment failures that are not intentional and intentional provision of waste, as part of a comprehensive systems-thinking approach. The main conceptual points are the re-conceptualization of household wastes as a predictable resource patch, where carrying capacity and territoriality is redefined, and the identification of temporal niche shifts in response to waste-collection routines, as well as the articulation of AI as a meta-framework for coexistence-oriented urban planning. The paper ends with a set of research directions around long-term evolutionary selection pressures on synanthropic species and governance ethics of algorithmic urban wildlife management.

* Corresponding Author's email: ku.abhishekkumargupta@kalingauniversity.ac.in

Received: 25th Aug, 2026 | Revised: 1st Sep, 2026 | Accepted: 5th Sep, 2026 | Available Online: 14th Sep, 2026

(DOI): 10.70102/AEJ.2026.18.5s.73

Introduction

Urban landscapes are growing at an unprecedented rate, with an increase in anthropogenic resource flows associated with it, particularly household waste. This was originally thought of as a problem of sanitation and logistics, but it is now becoming a determinant of urban ecological structure. An example is the use of AI-powered waste classification systems and smart collection networks, which enable the characterization of waste generation at a level of granularity that was previously unachievable, based on data from images and sensors (Yogamadhavan and Mannayee, 2024; Lakhout, 2025). Such technological advancements offer the empirical foundation for developing a more dynamic, behaviorally-based theory of the urban waste-wildlife interface. At the same time, there has been an increasing body of research that regards artificial intelligence as a general-purpose analytical lens for socio-ecological and environmental systems, not just for the purposes of narrow waste-management problems. The use of big-data and AI for decision support has been suggested in the context of urban ecological management in general (Wankhade et al., 2026), and regional sustainability scholarship has focused on how AI is transforming ecosystems governance and resilience (Pimenow et al., 2025). Complementary work finds AI embedded in agendas for sustainable transportation (Bibi and Yang, 2025), in environmental monitoring by means of the Internet of Things (IoT) (Miller et al., 2025), in innovation for wastewater treatment (Alprol et al., 2024), and in urban low-carbon transformation (Cheng et al., 2025). This

literature collectively gives the impression that AI is not just a narrow tool, but is rather an epistemological apparatus that can represent multi-variable, feedback-rich urban processes on a systemic level. Relevant most directly to the present analysis, AI-powered solutions have been proposed to help reduce human-wildlife conflict in biodiversity-sensitive contexts, providing predictive and early-warning capacities that are lacking when responding to conflict in a reactive manner (Ojija et al., 2025). Urbanist scholarship has also started to map the conceptual origins and spatial consequences of "AI urbanism," while problematizing the algorithmic reasoning that underpins the urban governance of cities and their ecological subsystems (Palmini and Cugurullo, 2023). The synthesis of these two strands - in the ecological and the urbanistic - becomes a productive terrain in the domain of household waste-wildlife interaction. The generation of household waste is not a technically or ecologically determined phenomenon, but also socially and economically patterned behavior. Urban cities and their consumption patterns, financial awareness and demographic structure influence the generation and containment of waste, especially among the rapidly changing lifestyles of the urban population (Rajendran, Ganesan, and Banwar, 2025). A full theoretical picture of the waste-wildlife interaction needs to be worked out, taking account human dimensions as well as ecological and computational ones. However, current models of wildlife ecology frequently consider waste distribution as a spatially fixed background variable instead of a dynamic, temporally rhythmic resource subsidy that is dependent on waste collection schedules,

containment methods, neighborhood socio-economic factors, and other factors. Existing frameworks are not yet able to predict non-linearly escalating human-wildlife interactions as a result of this theoretical gap. To this end, this paper seeks to build a conceptual/ predictive framework that treats artificial intelligence as a meta-framework: a highly generic and abstracted, pattern recognition lens, that can interpret the dynamic interaction between the provisioning of household waste and the behavioral ecology of urban-tolerant wildlife. In so doing, the paper makes a synthesis that connects resource landscape theory, behavioral plasticity research and algorithmic systems thinking into one and a policy relevant frame.

Conceptualizing the Urban Anthropogenic Foodscape

- ***Resource Landscape Theory***

In the ecological literature, municipal household waste has been understood as a by-product of human settlements which is of low value. The argument in this paper is for a re-frame: household waste is a high density and highly predictable spatial-temporal resource patch which closely approximates, if not surpasses, the caloric reliability of natural forage. According to resource landscape theory, the spatial structure, abundance, and temporal reliability of resource patches are important in determining how consumer species move and aggregate and whether are territorial. In the urban setting, the quantity of the curbside bins, communal bins, and informal bins are fixed, mappable, and influenced primarily by

administrative plans and domestic habits rather than by seasonality or climate.

- ***Subsidized Ecosystems***

While natural food resources are stochastic, varying with weather, phenology and predation pressure, waste-based resources are regular and can be as frequent as weekly. The regularity decreases the cost of searching and assessing the patch that would otherwise limit a forager's ability to exploit it, and thus subsidizes the energetic budget of the urban-tolerant species. Subsidized ecosystems is a concept that reflects this: ecosystems with a high percentage of anthropogenic food in the diet of a population also sees a reconfiguration of their natural forage economy, carrying capacity and territorial boundaries. Populations can even be maintained at levels well above the level of natural resource availability; territorial range may even be reduced around waste generating nodes that are reliable instead of expanded in line with the diffuse natural resources. This recalibration represents an ecological pre-adaptation to the behavioral adaptations which are covered in the next part. This chapter explores how responses of synanthropic species to their environments relate to their foraging strategies and behavioral adaptations.

Synanthropic Behavioral Adaptations and Foraging Strategies

- ***Behavioral Plasticity***

Persistent exploitation and persistence of anthropogenic subsidies require behavioral plasticity, or the ability of individuals or populations to adjust their foraging, activity, or

risk assessment behaviors in response to new resource environments. Theoretical models of risk-reward optimization suggest that urban-tolerant wildlife continually evaluates the perceived risk from the presence of humans, vehicles, and direct interaction with them, as well as the energetic benefits of waste exploitation. When benefits consistently outnumber perceived costs, such as with known, dense waste piles, there is a gradual increase in the tolerance to human activity, which may be referred to as habituation.

- ***Temporal Niche Shifts***

A key consequence of this plasticity is the temporal niche shift, that is, the reorganization of species, naturally active during the day or at dusk, in the night or early morning when human

activities are lower, and, more importantly, when trash is collected by the municipality. This chrono disruption is an adaptive response that allows access to environments that are rich in resources but dominated by humans, and that reduce the risk of direct encounter. This theorized pattern is conceptually represented in figure 1; where the baseline represents diurnal activity based on natural cues such as photoperiod, and the hypothesized represents activity in proximity to the waste-provisioned sites, peaking in the pre-dawn and late-evening hours around the collection window. The actual shape of the curves is not empirical, but rather reflects a theoretical testable hypothesis: the timing of waste availability, rather than its quantity, may be the most important factor in shaping temporal niche restructuring in synanthropic populations.

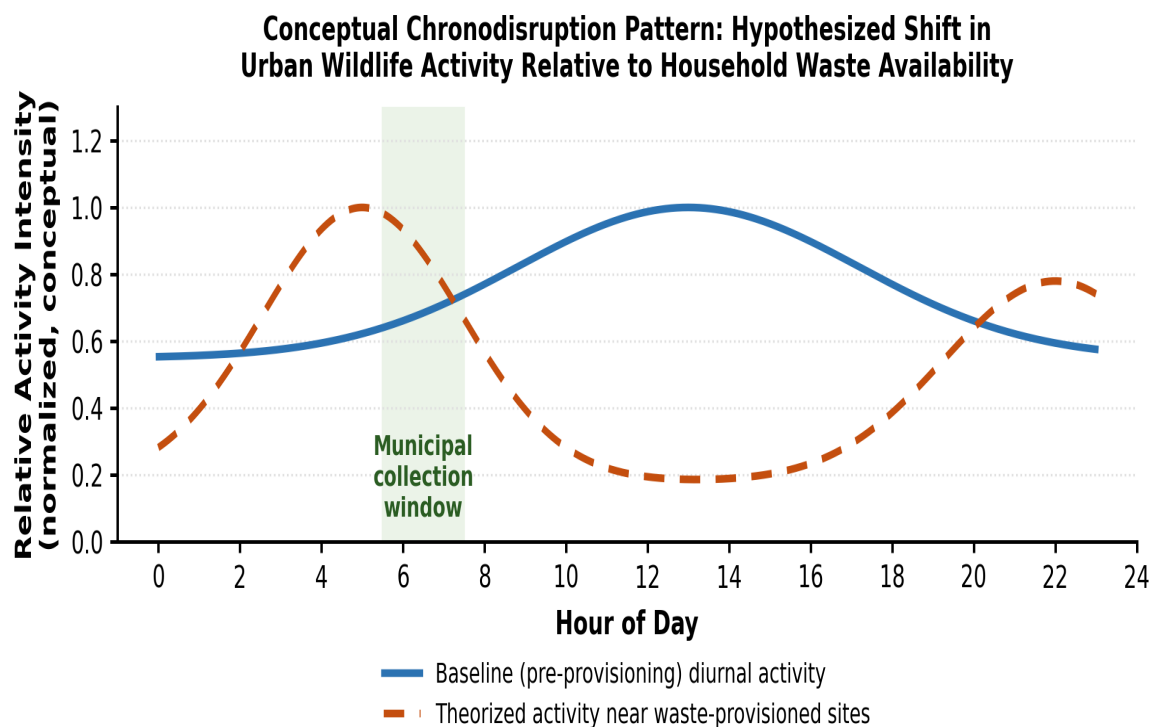


Figure 1: Conceptual chrono disruption pattern showing a hypothesized shift in urban wildlife activity relative to household waste availability

Epistemological Integration: AI as a Lens for Complex Socio-Ecological Systems

• *Systems Thinking and Pattern Recognition*

Modeling and understanding patterns through systems thinking. The waste-wildlife interface is a true complex socio-ecological system and should be addressed through an epistemological tool that can capture a multitude of interacting variables at once (human, infrastructure, animal and environmental factors), without reducing them to individual, linear relationships. The goal

of this paper is to place AI conceptually, separated from any specific algorithm or code base, as a meta-framework for systems thinking and for pattern recognition. The framework proposed here sees machine-learning paradigms (such as pattern discovery across heterogeneous data, iterative refinement of the models based on feedback, and multi-scale representation learning) as an analytical vocabulary for describing the co-evolution of human waste behavior and animal movement rather than merely as a forecasting tool.

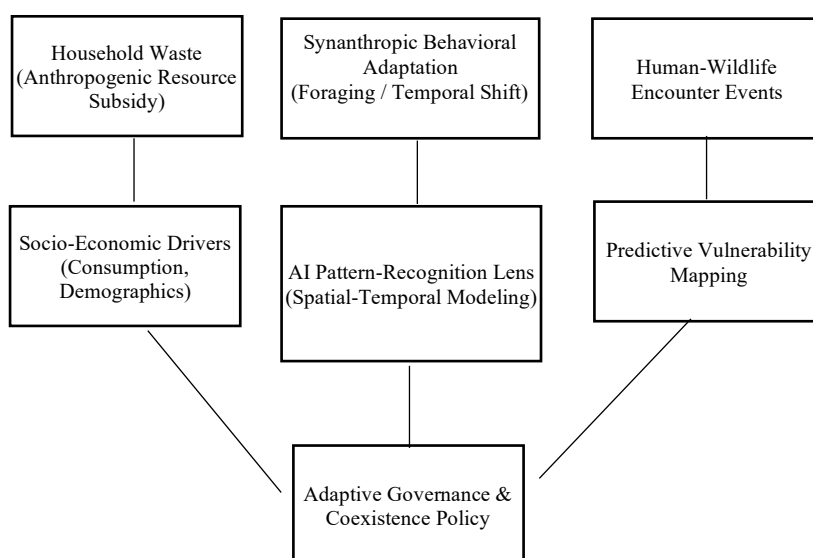


Figure 2: Conceptual feedback framework linking household waste, synanthropic behavior, and AI-informed urban wildlife governance

This integration is illustrated in a schematic way in figure 2. A socio-economically organized household waste creates a resource subsidy that influences the behavioral adaptation of synanthropic species, and therefore generates observable events of human-wildlife interactions. At the heart of this analytical feedback is the AI pattern-recognition lens, which conceptually maps the relationships between these variables to formulate predictions

on vulnerability assessments. These assessments are passed on to adaptive governance, which can also (in principle) feedback on socio-economic behavior and waste-handling infrastructure, thus closing the loop. This is a multi-loop and circular design, different from the linear and input-output logic of traditional wildlife-management models.

• *Non-Linear Dynamics*

Another conceptual advance of the AI lens is that it is able to account for non-linear effects, such as thresholds and sudden increases in encounter frequency. In ecology, the systems often have a tipping point, a point at which small changes in a control variable – such as buildup of waste or the failure to contain it – can lead to large changes in an output variable, like encounter rates or severity of conflict.

Algorithmic modeling paradigms that are specifically designed to identify non-linear relationships and inflection points in the high dimensional data space, provide a conceptual language for predicting these escalations, beyond just describing them in hindsight. Spatial-Temporal Dynamics of Urban-Wildlife Encounters

Table 1: Comparative Overview of Traditional versus AI-Informed Approaches to Modeling Household Waste-Wildlife Interactions

Dimension	Traditional Ecological Models	AI-Informed Conceptual Lens
Data input	Static, coarse waste-generation averages	Dynamic, high-frequency, multi-source data (schedules, imagery, sensor streams)
Temporal resolution	Seasonal or annual	Sub-daily to near real-time
Spatial treatment	Fixed, discrete resource points	Continuous probability surfaces
Behavioral assumption	Uniform foraging response	Adaptive, risk-reward optimizing behavior
Feedback representation	Linear, one-directional	Non-linear, multi-loop feedback
Predictive capacity	Retrospective / descriptive	Prospective vulnerability mapping
Governance orientation	Reactive (pest control)	Proactive, adaptive planning

Spatial-Temporal Dynamics of Urban-Wildlife Encounters

• Landscape Ecology Perspectives

The spatiotemporal manifestation of the waste-wildlife interface cannot be separated from landscape ecology in general. Urban sprawl creates new corridors, green belts and drainage lines, and residential alleyways, and also fragments natural habitat, that structure wildlife

movement through the built environment. These corridors often overlap with waste-disposal hotspots, such as perimeter bins and communal rubbish bins, and poorly managed storage spaces, forming de facto resource nodes in an otherwise unfriendly urban matrix. Wherever movement corridors meet resource nodes is the main spatial substrate of human-wildlife encounters.

Predictive Vulnerability Mapping

This landscape perspective, the paper proposes the development of 'predictive vulnerability mapping' as the spatial analog to the temporal 'chronodisruption model' mentioned above. Instead of waiting until encounter events begin to pile up to detect problem areas, an AI-driven solution would continuously generate probability surfaces from multiple layers of spatial data, corridor connectivity, waste-bin density and security, historical encounter data and neighborhood waste generation patterns and highlight interface areas with a high encounter probability beforehand. Table 1 conceptually shows how such a change can be distinguished from the traditional descriptive models in a few important dimensions of analysis, from a static to a prospective, dynamic perspective, and from a descriptive to a policy-actionable model of risk.

Socio-Economic Drivers of Waste Generation and Provisioning

- *Human Dimensions*

Human perspectives are an integral part of any discussion on waste-wildlife relationships. Waste generation is not "ecologically neutral", but is influenced by consumption habits, household structure, income and neighborhood demographics. Social science theories of consumption argue that the amount, types and time of disposal of household waste are regular functions of socio-economic groups, and that this will have implications for the density and predictability of resources available to urban wildlife within different areas of a city. Therefore, the inclusion of these human

dimensions in ecological frameworks is not an optional extra but a requirement in order to accurately model.

- *Inadvertent versus Intentional Provisioning*

Another conceptual separation has to do with inadvertent provisioning versus intentional provisioning. Inadvertent provisioning is caused by containment failures, broken bins, missed pickups, or improper storage which provides opportunities for wildlife access. Intentional provisioning on the other hand is an intentional feeding act by a resident, such as for reasons of affection, curiosity or understanding the ecological implications. These two pathways have different behavioral, spatial and policy implications: Inadvertent pathway is amenable to infrastructural and engineering interventions, intentional pathway is amenable to social and educational interventions aimed at changing household attitudes and norms. It is therefore important to have a solid theoretical framework that distinguishes these pathways from one another, and that does not assume that all human-provided resources are ecologically equivalent.

Theoretical Framework for Adaptive Urban Wildlife Management

- *Policy and Governance*

Traditionally, wildlife incursion has been dealt with in a reactive way, from a pest management perspective with culling or on a case-by-case basis when complaints have been received. These methods only attack symptoms and are not well suited to systems of dynamic feedback and non-linear escalation. The

application of the principles of predictive vulnerability mapping and pattern-recognition, as described above, to a theoretical shift towards more proactive and data driven governance can enable planners to intervene at the level of infra-structural design, waste-collection scheduling, and education at the neighborhood level before levels of conflict are reached.

- ***Coexistence Ethics***

Framing AI-based ecological knowledge as a tool for coexistence, instead of a tool for surveillance or eradication, places urban wildlife management in the wider context of the ethics of sharing space in the city. Coexistence-oriented governance does not regard synanthropic species as a problem to be solved but as partners of the ecosystem, whose actions are for the most part a sensible reaction to the human-changing resource configuration. The moral approach is more likely to lead to enduring and socially legitimate results than purely technocratic or punitive choices in adaptive governance.

Conclusion

The present paper has been based on the premise that household waste is not an inert 'ecological by-product' of urban living but a resource subsidy that is spatial and temporal, and actively influences the behavioral ecology of synanthropic wildlife. The analysis brings a conceptual approach to pattern recognition and systems thinking to view the study of urban wildlife encounters, instead of a narrow computational lens, and situates it in the context of dynamic feedback loops, non-linear thresholds, and predictive rather than purely

descriptive modeling. A combination of the different theories in resource landscapes, chronodisruption research, landscape ecology and socio-economic analysis in a single, AI-informed framework constitutes a more complete picture of the household waste-wildlife interface than any single disciplinary lens alone. This synthesis opens a number of research paths. Firstly, there are still open questions about the evolutionary pressures that anthropogenic provisioning might place on synanthropic populations such as morphological, cognitive and life-history changes over successive generations. Second, as more and more algorithmic systems are used to govern urban ecology, there are also unanswered ethical issues about who owns the data, how it is being monitored, and how far it should be allowed to intervene in people's lives as a predictive tool in shared urban flora and fauna. Future empirical research should validate these conceptual statements, including the hypothesized chronodisruption pattern, and the comparative predictive power of AI-driven vulnerability mapping, using observation and sensor-based data in a variety of urban settings.

References

- [1] Alprol, Ahmed E., Abdallah Tageldein Mansour, Marwa Ezz El-Din Ibrahim, and Mohamed Ashour. "Artificial intelligence technologies revolutionizing wastewater treatment: Current trends and future prospective." *Water* 16, no. 2 (2024): 314.
- [2] Bibi, Safia, and Ling Yang. "Artificial intelligence shaping a smarter and greener planet for sustainable energy transportation biodiversity and water

- management." *Discover Artificial Intelligence* 5, no. 1 (2025): 403.
- [3] Cheng, Yan, Zhisheng Zhang, Lian Hu, and Xin Duan. "Research on the impact of artificial intelligence development on urban low-carbon transformation." *Scientific Reports* 15, no. 1 (2025): 20438.
- [4] Lakhouit, Abderrahim. "Revolutionizing urban solid waste management with AI and IoT: A review of smart solutions for waste collection, sorting, and recycling." *Results in Engineering* 25 (2025): 104018.
- [5] Miller, Tymoteusz, Irmina Durlik, Ewelina Kostecka, Polina Kozlovska, Adrianna Łobodzińska, Sylwia Sokołowska, and Agnieszka Nowy. "Integrating artificial intelligence agents with the internet of things for enhanced environmental monitoring: applications in water quality and climate data." *Electronics* 14, no. 4 (2025): 696.
- [6] Ojija, Fredrick, Matthew C. Ogwu, Juma Ally, John P. John, Azaria Stephano, Nancy Felix, and Ramadhani Tekka. "Artificial intelligence-driven solutions for mitigating human–wildlife conflict in biodiversity hotspots." *Science Progress* 108, no. 4 (2025): 00368504251394584.
- [7] Palmini, Otello, and Federico Cugurullo. "Charting AI urbanism: Conceptual sources and spatial implications of urban artificial intelligence." *Discover Artificial Intelligence* 3, no. 1 (2023): 15.
- [8] Pimenow, Sergiusz, Olena Pimenowa, Piotr Prus, and Aleksandra Niklas. "The impact of artificial intelligence on the sustainability of regional ecosystems: Current challenges and future prospects." *Sustainability* 17, no. 11 (2025): 4795.
- [9] Rajendran, M., A. Ganesan, and S. Banwar. 2025. "Behavioral Determinants of Sustainable Consumption and Financial Literacy among Urban Gen Z Consumers." *International Academic Journal of Science and Engineering* 12 (3): 307–317.
- [10] Wankhade, Nisha, Supriya Awasthi, Satish V. Kakade, Shubhashish Goswami, Mahendran Arumugam, Kiran Ingale, and Gaurav Thakur. "Big Data Analytics and Artificial Intelligence for Decision Support in Urban Ecology and Environmental Management." *Journal of Animal Environment* 18, no. 1S (2026): 104-115.
- [11] Yogamadhavan, Vicknesh Kumar, and Giriraj Mannayee. "Evaluation of Performance of Different Optimizers of Convolutional Neural Network in the Classification of Images of Urban Domestic Solid Waste." *J. Internet Serv. Inf. Secur.* 14, no. 3 (2024): 42-77.