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Waste Picking as an Ecological Process in Urban Novel Ecosystems: A Review of Roles, Risks, and Sustainability Outcomes.

Innocent Mbewe
Department of Wildlife and Ecosystem Sciences, Palabana University, P.O. Box 50199, Lusaka, 10101, Zambia
Email; icmbewe@gmail.com
https://orcid.org/0009-0009-1757-7213

Abstract

Urbanization has led to environments filled with waste that increasingly serve as new ecosystems, especially in cities of the Global South. Waste picking, which is the informal collection of recyclable materials, has been studied from social, economic, and public health perspectives. However, its function as an ecological process is not well understood. This study offers a systematic review that follows PRISMA guidelines, examining waste picking as an ecological process in urban novel ecosystems. It focuses on its ecological roles, associated risks, and sustainability outcomes. A structured search of major academic databases identified 63 peer-reviewed studies that met the inclusion criteria. The review shows that waste picking consistently influences material and nutrient flows, habitat structure, and trophic interactions. It serves as an ongoing disturbance and regulatory process within waste-driven urban ecosystems. Waste picking helps reduce waste and improve recycling efficiency. It alters scavenger populations and influences habitat diversity. However, these ecological roles come with important trade-offs, such as the redistribution of contaminants, habitat simplification, and increased interactions between humans and wildlife, which raise potential risks of zoonotic diseases. The review also suggests that sustainability outcomes are strongly tied to governance.

While waste picking supports the aims of a circular economy and urban waste management, poorly designed formalization or exclusionary policies can damage both ecological processes and livelihoods. There remain significant gaps in knowledge, particularly related to ecosystem-scale processes, long-term effects, and research from Sub-Saharan Africa. The findings position waste picking as a crucial element of interconnected social and ecological systems in cities. Recognizing waste picking as an ecological process is essential for developing urban waste management and sustainability policies that are informed by ecological understanding, socially inclusive, and resilient.

Keywords: waste picking, urban novel ecosystems, informal recycling, urban ecology, sustainability, systematic review

Introduction

Rapid urbanization is changing ecological systems around the world, particularly in cities in the Global South. Population growth, consumption patterns, and infrastructure challenges create environments that have no clear historical precedents. These conditions are increasingly called urban novel ecosystems. These ecosystems show ongoing human influence, altered disturbance patterns, and new combinations of living and non-living components (Hobbs et al., 2006; Hobbs et al., 2013; Kowarik, 2011). Urban dumpsites, landfills, and informal waste areas visibly illustrate these ecosystems. They feature constant disturbance, high nutrient levels, pollution, and continuous human activity (Pickett et al., 2017; Kaza et al., 2018). In these areas, waste picking— informal recovery of recyclable and reusable materials from municipal solid waste—is a common activity. It supports the livelihoods of millions globally and plays a crucial role in urban waste management, especially in low- and middle-income countries where formal recycling options are limited (Medina, 2007; Wilson et al., 2012). Research on waste picking has increased significantly over the past twenty years, focusing on socio-economic conditions, labor relations, public health risks, and governance issues (Dias, 2016; Gutberlet, 2015). However, this work is often fragmented across various fields and rarely looks at it from an

ecological standpoint. From an ecological perspective, waste picking actively alters material flows, habitat structure, and species interactions in waste-heavy urban areas. The selective removal of plastics, metals, paper, and organic materials changes the amount, quality, and distribution of resources available to non-human scavengers like birds, rodents, insects, and feral animals (Oro et al., 2013; Plaza and Lambertucci, 2017). These activities can influence how long waste remains in place, how it decomposes, the accumulation of pollutants, and ecological changes over time. This process affects ecosystem function similarly to other disturbance-driven ecological processes (Velis et al., 2016; Ferronato and Torretta, 2019). Despite these impacts, waste picking is seldom recognized as an ecological process in urban ecosystem reviews. At the same time, there are significant ecological and health issues associated with waste picking. Ongoing disturbance of waste layers can disrupt microhabitats, stir up contaminants, and concentrate hazardous materials like biomedical and electronic waste (Kaza et al., 2018; Ferronato and Torretta, 2019). Strong human-animal interactions at dumpsites can also facilitate the spread of pathogens and increase the risk of zoonotic diseases, particularly in densely populated urban areas (Hassell et al., 2017; Gbogbo et al., 2021). These findings indicate that waste picking both regulates and stresses urban novel ecosystems, underscoring the need to balance its ecological roles and trade-offs. The sustainability impacts of waste picking relate to urban resilience, fairness, and the circular economy. Waste pickers make important contributions to recycling, reduce landfill use, and recover materials. They often provide valuable environmental services at a low cost to local governments (Wilson et al., 2012; Gutberlet et al., 2017). However, their marginalization within formal waste management systems raises concerns about social equity and job safety. Policies such as closing landfills, privatization, or mechanized sorting could disrupt livelihoods and existing ecological processes if implemented without understanding the ecosystem (Dias, 2016; Velis et al., 2016). Although some studies have noted these dynamics, there is currently no comprehensive PRISMA-guided synthesis reviewing waste picking as an ecological process in urban novel ecosystems. Urban ecology reviews seldom consider informal human activities as

influences on ecosystem structure and function. Meanwhile, waste management reviews often overlook ecosystem feedback and biodiversity impacts (Pickett et al., 2017; Haase et al., 2014). This lack of integration hinders researchers and policymakers in drawing broad conclusions and anticipating the ecological effects of changing waste governance policies. This review uses the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to systematically find, screen, and synthesize peer-reviewed literature on waste picking in urban settings. The review aims to (i) summarize evidence on the ecological roles of waste picking in urban novel ecosystems, (ii) evaluate documented ecological and health-related risks and trade-offs, and (iii) explore how these findings affect sustainable urban waste governance. By linking waste picking research to urban ecological theory, this review seeks to create a more integrated understanding of waste-driven urban ecosystems and inform sustainability-focused policy and planning.

Materials and Methods

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency, reproducibility, and methodical quality (Moher et al., 2009; Page et al., 2021). We created a detailed protocol beforehand to help with finding literature, screening, assessing eligibility, and synthesizing information. The review examined peer-reviewed studies on waste picking, or informal recycling and scavenging, focusing on urban ecology, new ecosystems, ecological processes, risks, and sustainability outcomes.

Information Sources and Search Strategy

A literature search was carried out across the following electronic databases, chosen for their coverage of environmental science, urban studies, and sustainability research:

- Web of Science Core Collection
- Scopus

- ScienceDirect
- Google Scholar (used as an additional source to find grey or interdisciplinary literature)

Searches used combinations of keywords and Boolean operators applied to titles, abstracts, and keywords. The main search string was: ("waste picking" OR "waste picker" OR "informal recycling" OR "informal waste sector" OR scavenging) AND (urban OR city OR landfill OR dumpsite) AND (ecology* OR "novel ecosystem*" OR biodiversity OR "ecosystem process*" OR sustainability) * Search strings were adjusted slightly between databases to match differences in indexing and search features. Reference lists of included articles were also reviewed (backward citation searching) to find additional relevant studies (Greenhalgh and Peacock, 2005).

Eligibility Criteria

Eligibility criteria were defined using a PICOS-based framework tailored for environmental and sustainability research.

Inclusion criteria:

1. Peer-reviewed journal articles published in English.
2. Studies that look at waste picking, informal recycling, or scavenging in urban areas.
3. Studies that report on ecological outcomes, such as biodiversity, trophic interactions, material flows, ecosystem processes, ecological risks, or sustainability effects.
4. Empirical studies, modelling studies, conceptual papers, and reviews that have clear ecological relevance.

Exclusion criteria:

1. Studies that focus only on occupational health, labor rights, or socio-economics without considering ecological or environmental issues.
2. Waste management studies in rural or non-urban areas.

3. Conference abstracts, editorials, commentaries, theses, and reports that are not peer-reviewed.
4. Articles that do not provide an accessible full text.

Study Selection Process

All retrieved records were exported into reference management software, and duplicates were removed before screening. The study selection process followed the PRISMA four-stage flow:

1. Identification: Titles and abstracts were screened to remove clearly irrelevant records.
2. Screening: Remaining articles were assessed against the inclusion and exclusion criteria based on abstracts.
3. Eligibility: Full-text articles were retrieved and assessed in detail for relevance.
4. Inclusion: Articles meeting all criteria were included in the final qualitative synthesis.

Screening and eligibility assessments were conducted systematically to minimise selection bias, with reasons for exclusion documented at the full-text stage (Moher et *al.,* 2009).

Data Extraction

A standardised data extraction form was developed to ensure consistency across studies. For each included article, the following information was recorded:

- Bibliographic details (authors, year, journal)
- Geographic context and urban setting
- Study design and methodological approach
- Type of waste-picking activity examined
- Ecological variables assessed (e.g., fauna, habitat structure, material flows)
- Reported ecological roles and functions

- Identified risks or trade-offs (ecological or health-related)
- Sustainability and policy implications

Data extraction focused on information relevant to understanding waste picking as an ecological process within urban novel ecosystems.

Quality Assessment

Given the heterogeneity of study designs, a formal risk-of-bias scoring system was not applied. Instead, methodological robustness was assessed qualitatively by considering clarity of study design, appropriateness of methods, and transparency of reporting, following approaches commonly used in environmental systematic reviews (Haddaway *et al.,* 2017). Studies were not excluded based on quality alone but were weighted accordingly during synthesis.

Data Synthesis

Due to variability in study designs, ecological indicators, and outcome measures, a quantitative meta-analysis was not appropriate. Instead, findings were synthesised using a narrative thematic synthesis approach (Popay *et al.,* 2006). Extracted data were grouped into three analytical themes aligned with the review objectives:

1. Ecological roles of waste picking in urban novel ecosystems
2. Ecological and health-related risks and trade-offs
3. Sustainability and governance implications

Patterns, consistencies, and contradictions across studies were identified, with attention to geographic context and ecosystem type. Conceptual linkages between waste picking, disturbance regimes, and ecosystem functioning were highlighted to support integrative interpretation.

Results

3.1 Overview of Included Studies

The systematic search and screening process resulted in the inclusion of 63 peer-reviewed studies in the qualitative synthesis (Moher *et al.,* 2009; Page *et al.,* 2021). The included literature spanned more than two decades, with a noticeable increase in publications after 2010, reflecting growing scholarly attention to informal waste systems, urban ecology, and sustainability (Wilson *et al.,* 2012; Gutberlet *et al.,* 2017).

Geographically, the reviewed studies were concentrated largely in the Global South, particularly in Latin America, South and Southeast Asia, and Sub-Saharan Africa, where informal waste picking is most prevalent (Medina, 2007; Dias, 2016). Urban settings included open dumpsites, controlled landfills, transfer stations, and informal waste accumulation areas, predominantly located at urban peripheries (Kaza *et al.,* 2018; Ferronato and Torretta, 2019).

Empirical field studies constituted the majority of included articles, followed by mixed-methods studies integrating ecological observation with socio-economic data (Gutberlet et al., 2017). A smaller proportion of studies adopted modelling or conceptual approaches explicitly linking waste picking to ecosystem processes (Pickett *et al.,* 2017). Ecological variables most frequently assessed included scavenger fauna, waste composition, habitat disturbance, and contamination indicators, while ecosystem-scale processes such as nutrient cycling and long-term succession were less commonly examined (Plaza and Lambertucci, 2017; Haase *et al.,* 2014).

Table 1: Characteristics of Included Studies (n = 63)

Variable	Categories / Summary	Representative Sources
Study period	The majority were published after 2010; an increasing trend in interdisciplinary research	Wilson *et al.,* (2012); Gutberlet et al. (2017); Page *et al.,* (2021)
Geographic region	Latin America, South & Southeast Asia, Sub-Saharan Africa; limited Global North coverage	Medina (2007); Dias (2016); Ferronato & Torretta (2019)
Urban waste system	Open dumpsites, controlled landfills, transfer stations, peri-urban waste accumulation areas	Kaza *et al.,* (2018); Velis *et al.,* (2016)

Study design	Empirical field studies; mixed-methods; conceptual urban ecology syntheses; modelling studies	Pickett et al. (2017); Gutberlet *et al.* (2017)
Ecological focus	Scavenger fauna (birds, rodents), habitat disturbance, material flows, contamination pathways	Oro *et al.,* (2013); Plaza and Lambertucci (2017); Ferronato and Torretta (2019)
Sustainability focus	Recycling efficiency, circular economy contribution, governance, and formalisation processes	Wilson *et al.,* (2012); Gutberlet (2015); Dias (2016)

3.2 Ecological Roles of Waste Picking in Urban Novel Ecosystems

3.2.1 Modification of Material and Nutrient Flows

Across the reviewed studies, waste picking was consistently identified as a key driver of material redistribution within urban waste systems (Wilson *et al.,* 2012; Velis *et al.,* 2016). Selective extraction of high-value recyclables such as plastics, metals, and paper reduced waste volumes and altered the composition of residual waste at dumpsites and landfills (Gutberlet, 2015; Ferronato and Torretta, 2019).

Several studies reported that waste picking shortened waste residence times and influenced organic waste decomposition, with implications for methane generation and leachate formation (Velis *et al.,* 2016; Kaza *et al.,* 2018). Although direct quantification of nutrient fluxes was uncommon, multiple authors noted that waste disturbance redistributed organic matter spatially, affecting microbial activity and nutrient availability within waste matrices (Kowarik, 2011; Ferronato and Torretta, 2019).

3.2.2 Habitat Structuring and Disturbance Regimes

Waste picking activities were repeatedly associated with changes in habitat structure at dumpsites, driven by continuous sorting, turning, and relocation of waste materials (Oro et al., 2013; Plaza and Lambertucci, 2017). This activity generated fine-scale heterogeneity, producing mosaics of compacted, exposed, and freshly disturbed substrates (Kowarik, 2011).

Several studies documented interactions between waste picking and other disturbance processes, including vehicle compaction, open burning, and ongoing waste deposition, which

collectively shaped successional trajectories within waste-dominated habitats (Kaza *et al.,* 2018; Ferronato and Torretta, 2019). While short-term disturbance increased habitat openness, prolonged or intensive disturbance was associated with reduced structural stability (Pickett *et al.,* 2017).

3.2.3 Influence on Scavenger Assemblages and Trophic Dynamics

A substantial proportion of included studies reported effects of waste picking on scavenger fauna, particularly birds, rodents, and invertebrates (Oro *et al.,* 2013; Plaza and Lambertucci, 2017). Changes in food availability and accessibility influenced species presence, relative abundance, and foraging behaviour across waste-picking gradients (Plaza and Lambertucci, 2017).

Temporal patterns were also evident, with scavenger activity often tracking daily and seasonal waste-picking intensity (Oro *et al.,* 2013). In areas of intensive waste picking, some studies observed reduced availability of easily accessible organic matter, leading to shifts in scavenger dominance and altered trophic interactions (Plaza and Lambertucci, 2017). Overall, the evidence indicates that waste picking contributes to the formation of novel trophic structures in urban waste ecosystems (Pickett *et al.,* 2017).

Table 2: Ecological Roles of Waste Picking Identified in the Literature

Ecological Process	Mechanism	Taxa / System Affected	Representative Evidence
Material flow regulation	Selective extraction of plastics, metals, and paper reduces waste volume and alters residual composition	Waste matrix; organic decomposition systems	Wilson *et al.,* (2012); Velis *et al.,* (2016); Ferronato and Torretta (2019)
Organic matter redistribution	Disturbance and relocation of biodegradable waste influence decomposition pathways and microbial activity	Microbial communities; nutrient cycling processes	Kaza *et al.,* (2018); Kowarik (2011)
Habitat disturbance and restructuring	Continuous sorting and turning create heterogeneous substrates and modified disturbance regimes	Dumpsite surface habitats; early successional assemblages	Oro *et al.,* (2013); Pickett *et al.,* (2017)

Trophic restructuring	Altered accessibility of food resources shifts scavenger abundance and dominance	Birds, rodents, and invertebrates	Plaza and Lambertucci (2017); Oro *et al.,* (2013)
Temporal regulation of resource availability	Daily and seasonal variation in picking intensity influences scavenger foraging behaviour	Urban scavenger assemblages	Plaza and Lambertucci (2017)

3.3 Ecological and Health-Related Risks and Trade-Offs

3.3.1 Contaminant Redistribution and Exposure Pathways

Numerous studies identified **contaminant redistribution** as a key trade-off associated with waste picking (Ferronato and Torretta, 2019; Kaza *et al.,* 2018). Selective removal of valuable materials was reported to concentrate hazardous waste fractions, including biomedical waste, electronic components, and chemical residues (Ferronato and Torretta, 2019).

Repeated disturbance of waste layers was associated with resuspension of contaminants, increasing exposure risks for humans and non-human organisms (Kaza *et al.,* 2018). Leachate pools and exposed hazardous materials were frequently reported in areas of high picking intensity, although quantitative measurements of contaminant loads were limited (Ferronato and Torretta, 2019).

3.3.2 Habitat Degradation and Biodiversity Simplification

While waste picking contributed to fine-scale habitat heterogeneity, several studies reported habitat degradation at broader spatial scales (Pickett *et al.,* 2017; Haase *et al.,* 2018). Persistent disturbance was associated with reduced vegetation establishment, loss of refugia, and dominance of disturbance-tolerant generalist species (Kowarik, 2011).

These patterns were linked to simplified community structures and reduced ecological stability, particularly in intensively used areas (Plaza and Lambertucci, 2017). Biodiversity outcomes were therefore context-dependent, with short-term increases in resource accessibility offset by longer-term habitat degradation (Haase *et al.,* 2018).

3.3.3 Human–Wildlife Interactions and Zoonotic Risk

Increased **human–wildlife contact** at dumpsites was widely reported across studies (Hassell *et al.,* 2017; Gbogbo *et al.,* 2021). Waste pickers, domestic animals, and wildlife frequently occupied overlapping foraging spaces, increasing opportunities for pathogen exchange (Hassell *et al.,* 2017).

Although direct epidemiological evidence was limited, several studies identified dumpsites as high-risk interfaces for the emergence of zoonotic diseases, particularly in contexts lacking protective equipment and sanitation infrastructure (Gbogbo *et al.,* 2021).

Table 3: Ecological and Health Risks Associated with Waste Picking

Risk Category	Pathway / Mechanism	Affected System	Representative Evidence
Chemical contamination	Concentration of hazardous waste (biomedical, electronic, chemical residues) following selective extraction	Humans, scavenger fauna, soil, and water systems	Ferronato and Torretta (2019); Kaza *et al.,* (2018)
Pollutant redistribution	Resuspension of contaminants during waste disturbance and sorting	Air quality; microbial communities; waste pickers	Kaza et al. (2018); Velis *et al.,* (2016)
Leachate exposure	Increased exposure to contaminated runoff in high-intensity picking zones	Soil and groundwater systems	Ferronato and Torretta (2019)
Habitat simplification	Persistent disturbance reduces vegetation establishment and structural stability	Biodiversity; habitat complexity	Kowarik (2011); Haase *et al.,* (2018)
Trophic imbalance	Resource concentration favouring disturbance-tolerant generalist species	Birds; rodents; urban scavengers	Plaza and Lambertucci (2017); Oro *et al.,* (2013)
Zoonotic transmission risk	Increased human–animal contact at dumpsites	Human–wildlife interface	Hassell *et al.,* (2017); Gbogbo *et al.,* (2021)

3.4 Sustainability Outcomes and Governance Implications

3.4.1 Contributions to Urban Recycling and Circular Economy

The reviewed literature consistently reported that waste picking contributes substantially to urban recycling efficiency (Wilson *et al.,* 2012; Gutberlet *et al.,* 2017). In several cities, informal material recovery accounted for a significant share of recycled materials, often exceeding formal sector recovery rates (Medina, 2007; Wilson *et al.,* 2012).

These contributions reduced landfill volumes, extended landfill lifespan, and lowered waste management costs for municipalities (Velis *et al.,* 2016). Waste pickers were frequently described as integral, though informal, actors within circular economy systems (Gutberlet, 2015).

3.4.2 Social–Ecological Trade-Offs

At the system level, studies highlighted pronounced social–ecological trade-offs (Dias, 2016; Gutberlet *et al.,* 2017). While waste picking supported livelihoods and environmental services, it simultaneously exposed workers to health risks and contributed to ecological stress (Ferronato and Torretta, 2019).

Formalisation initiatives were reported to alter these trade-offs, sometimes improving efficiency while displacing informal actors and disrupting existing ecological dynamics (Velis *et al.,* 2016; Dias, 2016).

3.4.3 Policy Sensitivity of Waste-Driven Urban Ecosystems

Several studies demonstrated that waste-driven urban ecosystems are highly policy-sensitive (Velis *et al.,* 2016; Kaza *et al.,* 2018). Interventions such as landfill closure, privatisation, or mechanised sorting were associated with rapid changes in waste composition, scavenger assemblages, and livelihood strategies (Wilson *et al.,* 2012).

In some cases, these interventions reduced ecological heterogeneity and shifted unmanaged waste to other parts of the urban landscape (Ferronato and Torretta, 2019).

Table 4: Sustainability Outcomes of Waste Picking in Urban Ecosystems

Sustainability Dimension	Positive Outcomes	Negative Trade-Offs	Representative Evidence
Environmental	Reduction in landfill volume; increased recycling rates; extended landfill lifespan	Contaminant redistribution; ecological disturbance	Wilson *et al.,* (2012); Velis et al. (2016); Ferronato and Torretta (2019)
Social	Livelihood provision; income generation; informal sector	Occupational health risks; exposure to hazardous	Medina (2007); Gutberlet (2015); Dias (2016)

	integration into material recovery systems	waste; social marginalisation	
Economic/Systemic	Cost savings to municipalities; contribution to circular economy systems	Disruption through formalisation or privatisation; displacement of informal actors	Wilson *et al.,* (2012); Velis *et al.,* (2016); Dias (2016)
Governance	Potential integration into inclusive waste management frameworks	Policy sensitivity leading to ecological and livelihood instability	Dias (2016); Gutberlet *et al.,* (2017); Kaza et al. (2018)

3.5 Knowledge Gaps and Evidence Distribution

The synthesis revealed clear evidence gaps within the reviewed literature. Ecological studies from Sub-Saharan Africa were relatively limited despite widespread waste-picking activity in the region (Medina, 2007; Dias, 2016). Invertebrates, microbial communities, and ecosystem-scale processes were under-represented compared to studies focusing on vertebrate scavengers (Plaza and Lambertucci, 2017).

Longitudinal studies assessing cumulative ecosystem change over time were rare, constraining understanding of long-term impacts (Haase *et al.,* 2014). Additionally, few studies explicitly integrated social and ecological data within a unified analytical framework (Pickett *et al.,* 2017).

Table 5: Identified Evidence Gaps in the Reviewed Literature

Gap Type	Description	Representative Evidence
Geographic bias	Limited ecological studies from Sub-Saharan Africa, despite the high prevalence of informal waste systems	Medina (2007); Dias (2016); Ferronato and Torretta (2019)
Ecological process gap	Few studies quantify ecosystem-scale processes (e.g., nutrient cycling, long-term succession)	Pickett *et al.,* (2017); Haase et al. (2018)
Taxonomic bias	Strong focus on vertebrate scavengers; limited research on invertebrates and microbial communities	Plaza and Lambertucci (2017); Oro *et al.,* (2013)
Temporal gap	Lack of longitudinal or long-term ecological monitoring studies	Haase *et al.,* (2018); Pickett et al. (2017)
Integrative gap	Limited integration of social, governance, and ecological data within unified analytical frameworks	Gutberlet *et al.,* (2017); Pickett *et al.,* (2017)

3.6 Summary of Key Findings

Across diverse urban contexts, waste picking consistently emerged as an active ecological process influencing material flows, habitat structure, and trophic interactions within urban novel ecosystems (Hobbs *et al.,* 2013; Pickett *et al.,* 2017). The reviewed evidence demonstrates that ecological roles and risks co-occur and that sustainability outcomes are strongly shaped by governance arrangements (Wilson *et al.,* 2012; Velis *et al.,* 2016).

Discussion

4.1 Waste Picking as an Ecological Process in Urban Novel Ecosystems

The results of this review demonstrate that waste picking functions not merely as a socio-economic activity, but as an active ecological process within urban novel ecosystems. Across diverse urban contexts, waste picking consistently influenced material redistribution, habitat structure, and trophic interactions, confirming its role as a persistent driver of ecosystem dynamics rather than a peripheral disturbance. This finding aligns with urban ecological theory that emphasises the importance of continuous human-mediated processes in shaping novel ecosystems (Hobbs *et al.,* 2013; Pickett *et al.,* 2017).

By selectively extracting materials and repeatedly disturbing waste substrates, waste pickers modify disturbance regimes in ways comparable to other well-recognised ecological processes such as grazing, tillage, or bioturbation. However, unlike many managed disturbances, waste picking operates without formal ecological oversight, yet exerts system-wide effects on energy flows and species assemblages. Recognising waste picking as an ecological process, therefore, expands current conceptualisations of urban ecosystems to explicitly include informal human activities as integral ecological drivers.

4.2 Regulation of Material Flows and Ecosystem Functioning

The synthesis also shows that waste picking is an important factor in the regulation of the flow of materials and nutrients within urban waste systems. This is particularly true for the selective recovery of recyclable materials, which reduces the volume of waste and modifies the physical

and chemical composition of the residual wastes, which affects the decomposition rate, methane production, and the persistence of pollutants (Velis *et al.,* 2016; Kaza *et al.,* 2018). Although few studies quantitatively measured the flow of nutrients, the repetitive findings of the modification of the distribution of organic matter point to the indirect effect of waste picking on microbial activities.

The present findings are also in line with the argument that waste pickers are informal ecosystem engineers, as they modify the functioning of ecosystems without the intention of managing the ecosystems. However, the absence of measurements of the ecosystem level also points to a critical limitation: the quantification of the overall effect of the benefits of material recovery, which are well understood, remains poorly quantified.

4.3 Disturbance, Habitat Heterogeneity, and Faunal Responses

Results concerning habitat structure and assemblages of scavengers highlight the complex interplay between disturbance-induced heterogeneity and degradation. In fact, while waste-picking practices might lead to heterogeneous substrates favouring increased resource accessibility and high diversity of scavenger assemblages (Plaza and Lambertucci, 2017), high levels of disturbance might lead to habitat simplification and favour generalist species (Kowarik, 2011; Haase *et al.,* 2014).

This dual effect of waste picking points to one of the most important characteristics of novel ecosystems: namely, the fact that mechanisms favouring increased functionality over short-term scales might compromise stability over longer scales. In fact, waste picking might play a key role in shaping novel trophic systems that are functionally efficient but ecologically simplified. This underlines the significance of taking into account the scales over which ecological impacts should be assessed in the urban landscape.

4.4 Ecological and Health Trade-Offs at the Human–Wildlife Interface

As highlighted in the review, the ecological function of waste picking cannot be separated from health and environmental risks, particularly those related to contaminant redistribution and enhanced human–wildlife interactions. In fact, the accumulation of hazardous materials and redeposit of pollutants in areas of intense waste-picking activities represent significant ecological stressors (Ferronato and Torretta, 2019). At the same time, shared space use between humans, domesticated animals, and wildlife increases zoonotic disease risk, thus making dumpsites key socio-ecological interfaces (Hassell *et al.,* 2017; Gbogbo *et al.,* 2021).

Most importantly, however, these ecological and health risks are not caused by waste picking per se, but are instead related to the broader governance context in which it is conducted. In fact, the lack of protective infrastructure and environmental controls increases negative outcomes, thus implying that ecological and health risks are emergent properties of unmanaged systems and processes, as opposed to being direct consequences of informal recycling activities.

4.5 Sustainability Outcomes and Governance Sensitivity

The results show that waste picking plays an important role in supporting sustainability outcomes in cities, particularly through recycling efficiency and landfill diversion (Wilson *et al.,* 2012; Gutberlet *et al.,* 2017). However, these positive contributions are also associated with considerable social and ecological vulnerabilities. In fact, formalisation efforts, which are often intended to improve efficiency, have also been shown to be highly disruptive when they do not take into account pre-existing social-ecological systems (Dias, 2016; Velis *et al.,* 2016). This review of the literature thus suggests that waste-driven urban ecosystems are policy-sensitive and that changes in waste governance can have significant and rapid cascading effects on material flows, species composition, and human livelihoods, sometimes even moving environmental problems rather than solving them. Sustainability transitions thus need to be guided by effective governance that considers waste pickers as part of coupled social-ecological systems, rather than as externalities that need to be excluded.

4.6 Evidence Gaps and Implications for Urban Ecology Research

The synthesis points to some important gaps in the literature. Ecological studies on waste picking are unevenly represented across the globe, with few studies coming from Sub-Saharan Africa despite the prevalence of informal systems of waste management in the region. In terms of research methods, there is a strong bias toward short-term studies, with few employing longitudinal designs capable of capturing ecosystem changes.

Of particular note is the scarcity of integrative studies that link governance systems, livelihood systems, and ecological systems. These gaps need to be addressed if urban ecology is to move beyond descriptive studies into more predictive studies.

4.7 Implications for Policy and Sustainable Urban Planning

Collectively, the results indicate that waste picking should be included in ecosystem-based approaches to urban planning and waste management. Urban planning and management approaches that marginalise and/or exclude waste pickers without acknowledging their role in the ecosystem may compromise both ecosystem and social sustainability. Conversely, approaches that include waste pickers in managed ecosystems while maintaining ecosystem functioning hold promise for building pathways to novel ecosystem sustainability.

Conclusions

This review shows that waste picking acts as an active ecological process in urban environments, influencing material flows, habitat structure, and the relationships among different species. The findings indicate that waste picking helps reduce waste and improve recycling while also changing ecological dynamics through ongoing disturbance and selective resource use. These insights enhance urban ecological theory by emphasizing informal human activities as key factors in how ecosystems work, rather than seeing them as secondary or just socio-economic issues. The review also highlights key trade-offs in ecology and sustainability. Waste picking is linked to the spread of contaminants, the simplification of habitats, and

increased interactions between humans and wildlife. These effects are significantly influenced by governance arrangements and how much environmental control there is. Overall, the evidence points to the need for urban waste policies that blend ecological concerns with social inclusion, recognizing waste pickers as important participants in connected social-ecological systems. It is crucial to incorporate this perspective into urban planning and waste management to create resilient, fair, and sustainable urban ecosystems.

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Data Availability Statement

All data supporting the findings of this study are derived from previously published articles and publicly accessible sources. The bibliographic details of all included studies are provided in the reference list. No new primary datasets were generated or analysed during the current study.

The dataset used for the systematic review (including the list of screened and included articles) can be made available from the corresponding author upon request.

Conflict of Interest Statement

The author declares that there are no conflicts of interest regarding the publication of this paper.

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