

**Waste Management and Pollution Reduction Strategies for Wildlife
Protection in Natural and Urban Ecosystems**

Research Proposal

University of Wales Trinity Saint David

Module Code: ACFA7004 | Research Methods and Professional Developments

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1. Introduction

The environmental consequences of mismanaged waste now extend well beyond public health concerns. In many landscapes, discarded materials have migrated out of formal disposal systems into drains, riparian corridors, wetlands, road margins and peri-urban habitats, where they interact directly with ecological processes and wildlife populations. This shift from a sanitation problem to an ecological one has been confirmed by a growing body of evidence linking waste accumulation to species injury, habitat degradation and long-term bioaccumulation of persistent pollutants (MacLeod *et al.*, 2021; United Nations Environment Programme and International Solid Waste Association, 2024)

The global scale of the challenge gives it considerable policy significance. (United Nations Environment Programme and International Solid Waste Association, 2024) estimates that municipal solid waste generation could rise from approximately 2.1 billion tonnes in 2023 to 3.8 billion tonnes by 2050, with the sharpest growth in regions where infrastructure and regulatory capacity have not kept pace with rising consumption (Figure 1). Even modest leakage rates from these expanding systems translate into substantial environmental loading, particularly where persistent materials such as plastics are concerned. (OECD, 2022) showed that of the 353 million tonnes of plastic waste generated globally in 2019, an estimated 22 million tonnes leaked into the environment in that year alone, adding to legacy stocks of approximately 109 million tonnes accumulated in rivers and 30 million tonnes in the ocean. The estimated annual cost of poor waste management is projected to reach USD 640.3 billion by 2050 (Figure 2), underscoring the combined environmental and economic magnitude of the problem (United Nations Environment Programme and International Solid Waste Association, 2024).

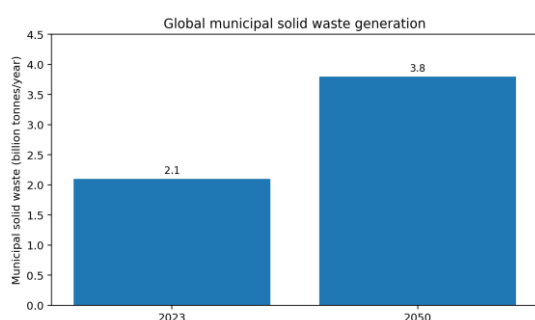


Figure 1. Global municipal solid waste generation (2023 and 2050). Source: UNEP (2024).

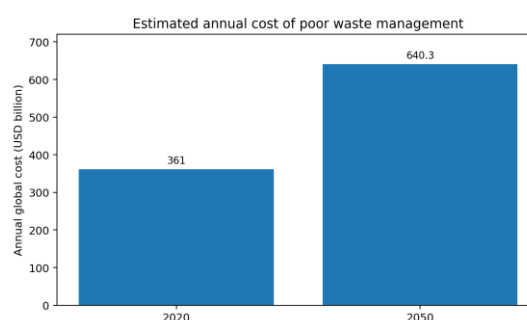


Figure 2. Estimated annual cost of poor waste management (2020 and 2050). Source: UNEP (2024).

Despite growing recognition of the problem, waste management policy has historically prioritised operational metrics rather than ecological outcomes. Strategies are typically evaluated by tonnage collected, recycling rates and landfill diversion rather than by measurable reductions in wildlife exposure or improvements in habitat condition. Geyer et al. (2017) demonstrated that of all plastics ever produced, only approximately 9% had been recycled and 12% incinerated, with the remaining 79% accumulating in landfills or the natural environment. The scale of this shortfall, combined with the persistence of plastics once they enter ecosystems, creates both immediate and long-term wildlife risks that conventional management metrics are poorly equipped to capture. Table 1 summarises the key global statistics that frame this research.

The central argument of this proposal is that effective wildlife-protective waste strategy cannot rely on downstream cleanup alone. The strongest ecological outcomes emerge from integrated approaches spanning the full causal chain: reducing material generation upstream, ensuring reliable collection and containment at the municipal level, intercepting high-risk materials at leakage hotspots, and designing cleanup operations in ways that are sensitive to biodiversity. Governance quality, accountability and public participation are not secondary considerations; they are structural conditions for success.

This proposal addresses three research questions. First, which wildlife exposure pathways are most consequential across terrestrial, freshwater and urban systems, and what waste types are principally responsible for generating them? Second, which waste management and pollution reduction strategies show the strongest evidence of reducing wildlife exposure, and under what conditions do they succeed or fail? Third, what governance and implementation factors explain variation in ecological outcomes across comparable policy contexts? These questions are addressed through a structured critical literature review employing a combined DPSIR, waste hierarchy and wildlife exposure analytical framework.

The study is bounded to terrestrial, freshwater and near-coastal urban systems, drawing on published evidence from both global north and global south contexts to allow comparative evaluation. The temporal scope prioritises work published after 2019, though methodologically significant earlier contributions are included where appropriate.

Table 1. Selected global waste and plastics statistics

Indicator	Value	Wildlife Relevance	Source
Municipal solid waste generation	2.1 billion tonnes in 2023; 3.8 billion by 2050	Rising material volume increases leakage risk into habitats if systems do not improve	UNEP (2024)
Annual cost of poor waste management	USD 361 billion in 2020; USD 640.3 billion by 2050	Confirms that ecological damage is economically significant, not a peripheral concern	UNEP (2024)
Global plastic waste generated	353 million tonnes in 2019	Indicates the scale of persistent material available for leakage and fragmentation	OECD (2022)
Plastic waste fate	9% recycled; 19% incinerated; approx. 50% landfilled; 22% uncontrolled or leaked	Shows why current material systems remain inadequate for biodiversity protection	OECD (2022)
Plastic leakage and legacy stocks	22 million tonnes leaked in 2019; 109 million tonnes in rivers; 30 million tonnes in ocean	Wildlife faces both current emissions and long-lived legacy pollution	OECD (2022); Meijer et al. (2021)

2. Literature Review

2.1 The Global Plastics Problem and Its Ecological Dimensions

Plastics have become the defining material of the contemporary waste challenge because they combine persistence, mobility and high exposure potential. Jambeck et al. (2015) estimated that between 4.8 and 12.7 million metric tonnes of plastic entered the ocean from land in 2010 alone, with projections indicating that this figure would grow substantially under business-as-usual trajectories. OECD (2022) shows that the global plastics economy remains structurally linear, with recovery rates that are insufficient to interrupt leakage even when collection systems operate as designed. Geyer et al. (2017) provide complementary historical context by showing that the cumulative production of all plastics ever manufactured has overwhelmingly outpaced recycling and recovery capacity, leaving the natural environment as a de facto long-term repository. Figure 4 illustrates how only a small fraction of global plastic waste was recycled in 2019, while the majority was landfilled, incinerated or entered the environment through uncontrolled pathways.

Awino and Apitz (2024) review how circular economy frameworks and the waste hierarchy are applied internationally, finding that while conceptual alignment between these frameworks is strong, implementation remains fragmented across regional and national governance systems. MacLeod et al. (2021) characterise plastic pollution as a global threat that interacts with climate change and biodiversity loss in ways that amplify harm beyond what any single stressor would generate independently. UNEP (2024) draws a direct connection between municipal waste growth and biodiversity pressure, estimating that the total annual cost of poor waste management could reach USD 640 billion by 2050 under a business-as-usual scenario, representing a projection of compounding ecological debt rather than simply a service-delivery shortfall.

A distinction critical for conservation is that between visible macroplastic litter and diffuse microplastic pollution. Policies that successfully reduce visible litter may leave particle pollution largely unaddressed, because tyres, textiles and fragmenting packaging generate microplastics that enter runoff, soils and food webs through pathways that conventional municipal waste services cannot easily intercept (OECD, 2022; Siña *et al.*, 2025). This distinction matters because it determines the range of policy tools required and the indicators used to measure success.

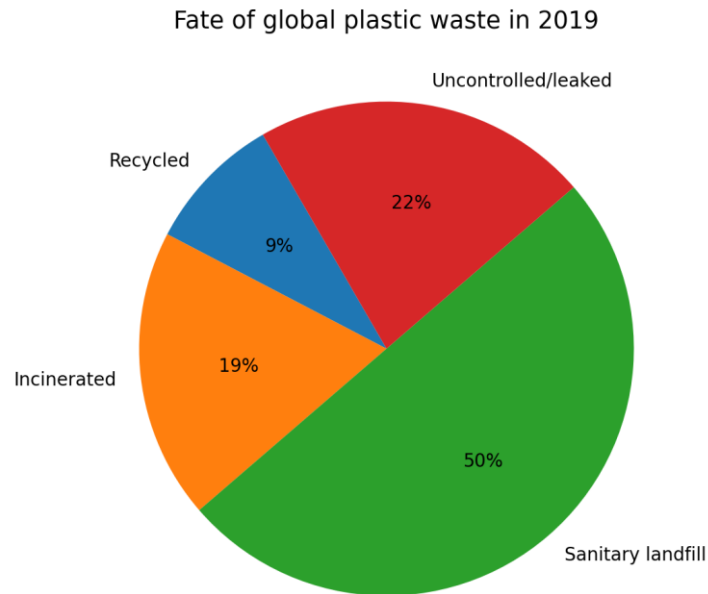


Figure 4. Fate of global plastic waste in 2019. Approximately 22% was uncontrolled or leaked into the environment (OECD, 2022)

2.2 Wildlife Exposure Pathways

The literature identifies four principal pathways through which waste causes wildlife harm. Understanding these pathways is important because each requires a different type of management response, and strategies that address one pathway effectively may leave others unresolved (Table 2).

The first pathway is direct physical injury through ingestion. Research by Jams et al. (2020) demonstrates that the size distribution of plastic particles likely to be ingested can be estimated systematically across animal groups, enabling more precise ecological risk assessment. This has practical value: if managers know which waste fractions most closely resemble food items for target species in a given habitat, source-control and cleanup priorities can be allocated more efficiently. Rochman et al. (2016) reviewed evidence across multiple taxa showing that ingestion of debris causes physical harm, obstruction and chemical exposure, with effects ranging from reduced feeding efficiency to reproductive impairment.

The second pathway is entanglement and entrapment. Flexible items including nets, strapping, rings and films can remain hazardous in wetlands and shorelines for extended periods, causing injury, restricting movement and reducing foraging success before any recovery operation takes place. Borrelle et al. (2020) confirm that entanglement remains a leading cause of injury and death in a range of taxa, while Issifu and Sumaila (2020) show that certain animal groups

face particularly elevated exposure, with turtles, eared seals and polar bears showing the highest entanglement proportions among reviewed species (Figure 5). Their analysis underlines that cleanup interventions alone are unlikely to keep pace with material leakage under current production and consumption trends.

The third pathway is chemical exposure through additives, leachates and combustion residues. Sigmund et al. (2023) provide a comprehensive analysis of how chemical pollution interacts with biodiversity research, arguing that the mixture complexity of leachate and contaminated runoff creates assessment challenges that conventional single-substance toxicology cannot fully address. Bean et al. (2024) extend this argument by noting that wildlife toxicological methods must account for sublethal effects on physiology, behaviour and reproduction, which standard mortality-based endpoints are likely to miss. Open burning of waste adds a further layer of risk by generating persistent organic pollutants that deposit across wide areas, often in landscapes lacking environmental monitoring capacity.

The fourth pathway is habitat alteration. Milner et al. (2025) provide direct evidence from urban waterways showing that anthropogenic litter alters macroinvertebrate assemblages, with littered reaches exhibiting lower diversity and a shift towards pollution-tolerant taxa relative to unlittered comparison sites. This demonstrates that even moderate litter accumulation, not only large-scale pollution events, can measurably degrade freshwater biodiversity. Agricultural landscapes face comparable pressures: Sheng et al. (2024) show that plastic pollution threatens pollinators and biocontrol agents by contaminating foraging substrates and disrupting plant-insect interactions, with implications for food security and ecosystem functioning. These field examples are illustrated in the photographs below (Photo 1; Photo 2).



Photo 1. Litter accumulation in a river channel illustrating uncontrolled leakage into freshwater habitat.

Photo 2. Weathered plastic fragments illustrating how macroplastics become diffuse and harder to manage over time.

Table 2. Main wildlife exposure pathways associated with waste and pollution

Pathway	Mechanism	Evidence Base	Wildlife Implication
Ingestion	Animals consume fragments or fibres that overlap with food size ranges	Jams et al. (2020); Rochman et al. (2016)	Reduces feeding efficiency, can block digestive tracts or transfer pollutants into food webs
Entanglement and entrapment	Flexible items such as straps, lines, films and containers trap or injure animals	Borrelle et al. (2020); Issifu and Sumaila (2020)	Causes injury, reduced mobility, drowning or death before cleanup occurs
Chemical exposure	Additives, leachates, combustion residues and sorbed pollutants enter soils, sediments and water	Sigmund et al. (2023); Bean et al. (2024)	Creates chronic ecological stress affecting physiology, behaviour and reproduction
Habitat alteration	Litter accumulation changes physical structure, water quality and substrate conditions	Milner et al. (2025); Sheng et al. (2024)	Can alter community composition and reduce habitat quality across freshwater and terrestrial systems
Diffuse microplastic exposure	Tyres, textiles and fragmentation release particles that move through runoff, soils and food webs	OECD (2022); Sina et al. (2025)	Increases persistent exposure even where visible litter appears limited

2.3 Evaluation of Management Strategies

The most fundamental finding in the intervention literature is that downstream cleanup alone cannot solve the wildlife harm problem. Borrelle et al. (2020) and Lau et al. (2020)

independently demonstrate that improvements in waste collection and cleanup are unlikely to keep pace with rising plastic generation unless upstream prevention also advances. This matters for conservation because harm often begins before cleanup teams arrive; an animal that has already ingested a fragment or become entangled in debris is not protected by a later cleanup operation.

Upstream prevention encompasses product redesign, reduction of unnecessary single-use materials, extended producer responsibility obligations and reuse systems. These approaches are strongest in principle but most institutionally demanding in practice, requiring regulatory capacity, market reform and sustained political commitment. Their principal conservation advantage is that they reduce the total volume of persistent material available for leakage, rather than managing the consequences after the fact.

Between upstream design and downstream handling, targeted product instruments offer an intermediate layer of intervention. Picuno et al. (2025) show that deposit return schemes for beverage containers can substantially reduce the prevalence of common leakage items when designed with sufficient deposit values, convenient return infrastructure and accessible collection networks. A main lesson from this literature is that policy tools cannot be judged by adoption alone; weak design or poor convenience may produce far less ecological benefit than headline policy announcements suggest. Extended producer responsibility works through a related logic, making producers more accountable for end-of-life management and creating incentives for redesign and recovery-system improvement.

Collection reliability and controlled disposal remain essential even under strong prevention frameworks because material already in circulation will require management for decades. The literature consistently shows that wildlife harm occurs most predictably at the edges of underperforming service systems, including overflowing bins, irregular collection schedules and disposal sites lacking leachate control. Wang et al. (2025), examining twenty-six community waste management experiments in Chinese cities, identify institutional learning, community participation and adaptive management as the most consistent factors distinguishing successful from failed programmes. Sasahara et al. (2024) develop a governance index for municipal solid waste in Global South contexts, finding that performance diverges sharply when governance quality falls below a critical threshold even where technical resources are comparable (Photo 3).

Targeting place is as important as targeting products. Meijer et al. (2021) show that more than 1,000 rivers account for 80% of global riverine plastic emissions into the ocean, which supports interventions at hydrological hotspots such as drains, stormwater outfalls and small rivers. These locations are practical intervention points because they intercept waste before it reaches larger wetlands, estuaries and coastal habitats. For freshwater ecosystems, Milner et al. (2025) caution that cleanup should be paired with habitat restoration in already-degraded systems, since indiscriminate removal can create short-term ecological trade-offs where natural physical complexity is stripped away without replacement.

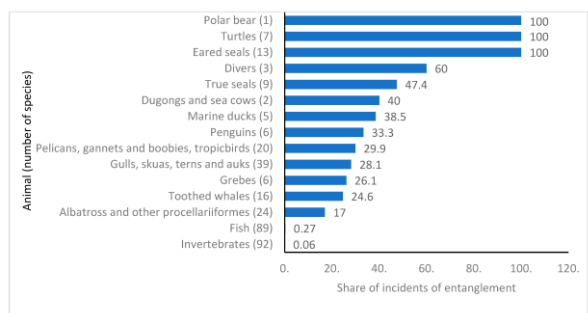


Figure 5. Reported marine plastic entanglement incidents by animal group (Issifu and Sumaila, 2020)



Photo 3. Community-based riverbank cleanup illustrating the social dimension of waste reduction and governance.

Table 3. Comparative evaluation of major strategy types for wildlife protection

Strategy Type	Where It Acts	Preventive Strength	Likely Wildlife Value	Main Limitation
Prevention and product redesign	At source, before waste is created	Very high	Very high: reduces the volume of material that can escape and fragment	Requires producer responsibility, regulation and market change
Segregation and reliable collection	Before leakage, during handling and transport	High	High: prevents routine escape from households, markets and streets	Fails where service continuity and public trust are weak

Strategy Type	Where It Acts	Preventive Strength	Likely Wildlife Value	Main Limitation
Controlled disposal and landfill upgrading	After collection, at final containment stage	Medium	High for preventing secondary leakage, leachate and facility-based pollution	Contains damage but does not reduce overall material throughput
Deposit return schemes and producer responsibility	Product and recovery system level	Medium to high	Medium to high, especially for common litter items such as bottles and caps	Performance depends heavily on scheme design and convenience (Picuno <i>et al.</i> , 2025)
Hydrological hotspot interception	At drains, streams, rivers and outlets	Medium	High in targeted locations with concentrated leakage (Meijer <i>et al.</i> , 2021)	Needs maintenance and cannot substitute for upstream reform
Cleanup linked to habitat restoration	After leakage has occurred	Low as prevention, but necessary for recovery	Medium to high where legacy pollution already harms habitat	May create short-term ecological trade-offs if restoration is absent (Milner <i>et al.</i> , 2025)

2.4 Literature Gap

Despite the growing evidence base, a systematic gap persists in the literature. The ecological effectiveness of waste management strategies has rarely been evaluated using wildlife-centred outcome measures. Most comparative studies rely on operational indicators, such as collection coverage and recycling rates, rather than on changes in wildlife exposure, habitat condition or species-level impacts. This limits the capacity of conservation practitioners to engage with waste policy reform using biodiversity evidence, and it makes it difficult to identify which combinations of interventions generate the best conservation outcomes per unit of investment. This proposal addresses that gap by constructing a systematic, evidence-based framework linking strategy type, implementation context and ecological outcome.

3. Methods

3.1 Research Design

This research adopts a structured critical literature review design. The approach is appropriate because primary field data collection would require multi-site ecological monitoring over extended timeframes that exceed the scope of this proposal. A rigorously conducted and critically evaluated literature review can nonetheless generate original insights by identifying evidence patterns, resolving apparent contradictions and producing transferable analytical frameworks (Awino and Apitz, 2024). This is consistent with methods used across environmental governance research, where synthesising existing knowledge constitutes an original scholarly contribution. The review follows a structured methodology adapted from systematic review principles, with search strategies, inclusion criteria, analytical categories and evidence-grading procedures defined in advance to reduce selection bias.

3.2 Source Selection and Search Strategy

The search strategy covers three source groups. The first is institutional reports from UNEP and OECD, which provide authoritative global baseline data on waste generation, plastics flows and leakage. The second is peer-reviewed ecological literature from journals including Environmental Pollution, Nature Communications, Science, Science Advances and Integrated Environmental Assessment and Management, searched through Web of Science, Scopus and Google Scholar using terms combining waste management, wildlife, pollution, biodiversity, plastic, exposure and governance. The third is governance and policy studies addressing municipal solid waste systems, circular economy instruments, extended producer responsibility and community-level programme evaluation.

Sources are selected on three grounds: whether they quantify waste generation or leakage, whether they provide direct evidence on wildlife exposure or ecosystem effects, and whether they evaluate a policy or governance instrument relevant to pollution reduction. Studies published before 2019 are included where they represent seminal methodological contributions, such as Jambeck et al. (2015) on plastic inputs to the ocean and Geyer et al. (2017) on global plastics production fate. Sources from low- and middle-income country contexts are actively sought to counteract the publication bias that disproportionately represents high-income country experiences in peer-reviewed environmental literature.

3.3 Analytical Framework

The analytical framework integrates three perspectives, as illustrated in Figure 3. The first is the driver-pressure-state-impact-response (DPSIR) model, which establishes the logical chain from social and economic systems to ecological change and management responses, preventing waste management from being treated as an isolated service function. The second perspective is the waste hierarchy, which provides a normative framework for evaluating where in the causal chain each strategy type acts and how prevention, reuse, recycling, recovery and disposal compare in their conservation value. The third is a wildlife exposure lens, which categorises harm by pathway, specifically ingestion, entanglement, chemical exposure and habitat alteration, and enables evaluation of strategies by their capacity to interrupt specific exposure mechanisms.

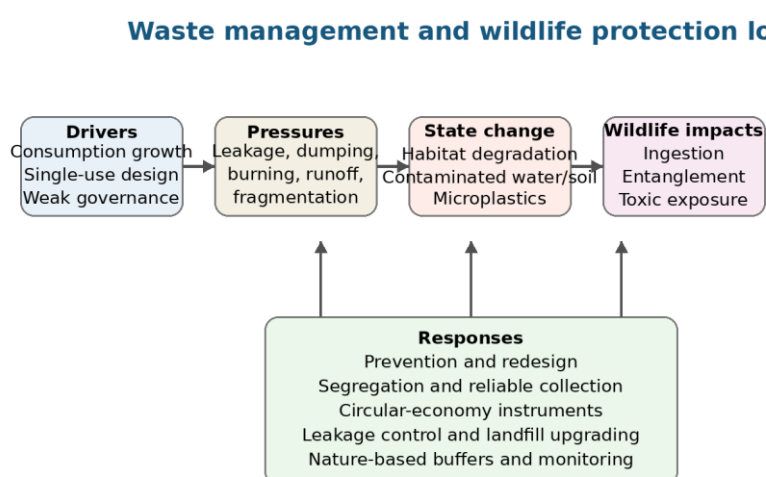


Figure 3. Waste management and wildlife protection logic linking drivers, pressures, ecological state change and management responses. Source: author synthesis.

Data extracted from each source are coded by strategy type (prevention, collection, interception, cleanup, governance), pathway addressed, ecosystem context (terrestrial, freshwater, marine or coastal), strength of evidence (experimental, observational, modelling or policy analysis) and documented implementation conditions. This structured coding approach allows systematic comparison of intervention types across contexts rather than a descriptive account of individual studies. The coding matrix will be developed iteratively during the screening phase and refined as synthesis progresses.

4. Expected Results

4.1 Evidence Matrix and Strategy Comparisons

The review is expected to produce three categories of output. The first is an evidence-graded matrix mapping strategy types against wildlife exposure pathways and ecosystem contexts. This matrix will identify which interventions have the strongest and most consistent evidence base, which are promising but under-tested, and which are commonly promoted but weakly supported by ecological outcome data. The matrix directly addresses the first two research questions and will form the empirical foundation for the practical recommendations arising from this proposal.

The second output is an analysis of implementation conditions that explain variation in ecological outcomes across comparable policy contexts. Based on preliminary engagement with the governance literature, it is anticipated that service reliability, accountability structures, community participation mechanisms and the integration of biodiversity monitoring into waste programme evaluation are consistent differentiators between effective and ineffective programmes. Wang et al. (2025) and Sasahara et al. (2024) already offer partial evidence for this interpretation, which the systematic review will test and extend across a wider range of geographical and institutional contexts.

4.2 Integrated Monitoring Framework

The third output is an integrated analytical framework structured around four questions for each strategy type: where in the causal chain does it act; which exposure pathways does it interrupt; what implementation conditions does it require; and what ecological indicators should be used to measure success. Table 4 presents the proposed indicator framework for monitoring waste management performance through a wildlife-centred lens. It is anticipated that the completed review will confirm that the most robust wildlife-protective strategies are not necessarily the most technically complex, but those implemented consistently within accountability structures that are capable of detecting and responding to ecological change.

Table 4. Proposed wildlife-centred indicators for monitoring waste management performance

Indicator Domain	Examples	Why It Matters
Exposure indicators	Litter density on riparian transects; storm-drain capture loads; counts of leakage-prone items at river outlets	Shows whether waste is still entering ecological pathways despite collection activity
Biological indicators	Entanglement records; faecal microplastic occurrence in sentinel species; macroinvertebrate community condition	Links management activity to organism-level outcomes rather than waste tonnage alone
Habitat indicators	Riparian vegetation cover; wetland condition; substrate quality following cleanup and restoration	Reveals whether ecological quality is recovering after pollution control
Governance indicators	Collection reliability; source-segregation participation rates; complaint resolution time; enforcement against illegal dumping	Measures the enabling conditions that determine whether technical strategies actually work in practice

A further anticipated finding is that conventional operational indicators, such as collection coverage and recycling rates, frequently decouple from ecological outcomes because they measure inputs and throughput rather than the interruption of exposure pathways. This decoupling is one of the reasons why waste policy reform often fails to deliver measurable biodiversity benefits even when it achieves stated operational targets. The results of this review will seek to demonstrate this gap empirically and to propose indicator combinations that more reliably track whether wildlife risk is actually declining.

5. Evaluation

5.1 Potential Impact and Contribution

This research contributes to the intersection of environmental conservation and waste management policy by establishing ecological effectiveness as the primary criterion for evaluating intervention strategies. Rather than accepting operational waste metrics as proxies for conservation outcomes, it argues that policy should be designed from the outset with wildlife exposure reduction as a measurable objective. This reframing has practical significance because it provides conservation organisations with a rigorous evidence base for engaging with municipal waste governance, and it offers policymakers a clearer basis for prioritising investments in waste management where biodiversity co-benefits are highest.

The research also contributes to the emerging literature on cross-ecosystem waste governance by integrating evidence from terrestrial, freshwater and peri-urban contexts that are frequently treated in isolation. The resulting framework will be relevant to a range of practitioners including environmental regulators, conservation organisations, municipal waste managers and researchers working at the interface of ecology and policy.

5.2 Limitations

Several limitations should be acknowledged. The literature review methodology cannot establish causal effectiveness with the certainty of controlled field experiments, and ecological monitoring data directly linked to specific policy interventions remain sparse in many regions, particularly across the global south. The scope is bounded to terrestrial, freshwater and peri-urban systems, meaning that deep-sea and oceanic pollution dynamics are not comprehensively addressed. Grey literature from national waste agencies may be underrepresented relative to peer-reviewed sources, reflecting publication processes rather than empirical gaps. These limitations will be addressed transparently in the final dissertation through explicit statements of evidence strength and scope boundaries. The indicative work plan for this research is provided in Appendix A.

6. Conclusion

Waste management and pollution reduction are now fundamental to wildlife protection, yet policy evaluation rarely reflects this priority. The literature reviewed here shows that harm occurs through multiple exposure pathways, that the most effective strategies act early in the causal chain, and that governance quality is as important as technical design in determining whether ecological outcomes are achieved. This proposal establishes a framework for evaluating strategies by their ecological outcomes rather than operational metrics, with the aim of improving the evidence base available to both conservation practitioners and policymakers. The research addresses a genuine gap in the existing literature and offers the prospect of more targeted, biodiversity-informed guidance on where and how waste management investments generate the greatest conservation returns.

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Appendix A. Indicative Work Plan

The work plan below remains indicative. It provides a realistic timetable for refining the topic, screening literature, completing the thematic synthesis and preparing the final submission within an approximately four-month period. Activities in the middle phase overlap to allow iterative refinement of coding categories as source screening progresses.

Table A1. Indicative work plan for the proposed study

Activity	Start	End	Days	Notes
Refine topic, aim and conceptual framework	01/04/2026	07/04/2026	7	Supervisor meeting
Database search and source screening	08/04/2026	21/04/2026	14	Web of Science, Scopus, Google Scholar
Source coding and comparative matrix	15/04/2026	27/04/2026	13	Overlaps with screening phase
Thematic synthesis and framework development	22/04/2026	08/05/2026	17	Core analytical phase
Draft proposal chapters	01/05/2026	16/05/2026	16	Overlaps with synthesis
Revise argument, formatting and references	17/05/2026	23/05/2026	7	Peer review recommended
Final review and submission preparation	24/05/2026	26/05/2026	3	Turnitin submission