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Microplastic Pollution in Sri Lankan Mangrove-Associated Ecosystems: Occurrence, Ecological Implications, and Research Gaps (2015–2025)

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***Abstract*— Mangrove-associated coastal wetlands are increasingly recognised internationally as sites of microplastic accumulation, yet the extent to which this has been documented for Sri Lanka has not been established. This review synthesises literature published between 2015 and 2025 on the occurrence, characteristics, distribution, methodologies, and ecological implications of microplastics in Sri Lankan mangrove-associated ecosystems, distinguishing mangrove-specific studies (sampling within a mangrove stand) from mangrove-associated studies (sampling in nearby lagoons, estuaries, or coastal habitats). Literature was identified through accessible search platforms, institutional repositories, and publicly available peer-reviewed publications; because subscription databases were not directly queried, the review is a structured literature review rather than a full systematic PRISMA review, and its coverage should not be read as exhaustive. Only three mangrove-specific studies were found, concentrated in Negombo Lagoon and five southern sites, while nine mangrove-associated studies document microplastics in nearby lagoons, water, sediment, and biota; four further coastal studies are retained only as national context. Fibers and fragments dominate reported particle shapes, and no Sri Lankan study has sampled biota within a mangrove stand or measured physical or chemical effects beyond ingestion. The most pressing gaps relate to geographical coverage, standardised reporting units, and field-based evidence of ecological effect. Overall, the evidence demonstrates documented contamination and, in lagoon biota, documented ingestion, but not demonstrated ecological damage within Sri Lankan mangroves; closing this gap requires standardised, geographically distributed sampling conducted directly within mangrove stands.**

***Keywords*—** microplastics; mangrove ecosystems; coastal wetlands; ecological implications; literature review

I. Introduction

Microplastics — plastic particles below 5 mm formed through fragmentation or manufactured directly at that size — are now documented across marine, freshwater, and terrestrial environments worldwide. Mangrove forests occupy the terrestrial–marine interface, and several physical characteristics make them susceptible to microplastic retention. Dense prop-root and pneumatophore systems slow tidal water flow and encourage fine-sediment deposition; tidal inundation delivers waterborne plastic debris on every flooding cycle while the root matrix damps the ebb flow that would otherwise carry particles back out to sea; and the resulting low-energy, frequently anoxic sediment environment functions as a long-term sink rather than a transport pathway. Internationally, this combination is well established: mangrove sediments have been shown to concentrate microplastics above adjacent non-vegetated habitats, and mangrove roots themselves can act as a physical trap for waterborne particles [18]. Whether, and to what extent, the same mechanisms operate within Sri Lankan mangrove ecosystems specifically — as distinct from the lagoons, estuaries, and coastal waters that border them — has not been systematically reviewed.

Sri Lanka retains an extensive mangrove-fringed coastline, estimated at 16,615 hectares in 2022 [21], and national attention to microplastic pollution rose markedly following the MV X-Press Pearl disaster of May 2021, which released large quantities of plastic nurdles and other debris into coastal and estuarine waters near Colombo [16]. A national review of Sri Lankan microplastic research covering 2018–2023

found a marked increase in publications from 2021 onward but, searching eleven peer-reviewed articles, located no study specifically targeting a mangrove ecosystem [17]. That review addressed Sri Lankan microplastic research broadly, across coastal habitat types in general; it did not focus on mangrove-associated ecosystems specifically, did not distinguish mangrove-specific from mangrove-associated evidence, and its search window closed in 2023. Whether subsequent research, and research published outside that window, has begun to close the mangrove-specific gap has not been established.

This review's contribution relative to existing Sri Lankan microplastic literature is threefold. First, to our knowledge it is the first review to focus specifically on mangrove-associated ecosystems rather than Sri Lankan coastal microplastic pollution in general. Second, it applies an explicit definitional distinction — between mangrove-specific studies, in which sampling was conducted directly within a mangrove stand, and mangrove-associated studies, in which sampling was conducted in an adjoining lagoon, estuary, or other coastal habitat — that prior syntheses of the Sri Lankan literature have not applied. Third, it extends coverage through 2025, capturing the post-2023 Negombo Lagoon research programme that falls outside the window of the most recent national review [17].

This review addresses three specific objectives: first, to synthesise what the literature published between 2015 and 2025 reports on the occurrence, characteristics, and distribution of microplastics in Sri Lankan mangrove-specific and mangrove-associated ecosystems; second, to evaluate the methodological approaches used in this literature, including sampling design, particle identification, and reporting practice; and third, to identify the principal evidence gaps and set out research priorities capable of closing them.

Correspondingly, the review is structured around three research questions: (i) what has been documented about microplastic occurrence and characteristics in Sri Lankan mangrove-specific ecosystems, as distinct from mangrove-associated lagoons and estuaries; (ii) how methodologically comparable is this evidence base across studies; and (iii) what does the literature currently support — and not support — regarding ecological impact?

II. Methodology

A. Search Strategy

Literature was identified through Google Scholar, together with institutional repositories and publicly available peer-reviewed publications. Search terms combined “microplastic” and “microplastic pollution” with “Sri Lanka”, “mangrove”, “mangrove-associated ecosystems”, and “ecological impact”, together with the names of specific Sri Lankan provinces and water bodies (e.g., Negombo, Puttalam, Batticaloa, Dondra). Searches were conducted during 2025.

Direct query access to subscription-based interfaces such as Scopus, Web of Science, and ScienceDirect was not available; consequently, this review is presented as a structured literature review rather than a full systematic PRISMA review, and its coverage should not be read as comprehensive across all indexed literature.

B. Screening and Eligibility

Approximately 60 candidate records were identified through the search strategy above and screened against the eligibility criteria set out below; 20 sources meeting these criteria are cited directly in this review. Screening was carried out by the corresponding author against the eligibility criteria in Section II-C, without a reference-management export or a formally logged duplicate-removal step; this count is reconstructed from the review's own search log rather than a database export, and is reported as an approximate rather than a precise PRISMA-style figure for that reason.

Consequently, this review does not claim the reproducibility of a full systematic review; the eligibility criteria below are reported in full so that the review can, in principle, be repeated.

C. Eligibility Criteria and Definitions

Inclusion criteria: primary research reporting original microplastic data from a Sri Lankan mangrove ecosystem, or from a mangrove-adjacent lagoon, estuary, or other directly relevant coastal water/sediment/biota matrix, published 2015–2025, in English. Exclusion criteria: studies addressing only macroplastic litter, beach debris without microplastic analysis, general waste management, or policy content without environmental microplastic evidence. International studies were retained only where they support a specific mechanism, methodological comparison, or ecological-impact interpretation, and are identified as international throughout.

Two further categories are distinguished consistently in the Results and Discussion. A study is classified as mangrove-specific where sampling of sediment, water, macrophytes, or biota was conducted directly within a mangrove stand. A study is classified as mangrove-associated where sampling was conducted in a lagoon, estuary, or other coastal habitat bordering or hydrologically connected to a mangrove system, without sampling occurring within the mangrove stand itself. A small number of retained Sri Lankan studies address open beach or coastal sites with no direct mangrove connection; these are reported separately as coastal-context studies and are not treated as mangrove-associated evidence in the Discussion, but are retained because they provide relevant national context (for example, the post-X-Press-Pearl baseline).

D. Data Extraction and Synthesis

For each retained study, author(s)/year, location, ecosystem classification (mangrove-specific, mangrove-associated, or coastal-context), environmental matrix, sampling period, sample size, particle size range, shape, colour, and polymer type (where reported), extraction and identification method — e.g., visual/morphological classification or Fourier-transform infrared (FTIR) spectroscopy — key finding,

and limitations were extracted; unreported fields are marked NR (not reported). Because studies report abundance in incompatible units, no pooled statistical test (ANOVA, regression, or correlation) was performed on cross-study abundance data; this is stated explicitly rather than substituted with an unjustified test.

III. Results

A. Literature and Research Trends

Approximately 60 candidate records were identified and screened; 20 sources meeting inclusion criteria are cited directly in this review, of which sixteen are Sri Lankan primary studies (dated 2018–2025), one is a national review, and three are international comparators used in a supporting role. Of the sixteen Sri Lankan primary studies, three are mangrove-specific (sampling conducted directly within a mangrove stand), nine are mangrove-associated (sampling in a lagoon or estuary bordering a mangrove system), and four are coastal-context studies retained for national context but not treated as mangrove-associated evidence in this review (Table 1). Sri Lankan records concentrate in 2023–2024, consistent with the broader post-X-Press-Pearl research increase [17]; no Sri Lankan mangrove-specific microplastic study was located for 2015–2017.

B. Occurrence and Characteristics

Microplastics have been confirmed in every Sri Lankan mangrove-associated matrix examined to date: mangrove sediment and water [1,2,3], lagoon water and sediment [4,9], macrophytes [5], and lagoon-caught shrimp, mud crab, and fish [6,7,8]. Of these, only refs. [1,2,3] report sampling conducted directly within a mangrove stand; the remainder are mangrove-associated. Where reported, fibers and fragments dominate particle shape (e.g., fibers 93% of shrimp-tissue microplastics [6]), and polyethylene (PE) and polypropylene (PP) recur as the dominant identified polymers [3,4]. Reported abundance ranges from 2.46 items/m³ in Negombo Lagoon water to 62.33 items/kg in its sediment [4]; comparable figures for other locations, together with available methodological detail, are summarised in Table 1.

Table 1. Summary of Sri Lankan mangrove-specific, mangrove-associated, and coastal-context microplastic studies (2015–2025). MP = microplastic(s); NR = not reported in the retrieved source.

Study	Ecosystem type	Location	Matrix	Sampling period / design	Particle size range	Extraction & ID method	Polymer(s)	Abundance (units)	Key finding	Limitations
Dilshani et al. [1]	Mangrove-specific	5 southern mangrove sites	Sediment, water	NR / 180-point sampling grid	NR	NR	NR	NR	MP present at all sites; no significant inter-site difference ($p>0.05$)	No apparent control for tidal state
Kanishka et al. [2]	Mangrove-specific	Negombo Lagoon (mangrove)	Sediment, water	NR	NR	NR	NR	NR	High tide > low tide MP levels	Partially verified record; single lagoon
Withanage Kanishka et al. [3]	Mangrove-specific	Negombo Lagoon (mangrove)	Leaf/root tissue	NR	NR	Density separation + FTIR	NR	NR	Tissue surface ≫ internal tissue MP	Bibliographic details partially verified
Athukorala et al. [4]	Mangrove-associated	Negombo Lagoon	Water, sediment	NR	NR	NR	PP dominant (PE also reported)	Water 2.46 items/m³; sediment 62.33 items/kg	PP dominant polymer	Single lagoon; units not standardised across studies
Rathnayake et al. [5]	Mangrove-associated	Negombo Lagoon	Macrophytes, sediment, water	NR	NR	Density separation + FTIR	NR	NR	First SL record of MP in macrophyte-associated matrices	NR
Lawan et al. [6]	Mangrove-associated	Negombo Lagoon	Shrimp (P. monodon)	NR	NR	Density separation + FTIR	NR	8.29 items/g	Fibers 93%; blue dominant colour	Single species; single lagoon
Dias et al. [7]	Mangrove-associated	Negombo Lagoon	Mud crab (S. serrata)	NR	NR	Density separation + FTIR	NR	NR	MP confirmed in gills/GI tract	NR
Athukorala et al. [8]	Mangrove-associated	Negombo Lagoon	Commercial fish	NR	677 fish examined	NR	Density separation + FTIR	NR	17% occurrence (118/677)	Species pooled; ingestion only
Jahan et al. [9]	Mangrove-associated	Batticaloa Lagoon	Sediment, water	NR / 12-station transect	NR	NR	NR	NR	MP confirmed near a municipal dumping site	Single sampling campaign implied
Bandara et al. [10]	Mangrove-associated	Dondra Lagoon	Fish, habitat	NR	NR	NR	NR	NR	Habitat/feeding-mode association reported	Venue partially verified
Bhathiya et al. [11]	Mangrove-associated	Puttalam Lagoon	Seagrass, sediment	NR	NR	NR	NR	Sediment 62.8 items/kg (vegetated)	86.7% of seagrass samples contained MP	NR

Gammanpila & Ranatunga [12]	Mangrove-associated	Coastal waters off Negombo	Seafood (trophic transfer)	NR	NR	NR	NR	NR	Trophic transfer reported	NR
Piyumali et al. [13]	Coastal-context	Western Province beaches	Beach sediment	Pre-disaster baseline	NR	NR	NR	NR	Fragments dominant (87.95%)	Not mangrove-associated; regional baseline only
Koongolla et al. [14]	Coastal-context	Southern coast	Beach sand, water	NR	NR	NR	NR	NR	60% of sand, 70% of water samples contained MP	Not mangrove-associated
Dharmadasa et al. [15]	Coastal-context	Southern Sri Lanka MPAs	NR	NR	NR	NR	NR	NR	NR	Not mangrove-associated; detail not extractable from retrieved source
Sewwandi et al. [16]	Coastal-context	Sarakkuwa beach	Buried sediment	Post-X-Press-Pearl	NR	NR	NR	NR	NR	Not mangrove-associated; post-disaster baseline only

C. Environmental and Geographical Distribution

Evidence is concentrated in the Western Province, almost entirely within Negombo Lagoon [2,3,4,5,6,7,8,12]. The Southern Province contributes the review's other mangrove-specific study [1], a mangrove-associated lagoon study [10], and two coastal-context studies retained only for national baseline purposes [14,15]. The Eastern Province is represented by a single mangrove-associated study in Batticaloa Lagoon [9], and the North Western Province by a single mangrove-associated study in Puttalam Lagoon [11]. No microplastic study specific to a mangrove-associated ecosystem was located for the Northern Province.



Fig. 1. Distribution of Sri Lankan mangrove-associated microplastic studies by province, as reported in this review (Section III-C).

D. Methodological Approaches

Sampling ranges from 180-point grids across five mangrove sites [1] to 12-station lagoon transects [9]. Identification methods progress from visual/morphological classification alone toward density separation combined with Fourier-transform infrared (FTIR) spectroscopy in the more recent Negombo series [3,5,6,7,8]. Methods are not standardised across studies: reporting units differ by matrix and study, particle-size thresholds are inconsistently stated, and polymer confirmation by FTIR or Raman spectroscopy is reported in only a minority of Sri Lankan records (Table 1).

E. Ecological Impacts

Sri Lankan evidence for ecological impact is currently limited to documented contamination and, in lagoon-caught biota, documented ingestion: microplastics have been recovered from the gut or tissue of lagoon-caught shrimp, mud crab, and commercial fish, with fish occurrence at 17% (118 of 677 individuals examined) [6,7,8]. No Sri Lankan study has examined biota collected from within a mangrove stand itself, nor measured physical or chemical effects beyond ingestion; consequently, the evidence base at present supports claims of contamination and ingestion, but not of demonstrated ecological damage. International research provides broader mechanistic context for potential ecological pathways: non-native mangrove roots in Hawai'i were found to concentrate microplastics far above surrounding sediment [18], and benthic fauna across Hainan mangrove wetlands showed microplastic contamination linked to feeding mode [20], suggesting food-web transfer pathways that remain untested — as opposed to demonstrated — in Sri Lankan mangroves specifically.

IV. Discussion

Read together, the Negombo Lagoon studies form the most developed body of evidence: microplastics are documented across water, sediment, macrophytes, and three biota groups, with one partially verified record indicating tidal variation and elevated microplastic levels on mangrove leaf and root surfaces relative to internal tissue [3]. This contrasts with the Southern Province's five-site dataset, which reports no significant inter-site difference [1] in a design that does not appear to control for tidal state. A plausible explanation is that tidal exchange, rather than geographical position alone, structures within-site microplastic distribution in mangrove sediments and on mangrove surfaces; if so, sampling that does not record tidal state at collection may understate real spatial variation — a discrepancy that future paired, tide-referenced sampling could resolve.

The Negombo series and the Southern Province dataset also differ methodologically in ways that complicate direct comparison. The former increasingly pairs density separation with FTIR polymer

confirmation [3,5,6,7,8], while earlier and non-Negombo studies rely more on visual or morphological classification alone (Table 1); visual classification alone is known internationally to both over- and under-count microplastics relative to spectroscopically confirmed counts, so apparent differences in abundance between locations may partly reflect method rather than true contamination differences. Reported particle-size thresholds are not stated consistently across studies, which further limits like-for-like comparison. Where polymer type is reported, polyethylene and polypropylene dominate [3,4], both low-density polymers consistent with fishing gear, packaging, and land-based plastic waste as plausible local sources, though no Sri Lankan study in this review has directly traced particles to source.

Sri Lankan evidence remains narrower than comparable international work. Malaysia's Kuala Gula mangrove study applied depth-profiled sediment cores with formal significance testing between stations [19], and Hainan's benthic-fauna survey linked microplastic burden to feeding ecology across multiple species [20] — a food-web analysis not yet attempted for any Sri Lankan mangrove system. The international finding that mangrove roots can concentrate microplastics far above surrounding sediment [18] has not been tested locally, despite its direct relevance to Sri Lanka's own mangrove conservation programmes. Extrapolating these international findings to Sri Lankan mangroves should nonetheless be done cautiously: species composition, tidal regime, sediment type, and proximity to plastic sources all differ between the Hawai'ian, Malaysian, and Hainan systems and Sri Lanka's own mangrove-associated ecosystems, and none of the mechanisms demonstrated abroad has yet been directly tested within a Sri Lankan mangrove stand.

Across this literature, four distinct evidentiary claims should be kept separate. Documented contamination — the presence of microplastics in sediment, water, or tissue — is well established for Sri Lankan mangrove-associated ecosystems [1–9]. Documented ingestion — microplastics recovered from the gut or tissue of an organism — is established for lagoon-caught shrimp, mud crab, and fish [6,7,8]. Potential ecological pathways — mechanisms by which contamination or ingestion could translate into harm, such as root-mediated concentration [18] or feeding-mode-linked burden [20] — are supported only by international, not Sri Lankan, evidence. Demonstrated ecological effects — measured physical, chemical, or population-level harm — have not been reported by any Sri Lankan study reviewed here. Conclusions about ecological risk to Sri Lankan mangrove ecosystems should therefore be read as resting on the first two categories only; this review does not find field-based evidence sufficient to support claims of demonstrated ecological damage.

Methodologically, the shift toward FTIR-supported identification in the most recent Negombo studies [3,5,6,7,8] is a genuine improvement over earlier visual-only classification, but inconsistent reporting units across the wider literature prevent direct quantitative comparison between locations, a limitation this review does not attempt to resolve by forcing an unjustified statistical pooling.

V. Research Gaps and Future Priorities

Table 2 summarises the strongest gaps identified from this mangrove-specific/mangrove-associated evidence base. Geographically, the Northern, Eastern, and North Western provinces remain almost entirely unstudied for mangrove-specific microplastics. In terms of environmental matrix, biota studies are limited to lagoon-caught organisms rather than fauna sampled within the mangrove stand itself, leaving the internationally documented root-concentration mechanism [18] untested locally. Methodologically, the absence of a standardised abundance unit and inconsistent polymer confirmation limit cross-study synthesis, and ecological-impact evidence remains restricted to ingestion records rather than measured physical, chemical, or food-web effects.

Table 2. Major research gaps and future priorities.

Gap	Evidence from literature	Recommended research
Geographical	No mangrove-specific MP study for Eastern, Northern, or North Western provinces [1–20]	Baseline surveys in under-studied mangrove provinces
Environmental matrix	No study samples fauna collected within the mangrove stand itself; only lagoon-caught biota studied [6–8]	In-forest biota sampling alongside sediment/water
Methodological	Incompatible units across studies (items/L, /m³, /kg, /g); mostly single-season sampling [1–13]	Standardised units; multi-season, multi-year designs
Ecological impact	Ingestion documented in lagoon biota [6–8]; no field evidence of physical or chemical harm within SL mangroves	Field-based impact and food-web transfer studies
Polymer identification	FTIR used inconsistently; only one Sri Lankan mangrove record reports it [3]	Routine FTIR/Raman as a reporting standard



Fig. 2. Relative evidence maturity across the five research-gap dimensions from Table 2. Axis levels are a qualitative synthesis from this review, not a quantified index.

A concise future-research sequence follows directly from these gaps: standardised sampling protocols, applied consistently across under-studied provinces and

conducted directly within mangrove stands rather than only in adjoining lagoons, feeding into microplastic extraction and polymer identification by FTIR or Raman spectroscopy, followed by spatial and seasonal monitoring, and finally field-based ecological assessment of mangrove-associated fauna, to support an evidence-based risk evaluation for Sri Lanka's mangrove ecosystems.

VI. Conclusion

This review distinguishes, for the first time in the Sri Lankan literature, between mangrove-specific studies — those sampling directly within a mangrove stand — and mangrove-associated studies of nearby lagoons, estuaries, and coastal waters. On that basis, microplastic contamination is confirmed across Sri Lankan mangrove-associated sediment, water, macrophytes, and biota, and ingestion is confirmed in lagoon-caught shrimp, mud crab, and fish; but direct evidence from within a mangrove ecosystem itself remains limited to three studies concentrated in two locations, and no Sri Lankan study has yet measured physical or chemical ecological effects beyond ingestion. The evidence available does not support a claim of demonstrated ecological damage to Sri Lankan mangrove ecosystems; it supports a narrower, still important claim of documented contamination and, in lagoon biota, documented ingestion.

This conclusion should be read alongside the review's own methodological limitations: literature was identified without direct access to major subscription databases, and the search and screening process, while conducted systematically, has not been documented here to full systematic-review reproducibility standards (see Methodology). The findings should therefore be treated as indicative of the current evidence base rather than as an exhaustive census of it.

The Negombo Lagoon research programme demonstrates that a methodologically sound, FTIR-supported evidence base is achievable within Sri Lanka. Building on it, the priorities in Table 2 — geographically distributed, mangrove-specific sampling; standardised reporting units; routine polymer confirmation; and field-based ecological-impact studies conducted within mangrove stands rather than in adjoining lagoons — follow directly from the gaps this review has identified, and represent the most direct route to establishing whether, and to what extent, the ecological pathways demonstrated internationally also operate in Sri Lanka's own mangrove ecosystems.

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