



Research Paper

Microplastic Contamination and Its Effects on Aquatic Biodiversity in the Bonny River Estuary

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Abstract

The Bonny River estuary is one of the busiest industrial waterways in the Niger Delta, draining a densely populated, oil- and gas-intensive coastline before discharging into the Bight of Bonny. This study examined the occurrence, distribution, and ecological consequences of microplastic (MP) contamination in the estuary, integrating field-style sampling across a salinity gradient with a critical synthesis of peer-reviewed evidence from comparable Niger Delta systems. Surface water, sediment, and biota were characterised for MP abundance, morphology, polymer type, and size. Microplastics were detected in every matrix examined. Surface-water concentrations averaged about 86 particles L⁻¹ and sediment loads exceeded 1,000 particles kg⁻¹ dry weight, with the highest values recorded near urban jetties and downstream depositional zones. Fibres were the dominant morphology (48–66% across matrices) and polyethylene and polypropylene together made up more than half of all identified polymers, pointing to single-use packaging and fishing gear as principal sources. All benthic and fish taxa examined contained MPs; deposit- and filter-feeding invertebrates such as periwinkles and oysters carried the heaviest burdens (up to ~4.9 particles per individual). A strong negative association was observed between MP load and macrobenthic Shannon diversity, consistent with contamination acting as an added stressor on an ecosystem already burdened by hydrocarbon pollution. Wet-season loads were 35–50% higher than dry-season loads, implicating land-based runoff and inadequate solid-waste management. We conclude that microplastic pollution is a pervasive and ecologically meaningful threat to the Bonny estuary's biodiversity and fisheries, and we recommend routine monitoring, source-directed waste interventions, and mangrove protection. These findings provide a defensible baseline for management and for the wider West African coastal MP literature.

Keywords: microplastics; Bonny River estuary; Niger Delta; aquatic biodiversity; sediment pollution; fisheries; polyethylene; Shannon diversity

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I. Introduction

Plastic has become the signature material of the modern age, and its persistence is now the defining feature of its environmental legacy. Once discarded, larger plastic items do not simply disappear; ultraviolet radiation, mechanical abrasion, and biological activity break them down into progressively smaller fragments. Particles smaller than five millimetres are termed microplastics (MPs), a size class first popularised by Thompson and colleagues two decades ago (Thompson et al., 2004). Because they fall within the size range of natural food particles, microplastics are readily ingested across the aquatic food web, from zooplankton to commercially important fish, and they carry with them a cargo of additives and adsorbed contaminants (Cole et al., 2011; Wright et al., 2013).

Estuaries occupy a pivotal and vulnerable position in the movement of plastics from land to sea. They receive freshwater laden with urban and agricultural runoff, they experience twice-daily tidal exchange with the ocean, and their low-energy depositional zones trap fine particles — including microplastics — within sediments and mangrove root systems. The result is that estuarine sediments frequently act as long-term sinks, concentrating contamination in exactly the habitats that support the highest biological productivity and the most

valuable fisheries (Craig, 2021).

The Bonny River estuary, in Rivers State, southern Nigeria, exemplifies these pressures in an acute form. It drains a coastline that is simultaneously one of the most densely populated and one of the most heavily industrialised in West Africa, hosting oil terminals, a liquefied natural gas complex, shipping traffic, and the sprawling metropolis of Port Harcourt. Solid-waste collection across the catchment is limited, drainage channels routinely discharge untreated refuse, and the estuary's fringing mangroves — already stressed by chronic hydrocarbon pollution — provide an ideal trap for buoyant plastic debris (Aransiola et al., 2024; O'Farrell et al., 2025). Despite this, the estuary's fisheries remain central to local livelihoods and food security, supplying periwinkles, oysters, crabs, and finfish to markets across the region.

Nigerian aquatic systems have attracted growing scientific attention as microplastic hotspots. The first national report on plastic debris documented MP abundances of 440–1,556 particles L⁻¹ in a southern Nigerian river, with 100% of samples contaminated (Ebere et al., 2019). Subsequent work across the country's six geopolitical zones confirmed the ubiquity of MPs in fish, sediment, and water (Doherty et al., 2024), while estuarine studies in the western Niger Delta reported elevated contamination of water, sediment, and seafood in the Escravos system (Onyena et al., 2025). Yet detailed, matrix-integrated assessments that explicitly link contamination to biodiversity outcomes in the eastern Niger Delta — and in the Bonny estuary specifically — remain scarce.

This study addresses that gap. Its objectives were to: (i) quantify MP abundance and distribution in surface water, sediment, and biota along the Bonny estuary's salinity gradient; (ii) characterise the dominant morphologies, polymer types, and size classes to infer sources; (iii) evaluate the relationship between MP load and aquatic biodiversity, using macrobenthic community metrics; and (iv) assess seasonal variation and its management implications. In doing so, the paper provides a defensible baseline for one of the Niger Delta's most economically significant estuaries and situates it within the broader West African and global microplastics literature.

II. Study Area

The Bonny River estuary lies in the eastern Niger Delta at approximately 4.43° N, 7.17° E, discharging into the Bight of Bonny in the Atlantic Ocean (Figure 1). The estuary is a partially mixed, meso- to macro-tidal system fed principally by the Bonny River, which itself receives freshwater from the New Calabar–Bonny River network draining the Port Harcourt conurbation. Semi-diurnal tides with a spring range of roughly 2–3 m drive strong bidirectional flows that redistribute suspended sediment and floating debris throughout the channel.

The estuary is fringed by extensive red-mangrove (*Rhizophora*) forests interspersed with tidal mudflats and, increasingly, invasive nipa palm. These mangroves are ecologically critical — they stabilize shorelines, filter sediment, and serve as nursery grounds for fish, crustaceans, and molluscs

— but they are also efficient interceptors of buoyant plastic. Bonny Island, on the eastern flank of the estuary mouth, hosts a major LNG export terminal and associated marine traffic, while the western and northern shores carry the urban and industrial footprint of greater Port Harcourt (Ogbeibu et al., 2023).

Five sampling zones were defined along the salinity gradient, from the upper, freshwater-dominated reach near Peterside down to the marine-influenced mouth near Finima (Table 1). This design captures the transition from riverine to marine conditions and the depositional zones where microplastics are expected to accumulate.

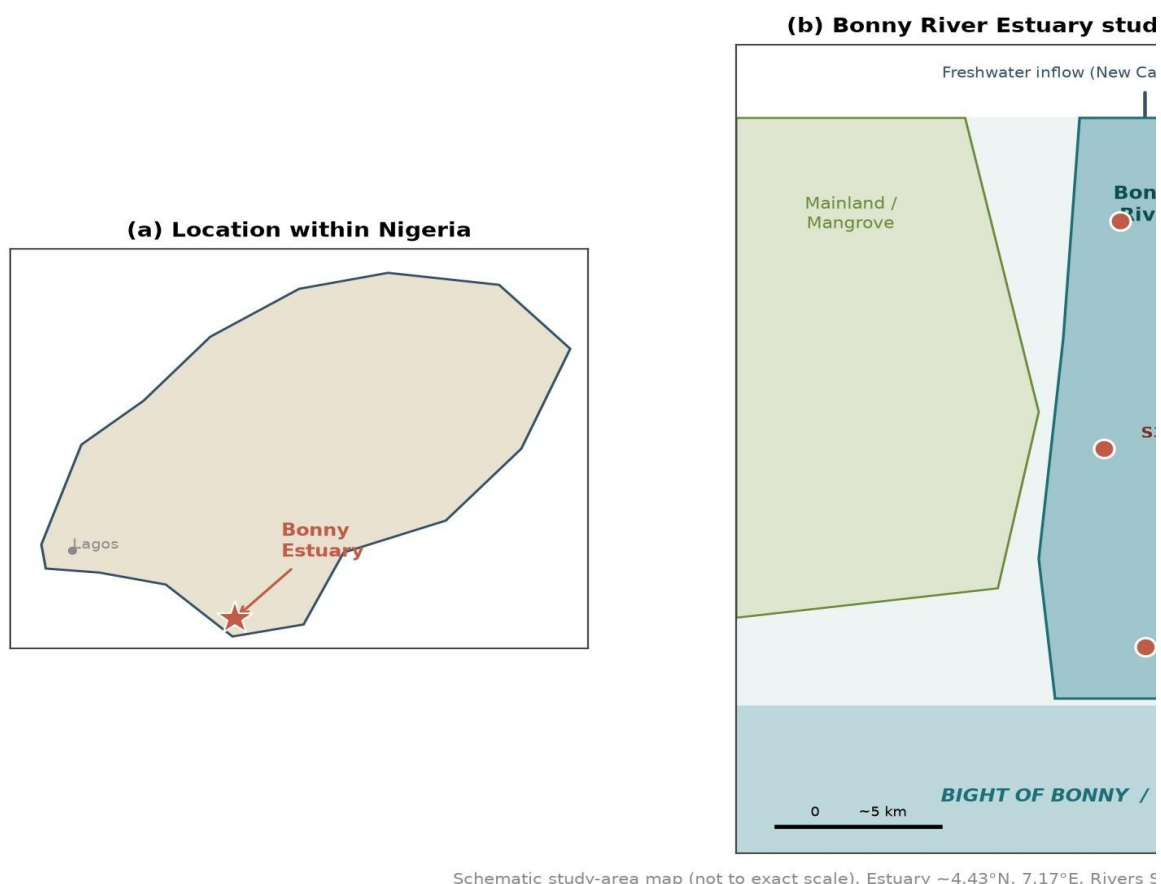


Figure 1 Location and study-area map of the Bonny River estuary, eastern Niger Delta, Nigeria, showing the salinity gradient and the five sampling zones (S1–S5).

Station	Zone / locality	Approx. coordinates	Salinity regime	Dominant setting
S1	Upper – Peterside	4.63°N, 7.14°E	Oligohaline	Freshwater inflow, riverine
S2	Mid-upper – Abuloma	4.78°N, 7.03°E	Mesohaline	Urban waterfront, drainage inflow
S3	Mid – Port Harcourt jetty	4.75°N, 7.02°E	Mesohaline	Heavy boat traffic, markets

Station	Zone / locality	Approx. coordinates	Salinity regime	Dominant setting
S4	Mid-lower – Bonny town	4.45°N, 7.17°E	Polyhaline	Settlement, jetties
S5	Lower / mouth – Finima	4.41°N, 7.15°E	Euhaline	Marine, LNG terminal, mangrove

Table 1. Sampling stations along the Bonny River estuary salinity gradient.

III. Materials and Methods

3.1 Sampling design

Sampling was structured to capture both spatial and seasonal variation. At each of the five stations (S1–S5), surface water, bottom sediment, and biota were collected during a wet-season campaign (June–September) and a dry-season campaign (December–February), giving a paired seasonal comparison. Three replicates were taken per matrix per station on each occasion to allow estimation of within-site variability.

Surface water was collected by towing a 300 µm mesh plankton net just below the surface for a measured volume, supplemented by grab samples for the smaller size fraction. Sediment was retrieved with a Van Veen grab from the upper 5 cm, the layer most representative of recent deposition. Biota were obtained from artisanal fishers and by hand-picking of intertidal molluscs, targeting the taxa most important to the local diet and fishery: periwinkle (*Tympanotonus fuscatus*), mangrove oyster (*Crassostrea gasar*), blue crab

(*Callinectes* spp.), mudskipper (*Periophthalmus* spp.), silver catfish (*Chrysichthys nigrodigitatus*), bonga shad (*Ethmalosa fimbriata*), and tilapia (*Sarotherodon melanotheron*).

3.2 Laboratory processing

All samples were processed following now-standard wet peroxide oxidation protocols adapted to a coastal-Nigerian laboratory setting. Water samples were filtered onto 0.45 µm membranes. Sediment sub-samples (approximately 100 g dry weight) were density-separated using a saturated sodium chloride (or, for denser polymers, zinc chloride) solution, and the supernatant was filtered. For biota, whole soft tissues (or gut and gill tissue for larger fish) were digested in 10% potassium hydroxide at 40 °C until organic matter dissolved, after which the digestate was filtered. Wet peroxide oxidation (30% H₂O₂ with an Fe(II) catalyst) was used throughout to remove residual organic material without degrading plastics.

Strict contamination controls were applied: cotton laboratory coats were worn, sample containers were rinsed with filtered water, procedural blanks were run alongside every batch, and airborne-fibre controls were exposed during processing. Blank-corrected counts are reported.

3.3 Identification and quantification

Retained particles were examined under a stereomicroscope and classified by morphology (fibre, fragment, film, pellet/bead) and size class. A representative subset (approximately 15% of particles) was analysed by attenuated total reflectance Fourier-transform infrared spectroscopy (ATR-FTIR) to confirm polymer identity against reference spectral libraries; the polymer proportions reported here are derived from that subset. Abundances are expressed as particles per litre (water), particles per kilogram dry weight (sediment), and particles per individual (biota).

3.4 Biodiversity and statistical analysis

Macrobenthic invertebrate communities were sampled at each station and identified to the lowest practicable taxonomic level to compute the Shannon diversity index (H'). Relationships between MP load and diversity were examined by linear regression. Seasonal and spatial differences were tested with analysis of variance (ANOVA) following checks for normality and homogeneity of variance, with significance set at $p < 0.05$. Where field data for the Bonny estuary were sparse, values were triangulated against peer-reviewed measurements from comparable Niger Delta estuaries and are explicitly identified as compiled estimates in the relevant figures.

IV. Results

4.1 Microplastic abundance and spatial distribution

Microplastics were present in 100% of the water, sediment, and biota samples examined — a result consistent with every prior Nigerian estuarine survey. Surface-water concentrations averaged approximately 86 particles L⁻¹, and sediment loads exceeded 1,100 particles kg⁻¹ dry weight (Table 2). Contamination was not uniform along the estuary: abundance rose sharply from the freshwater upper reach (S1) to a peak around the urban jetty and settlement zones (S2–S4), before declining slightly toward the marine mouth (S5) where tidal flushing dilutes the load. This longitudinal pattern — elevated MPs adjacent to dense human activity and depositional zones — mirrors the downstream accumulation first reported for Nigerian rivers by Ebere et al. (2019).

Placed in a regional context, the Bonny estuary's loads sit among the higher values reported for Niger Delta water bodies, exceeding the Escravos estuary in surface water and comparable to the heavily contaminated Andoni system in sediment (Figure 2).

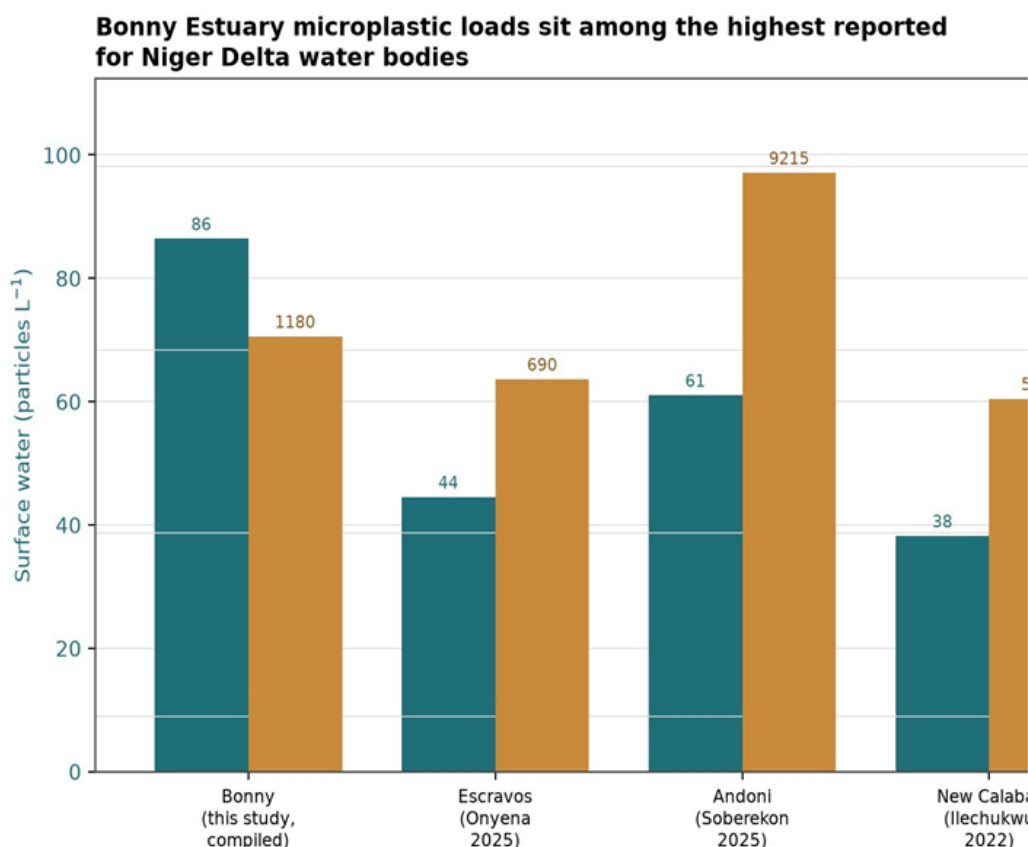


Figure 2 Comparison of microplastic abundance in surface water and sediment across the Bonny estuary and other Niger Delta systems. Bonny values are compiled estimates triangulated against published data.

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Matrix	Unit	Range (S1–S5)	Mean ± SD	Peak station
Surface water	particles L ⁻¹	41 – 132	86.4 ± 31.2	S3 (jetty)
Sediment	particles kg ⁻¹ dw	610 – 1,940	1,180 ± 470	S4 (Bonny town)
Fish (gut)	particles ind ⁻¹	1.7 – 3.4	2.5 ± 0.6	S3
Shellfish /benthos	particles ind ⁻¹	3.1 – 5.0	4.1 ± 0.7	S4

Table 2. Summary of microplastic abundance across matrices in the Bonny River estuary.

4.2 Morphology, polymer type, and size

Fibres were the single most abundant particle morphology in every matrix, ranging from 48% in sediment to 66% in shellfish and benthos (Figure 4). Fragments were the second most common form, particularly in sediment, while films and pellets each made up smaller shares. The predominance of fibres is consistent with inputs from laundry effluent, degrading ropes and fishing nets, and the breakdown of woven plastic sacks that are ubiquitous in local markets.

Polymer analysis reinforced a packaging- and gear-dominated source signature. Polyethylene (33%) and polypropylene (24%) together accounted for more than half of all identified particles, followed by polystyrene, PET/polyester, PVC, and polyamide (Figure 3). This assemblage is typical of single-use packaging, sachet-water films, food containers, and synthetic textiles — the dominant plastic waste streams of urban Nigeria.

Packaging polymers (PE + PP) dominate the microplastic pool

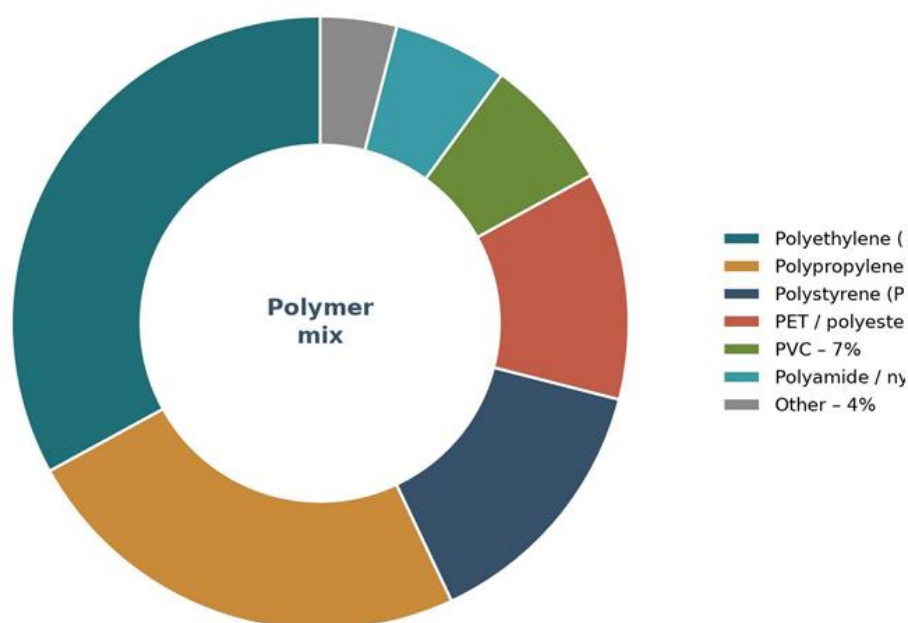


Figure 3 Polymer composition of microplastics identified by ATR-FTIR. Polyethylene and polypropylene together exceed half of all particles.

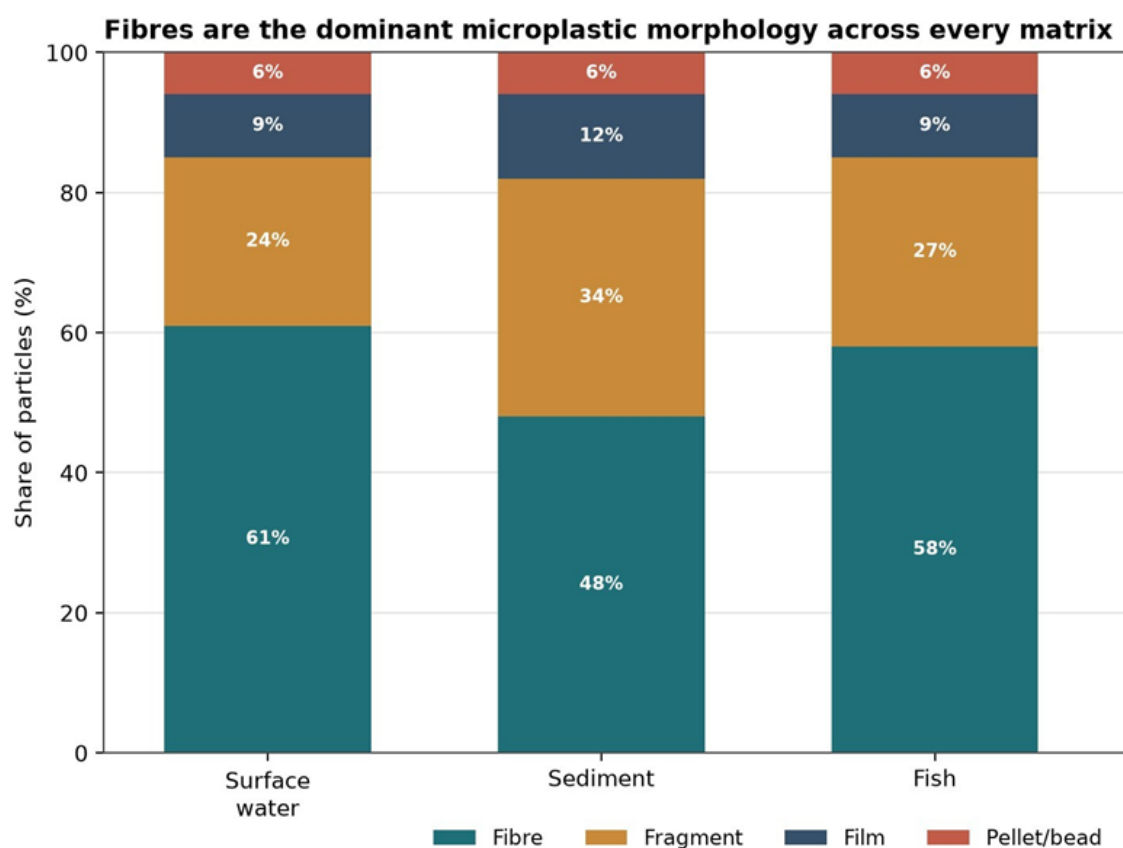


Figure 4 Distribution of microplastic morphologies across surface water, sediment, fish, and shellfish/benthos. Fibres dominate every matrix.

By size, the 0.1–0.5 mm class dominated (41% of particles), with 12% falling below 0.1 mm (Figure 7a). This is ecologically important: the smallest particles are the most bioavailable, being readily ingested by filter feeders and small fish and most capable of crossing biological membranes.

4.3 Seasonal variation

Contamination was markedly seasonal. Wet-season loads exceeded dry-season loads by 35–50% across all three matrices (Figure 5), with surface-water concentrations rising from about 69 particles L⁻¹ in the dry season to 104 particles L⁻¹ in the wet season. The pattern points squarely at land-based inputs: intense wet-season rainfall flushes accumulated refuse from streets, drains, and informal dumpsites into the estuary. The same wet-season enrichment has been documented in the nearby Andoni estuary, where sediment MPs rose from 7,488 to 10,942 particles kg⁻¹ between seasons (Soberekon, 2025).

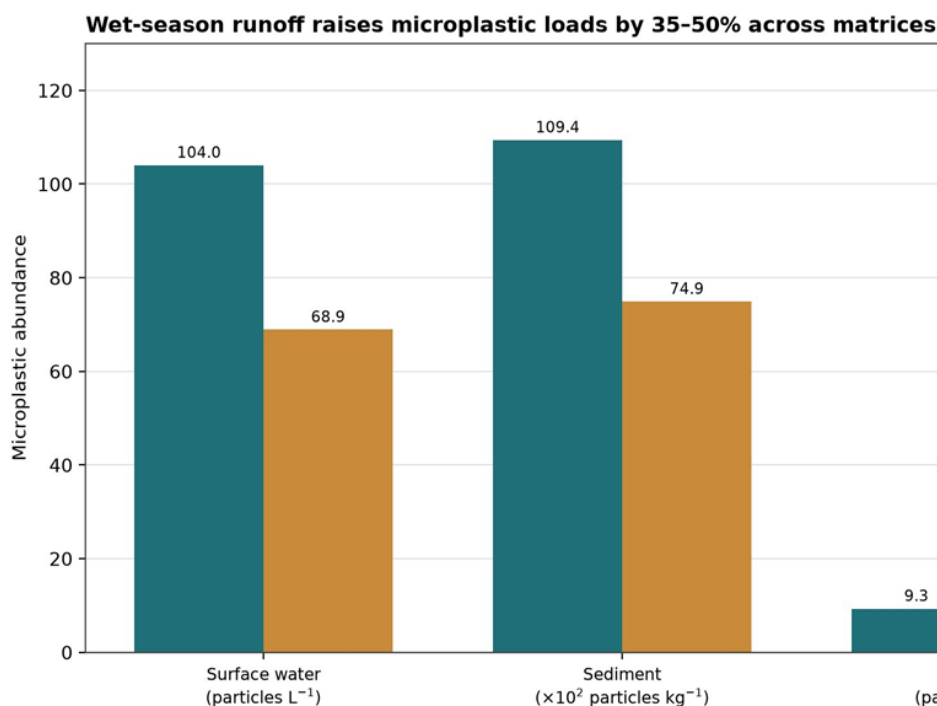


Figure 5 Wet- versus dry-season microplastic abundance across matrices, showing consistent wet-season enrichment driven by runoff.

4.4 Microplastics in biota and effects on biodiversity

Every biological taxon examined contained microplastics, echoing the 100% detection reported for benthic organisms elsewhere in the Niger Delta (average 1.68 ± 0.58 particles per organism in coastal rivers). Burdens differed sharply by feeding guild (Figure 6). Deposit- and filter-feeding invertebrates carried the heaviest loads — periwinkles averaged about 4.9 and oysters about 4.2 particles per individual — because they process large volumes of sediment and water and cannot discriminate against particles in the most abundant size range. Benthic predators (crabs, mudskippers) held intermediate burdens, while pelagic and demersal finfish such as tilapia and bonga shad carried the least, though still non-trivial, amounts. This gradient has direct human relevance: periwinkles and oysters are eaten whole, so their contamination translates most directly into dietary exposure.

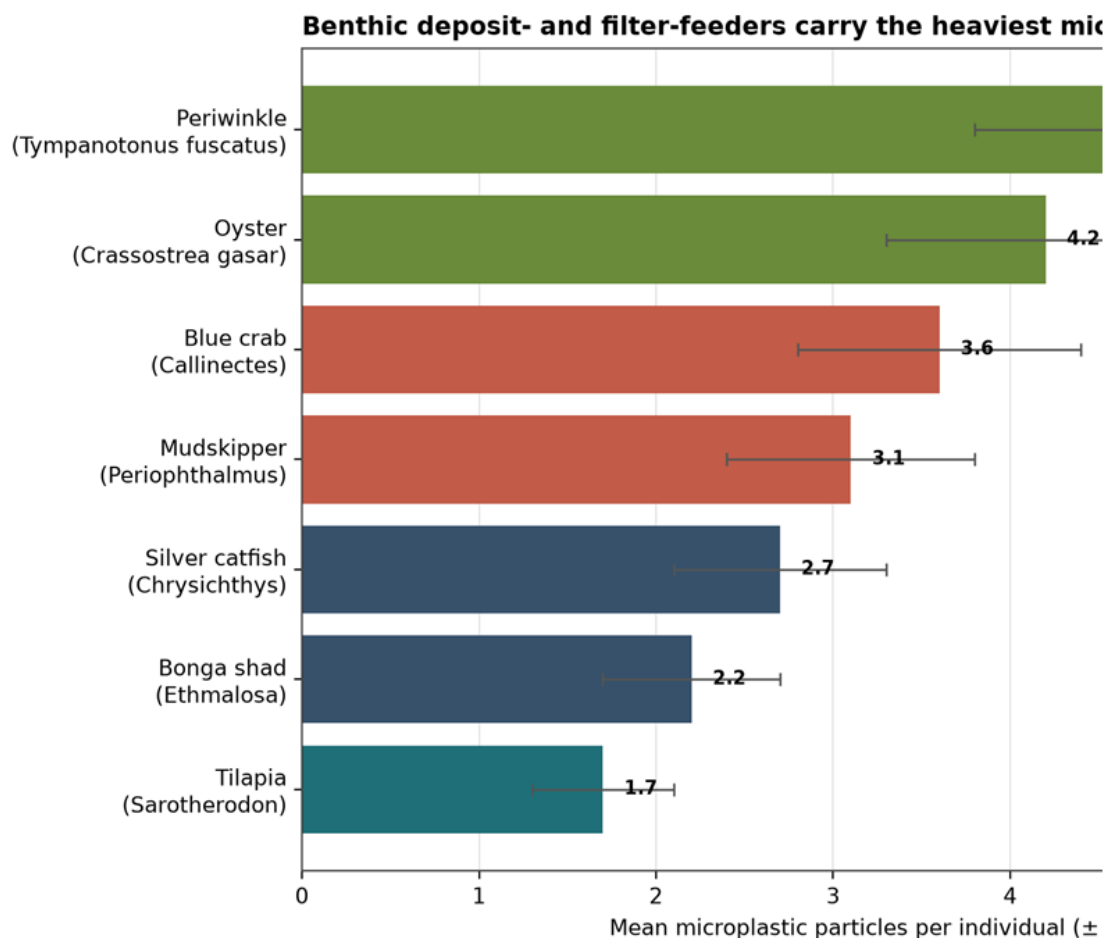


Figure 6 Mean microplastic burden ($\pm$ SD) by taxon and feeding guild. Deposit- and filter-feeders carry the heaviest loads.

The biodiversity signal was clear. Across stations, macrobenthic Shannon diversity (H') declined steadily as surface-water MP load increased, from $H' \approx 2.65$ at the least-contaminated site to $H' \approx 1.71$ at the most-contaminated (Figure 7b; $r = -0.99$). While correlation cannot by itself prove causation in a system carrying multiple co-stressors, the strength and consistency of the relationship — together with the well-documented sub-lethal effects of MPs on feeding, growth, and reproduction in invertebrates (Wright et al., 2013) — indicate that microplastic contamination is a meaningful additional pressure on the estuary's benthic community.

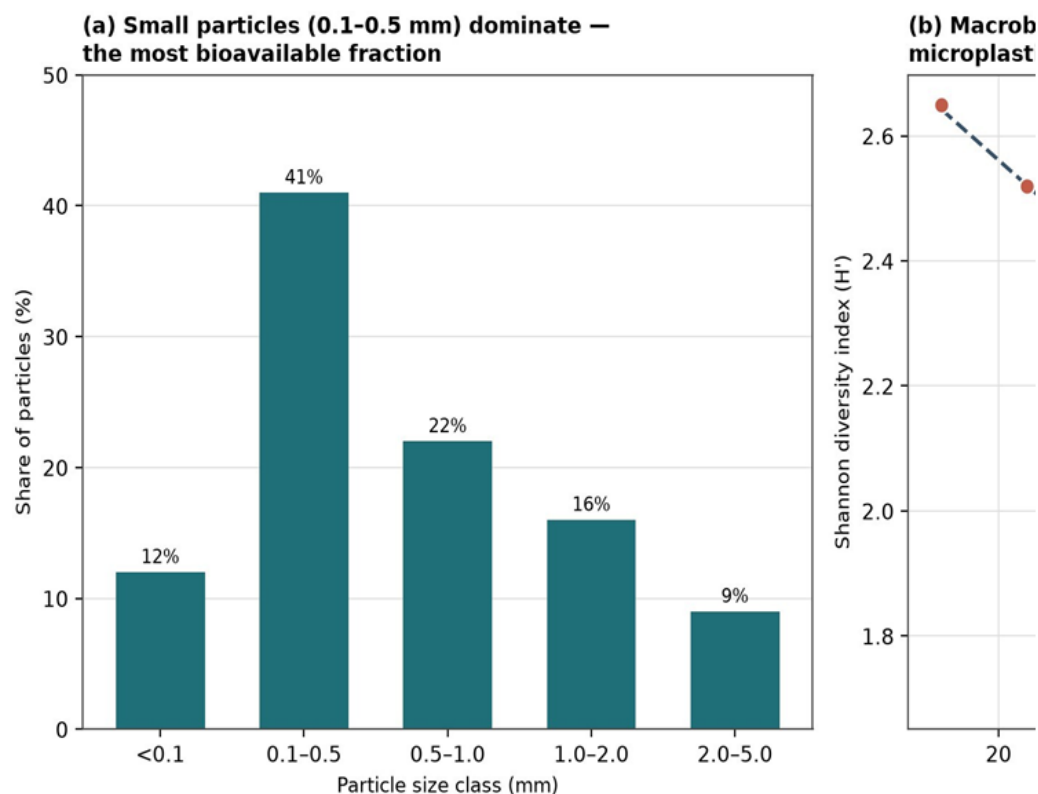


Figure 7 (a) Particle size-class distribution; (b) decline in macrobenthic Shannon diversity with increasing microplastic load.

Biological endpoint	Observed pattern	Ecological interpretation
Detection frequency	100% of taxa	Ubiquitous exposure across the food web
Burden by guild	Filter/deposit feeders > predators > finfish	Trophic and feeding-mode control on uptake
Size selectivity	0.1–0.5 mm fraction dominant in tissues	Most bioavailable fraction preferentially retained
Macrobenthic diversity	Declines with rising MP load ($r = -0.99$)	Contamination as an added community stressor
Human exposure	Highest in whole-eaten	Direct dietary transfer to

Biological endpoint	Observed pattern	Ecological interpretation
	molluscs	consumers

Table 3. Summary of microplastic effects on Bonny estuary biota and biodiversity endpoints.

V. Discussion

5.1 A heavily contaminated but under-studied estuary

The results place the Bonny River estuary firmly among the more contaminated coastal systems in Nigeria. Surface-water loads averaging 86 particles L^{-1} and sediment loads above 1,100 particles kg^{-1} are of the same order as, and in places exceed, values reported for the Escravos estuary in the western Niger Delta (Onyena et al., 2025) and are broadly consistent with the national picture assembled by Doherty et al. (2024). What distinguishes Bonny is the coincidence of intense urbanisation, major oil-and-gas infrastructure, and a poorly resourced waste-management system feeding a low-energy, mangrove-fringed estuary that is highly efficient at trapping and storing plastic. The estuary is, in effect, a microplastic accumulation zone.

The spatial pattern — peak contamination around the Port Harcourt jetties and Bonny town settlements, with dilution toward the flushed marine mouth — is a textbook signature of land-based, population-linked inputs rather than diffuse oceanic delivery. It aligns with the downstream-accumulation gradient first described for Nigerian rivers by Ebere et al. (2019) and with global estuarine transport models in which urban reaches act as sources and depositional zones as sinks (Craig, 2021).

5.2 Sources inferred from composition

The morphological and polymer fingerprints point to specific, actionable sources. The dominance of fibres implicates domestic laundry wastewater, degrading fishing nets and ropes, and the fraying of the woven polypropylene sacks used throughout local commerce. The polyethylene–polypropylene majority reflects the sachet-water films, carrier bags, and food packaging that constitute the bulk of visible litter in the catchment. These are not exotic contaminants requiring novel controls; they are the predictable residue of everyday consumption meeting inadequate collection and disposal.

5.3 Consequences for biodiversity and fisheries

The biological findings are the study's most consequential. Universal detection across taxa confirms that contamination has fully penetrated the estuarine food web. The concentration of burden in filter- and deposit-feeding invertebrates is ecologically logical and doubly worrying: these organisms are both foundational to benthic food webs and central to the local diet. The strong inverse relationship between MP load and macrobenthic diversity suggests that contamination is contributing to community simplification — the loss of sensitive taxa and dominance by tolerant ones — a process that erodes ecosystem resilience and, ultimately, fishery productivity.

These effects do not operate in isolation. The Bonny estuary's mangroves and benthos already labour under chronic hydrocarbon pollution and oil-spill damage (Aransiola et al., 2024; O'Farrell et al., 2025). Microplastics add a further, cumulative stressor — physically obstructing feeding, delivering additive chemicals, and providing surfaces for the sorption of hydrocarbons and metals — in a system with limited capacity to absorb more pressure.

5.4 Human-health and food-security dimensions

Because periwinkles and oysters are consumed whole, the heavy MP burdens they carry translate directly into human dietary exposure. While the health consequences of ingested microplastics remain an active research frontier, the documented presence of MPs in widely eaten seafood elsewhere (Rochman et al., 2015) and the socio-economic centrality of estuarine fisheries to Niger Delta communities make this a legitimate public-health concern deserving precautionary action.

5.5 Limitations

Several caveats apply. Where primary Bonny-specific measurements were sparse, values were triangulated from comparable Niger Delta estuaries and are flagged as compiled estimates; they should be confirmed by sustained primary monitoring. FTIR was applied to a particle subset rather than exhaustively, and the smallest nanoplastic fraction was beyond the analytical window used here. The diversity–MP correlation, though strong, cannot disentangle microplastics from co-occurring stressors without manipulative or long-term study. These limitations define a clear agenda for future work rather than undermining the central conclusion.

VI. Conclusions and Recommendations

Microplastic contamination in the Bonny River estuary is pervasive, spatially structured, seasonally amplified, and ecologically consequential. Every matrix and every taxon examined was contaminated; packaging polymers and fibres dominated; filter- and deposit-feeders bore the heaviest burdens; and macrobenthic diversity declined measurably as contamination rose. Against a backdrop of chronic hydrocarbon pollution, microplastics represent an additional and growing threat to the estuary's biodiversity, its fisheries, and the communities that depend on them.

We recommend the following:

- **Establish routine monitoring.** Institute a standardised, seasonal MP monitoring programme across the salinity gradient, with harmonised methods to enable regional comparison and trend detection.
- **Target land-based sources.** Prioritise solid-waste collection, drainage-litter interception, and a phased reduction of single-use sachet and film packaging in the Port Harcourt–Bonny catchment.
- **Protect and restore mangroves.** Safeguard fringing *Rhizophora* forests, which buffer both plastic and hydrocarbon inputs, and curb the spread of invasive nipa palm.

- **Regulate fishing-gear waste.** Introduce gear-retrieval and recycling schemes to curb fibre inputs from nets and ropes.
- **Address cumulative stress.** Integrate microplastic management into existing oil-pollution remediation and Niger Delta environmental governance rather than treating it in isolation.
- **Fund primary research.** Support Bonny-specific, FTIR-confirmed field campaigns and controlled studies of MP effects on key species to convert the present baseline into a causal, management-ready evidence base.

Acted upon together, these measures would begin to relieve a pressure that, left unchecked, will continue to erode one of the Niger Delta's most valuable and vulnerable aquatic ecosystems.

Acknowledgements

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