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Macroplastic Pollution in Mangrove Ecosystems of Baganga, Davao Oriental, Philippines

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ABSTRACT

Plastic debris accumulates readily in mangrove forests because complex aerial roots and low-energy intertidal conditions retain materials transported from land and sea. This study quantified the abundance, mass, composition, and spatial variation of macroplastic debris in mangrove sites in Barangays Lucod and Kinablangan, Baganga, Davao Oriental, Philippines. Field surveys were conducted along three transects subdivided into sampling plots. Debris items larger than 5 mm were counted, classified, and weighed, while field observations and geotagged photographs were used to document their distribution and possible sources. Lightweight consumer packaging, particularly food wrappers, cellophane, and plastic bottles, dominated item abundance, whereas sacks, rubber materials, and miscellaneous bulky debris contributed disproportionately to total mass. The findings support source reduction, improved collection services, fishing-gear recovery, stronger controls on dumping, and regular mangrove cleanups and monitoring.

INTRODUCTION

Plastic pollution is a persistent global environmental problem because increasing production, short product lifetimes, and inadequate collection systems allow durable materials to enter terrestrial, freshwater, and marine environments. Without stronger policies supporting waste prevention, reuse, recycling, and circular material use, plastic production and waste generation are projected to continue increasing (OECD, 2022). Plastic pollution therefore extends beyond visible litter and includes resource loss, chemical exposure, habitat degradation, and the progressive fragmentation of larger debris into smaller particles (UNEP, 2021).

Rivers are among the principal pathways through which land-based plastic waste reaches coastal and marine environments. More than 1,000 rivers are estimated to account for approximately 80% of global riverine plastic emissions to the ocean, with emissions influenced by population density, rainfall, waste-management capacity, and the proximity of discarded materials to waterways (Meijer et al., 2021). Once plastics enter rivers and drainage systems, they may travel considerable distances, become stranded along shorelines, accumulate in coastal vegetation and sediments, or fragment into particles that are difficult to recover.

The Philippines is particularly vulnerable to marine plastic pollution because of its extensive coastline, numerous river systems, frequent heavy rainfall, widespread consumption of single-use packaging, and uneven waste collection and recycling services. The country generates substantial quantities of plastic waste, while recyclable materials are lost because of deficiencies in collection, sorting, processing capacity, and markets for recovered plastics (World Bank, 2021). These conditions increase the likelihood that household, commercial, and fishing-related waste will enter drainage channels, rivers, estuaries, and coastal habitats.

Mangrove forests are efficient sediment and debris traps. Their prop roots, pneumatophores, trunks, and accumulated organic matter reduce water velocity and intercept floating materials. Although this retention may temporarily reduce debris movement into adjacent waters, it exposes mangrove habitats to prolonged plastic accumulation. Extensive macroplastic coverage can restrict gas exchange, alter sediment conditions, obstruct seedlings and root structures, and reduce mangrove growth and survival (van Bijsterveldt et al., 2021).

Baganga, Davao Oriental, faces the Philippine Sea and contains mangrove stands that support fishing, shellfish collection, shoreline protection, and other coastal livelihoods. Barangays Lucod and Kinablangan include naturally established and planted mangroves exposed to waste from nearby settlements and coastal activities, as well as materials transported by tides, runoff, rivers, wind, and extreme weather. Site-specific information on the abundance, composition, mass, and spatial distribution of macroplastic debris remains limited. Accordingly, this study aimed to: (1) identify and quantify the dominant macroplastic debris categories in the mangrove forests of Lucod and Kinablangan; (2) compare macroplastic abundance and mass among transects;

and (3) describe spatial variation and the likely sources and transport pathways of debris within the sampled areas.

THEORETICAL REVIEW

Plastic pollution in coastal environments is primarily associated with increasing plastic consumption, inadequate waste collection, and improper disposal practices. Mismanaged plastic waste may enter rivers, drainage systems, and coastal waters through surface runoff, wind transport, and direct dumping. Rivers are particularly important pathways because they facilitate the movement of land-based plastics toward estuarine and marine ecosystems (Meijer et al., 2021).

Mangrove forests function as effective retention zones for plastic debris. Their complex root systems, trunks, pneumatophores, and sedimentary environments reduce water velocity and trap materials transported by tides, rivers, and runoff. Consequently, plastic debris may remain within mangrove habitats for extended periods, particularly in areas influenced by nearby settlements, waterways, and fishing activities (Martin et al., 2019).

Macroplastic pollution may be evaluated in terms of abundance, mass, and composition. Item abundance indicates the frequency of particular debris categories, whereas mass reflects the contribution of larger and denser materials. Thus, lightweight items such as wrappers and bottles may dominate numerical abundance, while sacks, tires, and other bulky materials may account for a substantial proportion of total mass (Galgani et al., 2015).

The accumulation of plastic debris may adversely affect mangrove ecosystems. Plastic bags, films, sacks, and tarpaulins can cover sediments, obstruct root structures, limit gas exchange, and interfere with seedling establishment. Prolonged exposure may reduce mangrove growth and survival, while the gradual fragmentation of larger debris may generate microplastics that are more difficult to remove and may be ingested by aquatic organisms (van Bijsterveldt et al., 2021).

The occurrence of household and fishing-related plastics in mangrove areas also reflects deficiencies in local waste-management systems. Effective mitigation requires improved waste collection, segregation, recycling, enforcement against illegal dumping, recovery of discarded fishing gear, and regular environmental monitoring. Source reduction and community participation are essential because cleanup activities alone cannot prevent the continued entry of plastic waste into coastal habitats (UNEP, 2021).

These concepts provide the theoretical basis for examining the abundance, mass, composition, and spatial distribution of macroplastic debris in the mangrove forests of Lucod and Kinablangan. They further support the interpretation of observed differences among transects in relation to waste sources, transport pathways, and the retention characteristics of mangrove ecosystems.

METHODOLOGY

Study Area

The study was conducted in the mangrove forest areas of Barangays Lucod and Kinablangan in the Municipality of Baganga, Davao Oriental, southeastern Mindanao (Figure 1). The study sites face the Philippine Sea and include muddy intertidal environments where freshwater and marine influences support diverse mangrove communities and coastal livelihoods. Naturally established and planted mangroves occur in both barangays, and the sites are exposed to settlement-related waste, fishing activities, runoff, tidal transport, and storm-driven debris movement.

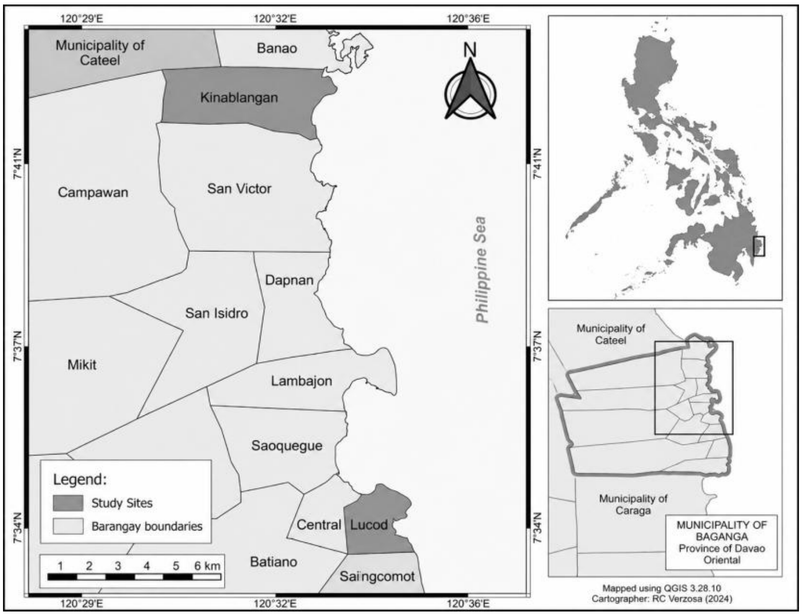

Figure 1. Location of the study sites in Barangays Lucod and Kinablangan, Baganga, Davao Oriental.

Sampling Design

Sampling locations were selected purposively to represent accessible mangrove areas with contrasting shoreline exposure and proximity to human activity. Three transects were established and subdivided into sampling plots. Within each plot, all visible macroplastic debris was collected or recorded systematically. Because site selection was purposive rather than probability-based, the findings are interpreted as baseline evidence for the sampled mangrove areas and should not be extrapolated uncritically to all mangroves in Baganga.

Data Collection and Debris Classification

Field data sheets were used to record transect, plot, debris category, item count, and mass. Macroplastic was operationally defined as visually identifiable plastic debris larger than 5 mm. Items were classified into practical use-based categories, including food wrappers, cellophane or film, bottles and containers, fishing-related materials, rubber items, hygiene products, sacks, tarpaulins, and miscellaneous debris. A portable weighing scale was used to determine mass in grams. Photographs and geotagged records documented sampling locations and representative waste.

Where wet or absorbent materials were encountered, the recorded value was treated as field mass unless the item had been dried before weighing. This limitation was considered when interpreting diapers, textiles, and other materials capable of retaining water. Local residents, fisherfolk, barangay officials, and environmental personnel were consulted only to provide contextual information on possible debris sources, disposal practices, and site access.

Data Analysis

Macroplastic data were analyzed using descriptive statistics. Item counts and masses were summarized by debris category, plot, and transect. Totals, frequencies, percentages, and ranges were used to describe macroplastic abundance and composition. Summary tables and bar graphs were prepared to compare debris loads among transects and identify the materials contributing most strongly to item abundance and total mass. Field observations, photographs, geotagged records, and contextual information from local stakeholders supported the interpretation of possible debris sources and transport pathways.

RESULTS

Macroplastic Composition and Abundance

Across the three sampling transects, 317 macroplastic items with a combined recorded mass of 9,625.5 g were documented (Table 1). Transect 01 contained the greatest number of items and the highest recorded mass, with 208 pieces weighing 4,714.5 g. Transect 02 contained only 65 items, but its total mass remained high at 4,036.0 g because several large and dense objects, particularly plastic sacks and a discarded rubber tire, contributed disproportionately to the overall weight. Transect 03 had the lowest macroplastic load, with 44 items weighing 875.0 g. These differences show that item abundance and total mass represented distinct dimensions of pollution.

Lightweight consumer packaging was the most widespread component of the collected debris. Food wrappers were the most abundant individual item, with 97 pieces weighing 261 g. Cellophane, plastic wrappers, and beverage bottles were also repeatedly recorded across the sampling plots. Although these materials contributed less mass than bulky debris, their high frequency indicates sustained input of disposable plastics into the mangrove environment. Their occurrence in all three transects also shows that the problem was not confined to a single localized dumping point.

In contrast, materials classified as others or possible electronic waste produced the greatest recorded mass, amounting to 2,590.08 g despite being less abundant than food wrappers. Fishing-related materials, rubber items, slippers, diapers, sanitary products, tarpaulins, sacks, plastic utensils, cups, and fragments were also present. The diversity of these objects indicates that macroplastic pollution originated from several waste streams, including household consumption, fishing activities, small commercial operations, and the disposal or transport of bulky materials.

Table 1. Summary of macroplastic abundance and mass by transect

Transect	Number of items	Total mass (g)	Dominant pattern
Transect 01	208	4,714.5	Numerous lightweight wrappers, cellophane, and bottles
Transect 02	65	4,036.0	Fewer items but high mass due to sacks, a tire, and bulky debris
Transect 03	44	875.0	Lower overall load dominated by smaller consumer plastics
Total	**317**	**9,625.5**	**–**

Spatial Variation Among Transects

Macroplastic composition varied markedly among transects (Figure 2). Transect 01 was characterized by a large number of lightweight and frequently discarded materials, particularly wrappers, cellophane, and plastic bottles. Their high abundance suggests repeated deposition or continuous transport into the site. Transect 02 differed because a small number of bulky objects accounted for much of its total mass, a pattern consistent with direct dumping, flood-related transport, or retention of larger debris.

Transect 03 contained substantially less debris by both count and mass. Nevertheless, wrappers, cellophane, bottles, plastic cups, utensils, diapers, and a sack remained present. Its lower total mass should therefore not be interpreted as an absence of pollution; rather, smaller and lighter materials were more prominent in this section of the mangrove area.

The repeated occurrence of single-use plastics across all transects is important because these materials are readily transported by wind, runoff, rivers, and tidal movement. Their spatial distribution may reflect both nearby disposal practices and external transport. In contrast, heavy objects are less likely to travel long distances under ordinary conditions and may provide stronger evidence of nearby dumping or localized human activity.

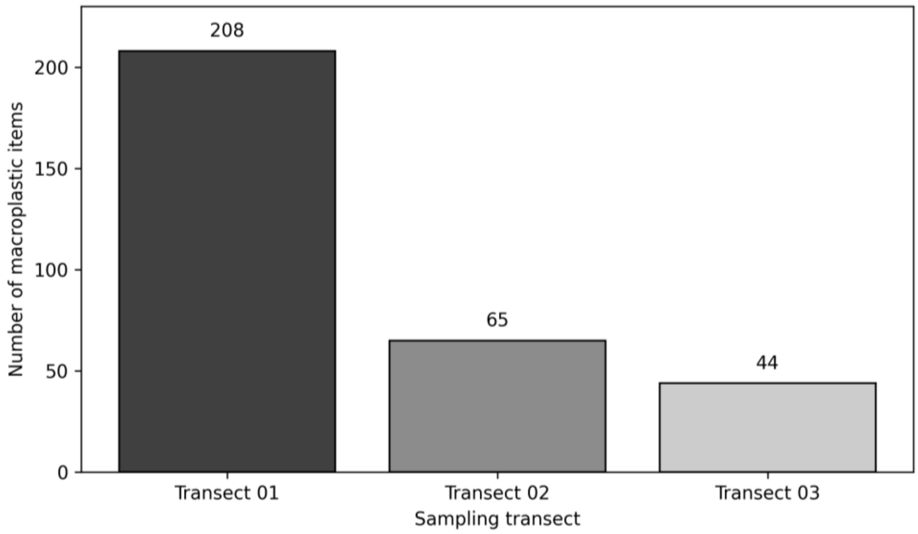

Figure 2. Total number of macroplastic items recorded in each sampling transect.

DISCUSSION

The predominance of food wrappers, cellophane, and plastic bottles indicates that single-use consumer packaging was the principal component of macroplastic pollution in the surveyed mangrove areas. Their occurrence across all three transects suggests continuous and spatially widespread waste inputs rather than an isolated dumping event. Similar patterns have been documented in Southeast Asian coastal environments, where packaging materials, plastic bags, bottles, and other short-lived consumer products commonly dominate marine debris because of extensive use and inadequate recovery after disposal (Jambeck et al., 2015; Purba et al., 2019). In the Philippines, flexible packaging and multilayer sachets are especially problematic because they have low recycling value and are difficult to process through conventional material-recovery systems (World Bank, 2021).

The widespread distribution of lightweight plastics may be explained by their mobility in wind, surface runoff, rivers, and tidal water. Wrappers and plastic films can be transported from settlements, drainage channels, commercial areas, and fishing grounds before becoming lodged among mangrove roots and branches. Rivers are major pathways connecting land-based waste sources with coastal environments, and numerous small and medium-sized waterways contribute substantially to ocean plastic emissions (Lebreton et al., 2017; Meijer et al., 2021). The debris collected in Lucod and Kinablangan may therefore represent a combination of locally discarded waste and materials transported from other areas.

Differences between item abundance and total mass were evident among the transects. Transect 01 contained the greatest number of items because lightweight wrappers, cellophane, and bottles were numerous. Transect 02 contained far fewer objects but retained a relatively high mass because of sacks, a tire, slippers, and other bulky materials. Transect 03 had the lowest abundance and mass but still contained recurring consumer plastics and household waste. These findings show that item count and mass provide complementary information: abundance reflects how frequently particular products occur, whereas mass emphasizes the contribution of large and dense debris. Marine-litter assessments should therefore report both measurements together with debris composition (Galgani et al., 2015).

Bulky materials such as sacks, tires, tarpaulins, slippers, fragments, and possible electronic waste indicate inputs beyond routine food and beverage consumption. These objects may have entered through direct dumping, flooding, storm runoff, shoreline activities, and disposal associated with households and coastal livelihoods. Research in Asian coastal systems shows that rainfall, river discharge, population density, and inadequate waste collection can substantially increase the transfer of land-based debris into aquatic environments (Cordova and Nurhati, 2019). Heavy objects may also indicate nearby sources because they are generally less mobile than thin packaging under ordinary tidal conditions.

Although bulky debris occurred less frequently than wrappers, it may produce substantial ecological effects. Flexible sacks and tarpaulins can cover sediments and seedlings, while tires and rigid materials may obstruct tidal channels, damage young mangroves, and interfere with root exposure and gas exchange. Experimental research has shown that extensive plastic coverage can reduce mangrove growth and survival by obstructing pneumatophores and altering sediment conditions (van Bijsterveldt et al., 2021). Mangrove forests are particularly vulnerable because complex root systems efficiently intercept floating waste and may retain it for prolonged periods (Martin et al., 2019).

Fishing-related debris, including ropes, nylon, and netting, was less abundant than consumer packaging but remains ecologically significant. Lost fishing gear can persist for extended periods, entangle wildlife, and continue capturing organisms after abandonment. Global evidence identifies lost nets, lines, and traps as a persistent source of marine pollution, while studies in Indonesian coastal environments have similarly documented fishing materials among common debris types (Richardson et al., 2019; Uneputty and Evans, 1997). Their presence supports designated disposal sites, retrieval programs, and cooperation with local fisherfolk.

The continued weathering of wrappers, bottles, ropes, and other macroplastics may generate secondary microplastics. Sunlight, temperature changes, wave action, and abrasion gradually fragment larger debris into particles that are more difficult to recover and more readily ingested by aquatic organisms. Plastic particles have been detected in fish and bivalves sold for human consumption in Indonesia, while biological effects of microplastic exposure have been reported among coastal invertebrates in Thailand (Rochman et al., 2015; Thushari et al., 2017). The visible macroplastic debris in the study area may therefore represent both an immediate physical pollutant and a future source of smaller plastic particles.

The occurrence of diapers and sanitary products indicates that mixed household waste was also reaching the mangrove environment. These materials contain plastic films, synthetic fibers, adhesives, and absorbent polymers and may retain organic and microbial contaminants. Their presence may reflect inadequate collection, poor household segregation, limited disposal facilities, or direct dumping into waterways. Similar deficiencies in developing Asian waste-management systems have been associated with the movement of municipal waste into rivers and coastal habitats (Kaza et al., 2018). Because absorbent materials become heavier when wet, future surveys should apply standardized cleaning, drying, and weighing procedures.

CONCLUSIONS AND RECOMMENDATIONS

Macroplastic pollution was evident in the sampled mangrove areas of Barangays Lucod and Kinablangan. Across the three transects, 317 debris items with a combined mass of 9,625.5 g were recorded. Transect 01 had the greatest abundance and mass, while Transect 02 contained fewer items but retained a high mass because of sacks, a tire, and other bulky debris. Transect 03 had the lowest overall load but remained affected by wrappers, cellophane, bottles, hygiene products, and other household waste. Lightweight consumer packaging dominated item abundance, whereas large and dense materials contributed disproportionately to total mass. The diversity and spatial distribution of debris indicate inputs from household consumption, fishing activities, localized dumping, runoff, and tidal transport. These findings support improved solid-waste collection, source reduction, fishing-gear recovery, enforcement against dumping, and regular cleanup and monitoring of high-load mangrove areas. Because the survey was purposive and temporally limited, the results should be treated as baseline evidence for the sampled sites. Repeated seasonal surveys are recommended to evaluate changes in debris abundance, composition, and transport over time.

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REFERENCES

Borrelle, S. B., Ringma, J., Law, K. L., et al. (2020). Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. Science, 369(6510), 1515–1518.

Cordova, M. R., and Nurhati, I. S. (2019). Major sources and monthly variations in the release of land-derived marine debris from the Greater Jakarta area, Indonesia. Scientific Reports, 9, 18730.

Galgani, F., Hanke, G., and Maes, T. (2015). Global distribution, composition and abundance of marine litter. In M. Bergmann, L. Gutow, and M. Klages (Eds.), Marine Anthropogenic Litter (pp. 29–56). Springer.

Jambeck, J. R., Geyer, R., Wilcox, C., et al. (2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768–771.

Kaza, S., Yao, L. C., Bhada-Tata, P., and Van Woerden, F. (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. World Bank.

Lau, W. W. Y., Shiran, Y., Bailey, R. M., et al. (2020). Evaluating scenarios toward zero plastic pollution. Science, 369(6510), 1455–1461.

Lebreton, L. C. M., van der Zwet, J., Damsteeg, J. W., Slat, B., Andrady, A., and Reisser, J. (2017). River plastic emissions to the world's oceans. Nature Communications, 8, 15611.

Martin, C., Almahasheer, H., and Duarte, C. M. (2019). Mangrove forests as traps for marine litter. Environmental Pollution, 247, 499–508.

Meijer, L. J. J., van Emmerik, T., van der Ent, R., Schmidt, C., and Lebreton, L. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. Science Advances, 7(18), eaaz5803.

OECD. (2022). Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options. OECD Publishing.

Purba, N. P., Handyman, D. I. W., Pribadi, T. D., et al. (2019). Marine debris in Indonesia: A review of research and status. Marine Pollution Bulletin, 146, 134–144.

Richardson, K., Hardesty, B. D., and Wilcox, C. (2019). Estimates of fishing gear loss rates at a global scale: A literature review and meta-analysis. Fish and Fisheries, 20(6), 1218–1231.

Rochman, C. M., Tahir, A., Williams, S. L., et al. (2015). Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. Scientific Reports, 5, 14340.

Thushari, G. G. N., Senevirathna, J. D. M., Yakupitiyage, A., and Chavanich, S. (2017). Effects of microplastics on sessile invertebrates in the eastern coast of Thailand. Marine Pollution Bulletin, 124(1), 349–355.

Uneputty, P. A., and Evans, S. M. (1997). The impact of plastic debris on the biota of tidal flats in Ambon Bay, eastern Indonesia. Marine Environmental Research, 44(3), 233–242.

UNEP. (2021). From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution. United Nations Environment Programme.

van Bijsterveldt, C. E. J., van Wesenbeeck, B. K., Ramadhani, S., et al. (2021). Does plastic waste kill mangroves? A field experiment to assess the impact of macroplastics on mangrove growth, stress response and survival. Science of the Total Environment, 756, 143826.

World Bank. (2021). Market Study for the Philippines: Plastics Circularity Opportunities and Barriers. World Bank.