

Quantification and characterization of macroplastics present in the mangrove ecosystem of SUCITAPPLAS, Surigao del Norte, Philippines

Medielyn M. Odtojan^{*1,2} and Emily S. Antonio²

¹College of Arts and Sciences, Surigao del Norte State University, Surigao City, 8400 Philippines

²Faculty of Advanced and International Studies, Davao Oriental State University, City of Mati, Davao Oriental, 8200 Philippines

ABSTRACT

Despite variations in the surrounding land use and human disturbance, macroplastic pollution was observed in the mangrove forests in SUCITAPPLAS. Site-specific variations in plastic abundance, mass density, and composition were attributed to local human activity, hydrological processes, and environmental exposure. This study aimed to establish baseline data on macroplastic pollution in the mangrove ecosystem in SUCITAPPLAS, Surigao del Norte. The samples were collected in four sampling sites within the study area. The macroplastics (>25 mm in size) found on tree branches, roots and the forest floor within each quadrat were 100% collected through hand picking. All collected macroplastics were counted, cleaned, weighed, measured, and categorized. A total of 346 items of plastic with a combined weight of 9,002 grams and a cumulative measured length of 117,350 mm were recorded across the four sampling locations. Condana Island recorded the highest abundance (0.183 items/m²) and density (2.07 g/m²), while Lamangon Island had the lowest (abundance = 0.022 items/m²) and density (0.26 gm²). Beverage bottles, plastic bags, film fragments, and food wrappers were the most common macroplastics found across all sampling sites. Among these, film fragments has the highest count (120 items = 34.7%). The findings suggest that plastic pollution in mangrove forests is affected by localized human activities and environmental processes; however, the ubiquity of plastic debris across all sites highlights the natural trapping ability of mangrove ecosystems. These findings support improvements in community-level solid waste management, awareness campaigns, and environmental education.

INTRODUCTION

Plastic, an archetypal modern material, has existed for more than a century (Geyer et al., 2017). Worldwide production of plastic has almost doubled in the last decades, reaching 460 million tonnes in 2019 (Our World in Data, n.d.). Although plastic is crucial to sectors such as healthcare, agriculture, construction, and packaging, the modern plastic era has produced a deep human dependence that drives severe overproduction (Geyer et al., 2017; Napper & Thompson, 2023; Inocente & Bacosa, 2022). Hence, plastic pollution has become one of the main threats to marine ecosystems worldwide and a serious challenge for the Philippines (Requiron & Bacosa, 2022).

Plastic waste is now present in every ocean basin, ecosystem, habitat, and food web, including in seafood and sea salt. Although early studies focused on isolated ocean gyres, research now examines the sources, fate, transformation, and impacts of plastic pollution. The numerous ways that plastic waste impacts physical and biological systems and interacts with planetary cycles have become clearer as knowledge has grown (Rochman, 2020). A burgeoning policy movement spanning many governmental levels, from local to global, has coincided with an expanding scientific area.

UNEP (2009) affirms that half of plastic trash is single-use plastic. According to a research study, half of the 8.3 billion tonnes of plastic created to date has come from 2004 onward (Rhodes, 2018). Additionally, 60% of all plastic ends up in landfills or the environment with present annual plastic waste production is approximately 300 million tons. Global waste generation is expected to increase by 70% over the next 30 years, driven in part by increasing per-capita plastic consumption in many countries (World Bank, 2018).

*Corresponding author

Email Address: modtojan@ssct.edu.ph

Date received: 07 February 2026

Date revised: 08 May 2026

Date accepted: 20 June 2026

DOI: <https://doi.org/10.54645/2026191APR-65>

KEYWORDS

mangrove forest, macroplastics, plastic pollution, SUCITAPPLAS

The Philippines is the third-ranking contributor to plastic pollution in the world, with estimates ranging between 2.7-5.5 million metric tonnes generated each year, 20% of which leaks into the environment (Schachter & Karasik, 2022; Braganza, 2017; Ocean Conservancy, 2015). With no interventions, mismanaged plastic waste could reach 9 million metric tonnes by 2040 and 11 million metric tonnes by 2060. A major source of plastic pollution is leakage from open landfills (Mensah, 2024). The heavy use of single-use plastics, notably sachets has exacerbated the problem in recent years.

Plastic waste has reached crisis levels in the Philippines, where 60% of the population lives on the coast. National estimates indicate that about 10% of the 14 million tons of solid waste produced annually is plastic (SEPO, 2017; EMB, 2018). Furthermore, it is estimated that an additional 750,000 tons of mismanaged plastic enter the ocean from the archipelago each year (Jambeck et al., 2015). Although these figures are alarming, localized baseline data remained limited. Sources of mismanaged plastic are often discussed broadly but the actual accumulation rates and characteristics within sensitive ecosystems are overlooked. This data gap is particularly glaring in the SUCITAPPLAS area of Surigao del Norte where there is no baseline assessment of macroplastic pollution for its mangrove forests. Understanding these local dynamics is critical for developing targeted conservation strategies. Thus, the present study aims to fill this gap by presenting the first baseline data on macroplastic pollution in the SUCITAPPLAS mangrove ecosystem.

MATERIALS AND METHODS

Study Area

The province of Surigao del Norte lies in the northeastern part of Mindanao Island in the Philippines. Geographically, it is located between latitudes 9°18' to 10°30' north and longitudes 125°15' to 126°15' east. As of the 2020 Census, there were 534,636 people living in the province, with a land area of 1,952.62 km² (PhilAtlas, n.d.). The population density is approximately 274 persons per square kilometer, or 709 persons per square mile. The mainland portion of the province has a variety of topography, including rough, mountainous, and flat areas.

The study was conducted in the Municipality of Tagana-an and Surigao City, Surigao del Norte. These shorelines face the Philippine Sea, which is located east of the Philippine Archipelago and is a marginal sea of the Western Pacific Ocean (Figure 1).

Site 1 is situated on Cobeton Island in Barangay Nabago, Surigao City, close to coastal settlements that may have an impact on the spread of plastic pollution. Site 2 is located on Lamangon Island, a popular tourist destination with lots of visitors and regular leisure activities. Site 3 is located beside a sizable river that flows through a populous area. This area is expected to receive macroplastic inputs from upstream sources, including industrial discharge, urban runoff, and sewage effluents transported by the river into the coastal system. Additionally, Site 4 is considered less disturbed area, due to its distance from residential areas, famous tourist spots, and major waterways, it is less susceptible to direct human influences.

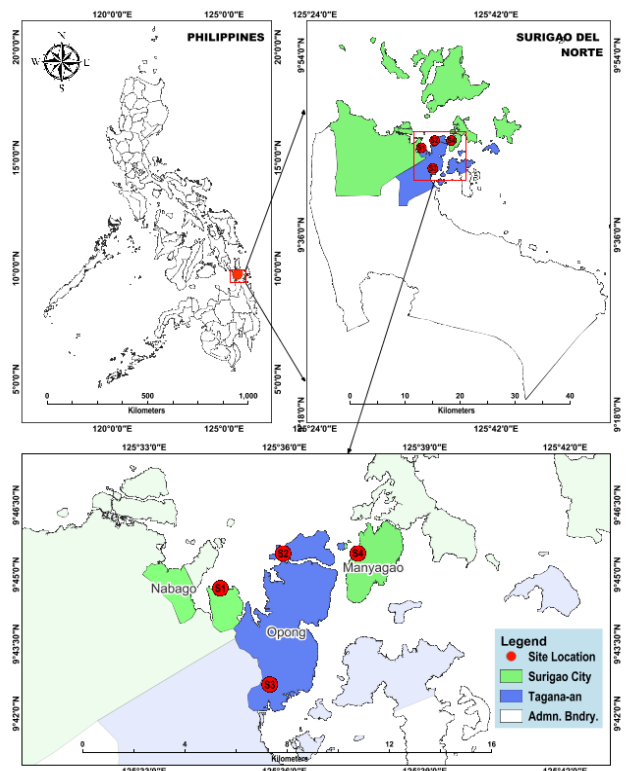


Figure 1: Map of the Study Area. The upper left shows the map of the Philippines indicating the location of Surigao del Norte. The upper right displays the map of Surigao del Norte with marked sampling points. The lower map provides a closer view of the specific sampling locations (S1-Cobeton Island, S2-Lamangon Island, S3-Cobeton Island, and S4-Bilabid Island).

Data Gathering Procedure

Sampling site establishment

The establishment of sampling sites was adapted from Paculba et al. (2024). Using calibrated string/twine, each site was set up with three (3) 100 m transect lines spaced 50 m apart and perpendicular to the beach (Figure 2). Four quadrats measuring 10 m x 10 m and spaced 20 m apart were used to lay each transect line. There were 12 quadrats that measured 10 m x 10 m all in all.

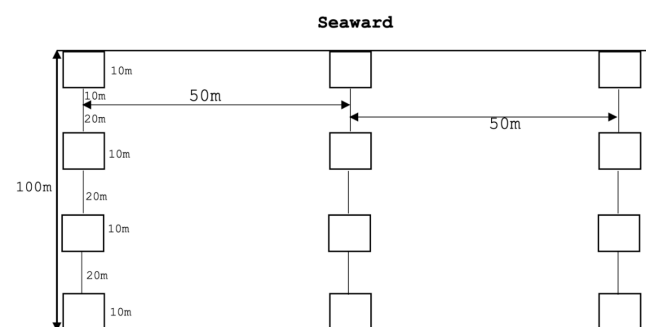


Figure 2: Sampling Layout

Macroplastics collection

For the collection of macroplastics, this study adopted the methods of Cappa et al. (2023); and Paculba et al. (2024). The macroplastics (>25 mm in size) found on tree branches, roots, and mangrove floor were collected exhaustively by hand picking and placed in sacks. The macroplastic collection was done during low tide.

Macroplastics category and classification

All collected plastic litter was properly accounted, washed to remove sediment, unfolded, and air-dried outdoors. Each item was then weighted, measured, and categorized following Cappa et al. (2023), Martin et al. (2019) and Paler et al. (2022).

Macroplastics Polymer type identification

Following the method used in the study of Paculba et al. (2024) and PlasticsEurope (2023), the polymer types were inferred based on item application and typical polymer use. Due to their resistance to corrosion, the majority of plastics were regarded as "persistent materials" materials (Porta, 2021; Kasmuri et al., 2022; Stenzel, 2026).

Data Analysis

Composition of macroplastics

The following equation that was used to determine the percentage composition of plastic litter was derived from the study of Abreo et al. (2020) and Paculba et al. (2024):

$$C = \left(\frac{n_i}{N}\right) \times 100$$

where:

C = percentage composition (%) of a specific microplastic category
 n_i = total number of plastic items counted within that specific category
 N = total number of plastic items collected across all categories combined

Abundance of macroplastics

The calculation of density of the plastic litter collected was based on the study of Abreo et al. (2020) and Paculba et al. (2024) where the total number of items collected was divided by the entire sampled area. This result was expressed in no. of items/m².

$$D = \frac{N_{total}}{A}$$

where

D = macroplastic density (items/m²)
 N_{total} = total number of plastic items collected
 A = total sampled surface area (m²)

Clean Coast Index (CCI)

Alkalay et al. (2007) initially introduced the Clean-Coast Index (CCI) as a method to measure the cleanliness of coastal areas. It considered several variables, such as the quantity and type of plastic litter found, as well as the degree of public awareness and involvement in cleanup activities. This mathematical tool provides a standardized metric that reduces subjective bias (Alkalay et al. 2007). To qualitatively evaluate each mangrove area's cleanliness, the total amount of plastic litter collected during fieldwork was examined using the CCI evaluation (Table 1).

$$CCI = \frac{\text{Total number of plastic items on site}}{\text{Total area of site}} \times K$$

where:

CCI = Clean Coast Index value
 Total plastic items collected = Total count of plastic litter found within the transect
 Total sampled area = Total surface area evaluated (m²)
 K = Constant scaling factor equal to 20

Table 1: The classification of Clean Coast Index (CCI)

Clean Coast Index	Cleanliness Rating	Visual Assessment
0–2	Very Clean	Very little debris is seen
2–5	Clean	Little debris is seen over a large area
5–10	Moderate	A few pieces of debris can be detected
10–20	Dirty	A lot of debris in the mangrove area
>20	Extremely Dirty	Most of the mangrove area is covered with plastics

Significant difference

To determine whether plastic accumulation differed significantly between sampling sites, One-way Analysis of Variance (ANOVA) was used as a statistical tool. To further determine the sites that differed significantly, a Tukey post hoc analysis was carried out.

RESULTS

Composition and Distribution of Plastic

The results demonstrate the diversity and dominance of land-based consumer waste in macroplastic pollution across all sampling sites. A total of 346 plastic items were collected with a total weight of 9,002 g and cumulative measured length of 117,350 mm which is an indication of a significant build-up of macroplastics across the study area. The smallest macroplastics collected were a film fragment (30 mm) in Condon Island and a foam fragment in Bilabid Island, while the largest items by length was rope/netting in Condon Island.

Plastic bottles, plastic bags, film fragments, foam fragments, and food wrappers were the most common consumer-related materials found in macroplastic across all sampling sites (Table 2). Film fragments had the highest count, with 120 items (34.7%) weighing 999 g, followed by beverage bottles comprising 15.3% (53 items) with an equivalent weight of 982 g, and plastic bags consisting of 14.7% (51 items) with total weight of 946 g. These categories were present across all sampling sites. Fishing nets and gears has the lowest count of 15 (4.3%) which recorded at Cobeton and Condon Islands only.

It is interesting to note that fishing nets and gears had a high total weight (11,130 g) despite having a very low count (n = 15, 4.3%). This implies that, despite being less common, heavier and likely bulkier plastic materials contribute disproportionately to the total plastic load.

In terms of macroplastic distribution, among the 7 types identified, Condon and Cobeton Islands recorded all types, followed by Lamangon Island with 6 types, while Bilabid Islands only recorded 5 types of macroplastics. Cutlery, fabric fragments, and fishing nets and gears were recorded only in Cobeton and Condon Islands,

Table 2: Macroplastics recorded across all sampling sites.

Types of Plastic	Count	Composition (%)	Weight (g)	Size (mm)
Film Fragments	120	34.7	999	38,610
Plastic bags (opaque & clear)	51	14.7	946	25,440
Plastic Beverage Bottles	53	15.3	982	11,860
Food Wrappers	42	12.1	179	7,650
Foam Fragments	22	6.4	721	4,180
Fishing Nets & Gears ^a	15	4.3	1,415	18,130
Other Plastic Debris ^b	43	12.5	3,760	11,480
TOTAL	346	100.0	9,002	117,350

^a Combined category representing commercial/municipal fishing nets, lures, traps, pots, and synthetic line weights.

^b Unified category for minor compositions (<5% individual frequency) including personal care product packaging, plastic utensils/cutlery, single-use food pack containers, fabric fibers, and fiberglass fragments

The composition of macroplastics was site-specific and greatly influenced by surrounding environmental and anthropogenic factors. Cobeton Island (Figure 3A), situated near a community, showed a balanced distribution of plastic bottles, bags and film fragments, indicative of continuous input from household waste. Plastic bags were dominant at Lamangon Island (Figure 3B), a tourism site, pointing to high consumption of single-use plastics among the visitors. Condonga Island (Figure 3C), located by a river mouth, showed a high proportion of film fragments, indicating

accumulation and degradation of plastics transported from upstream sources. In contrast, the least disturbed area, Bilabid Island (Figure 3D) still had significant plastic debris, indicating indirect transport via natural processes. Generally, the results emphasize the combined effect of human activities and environmental transport processes on the distribution of macroplastics.

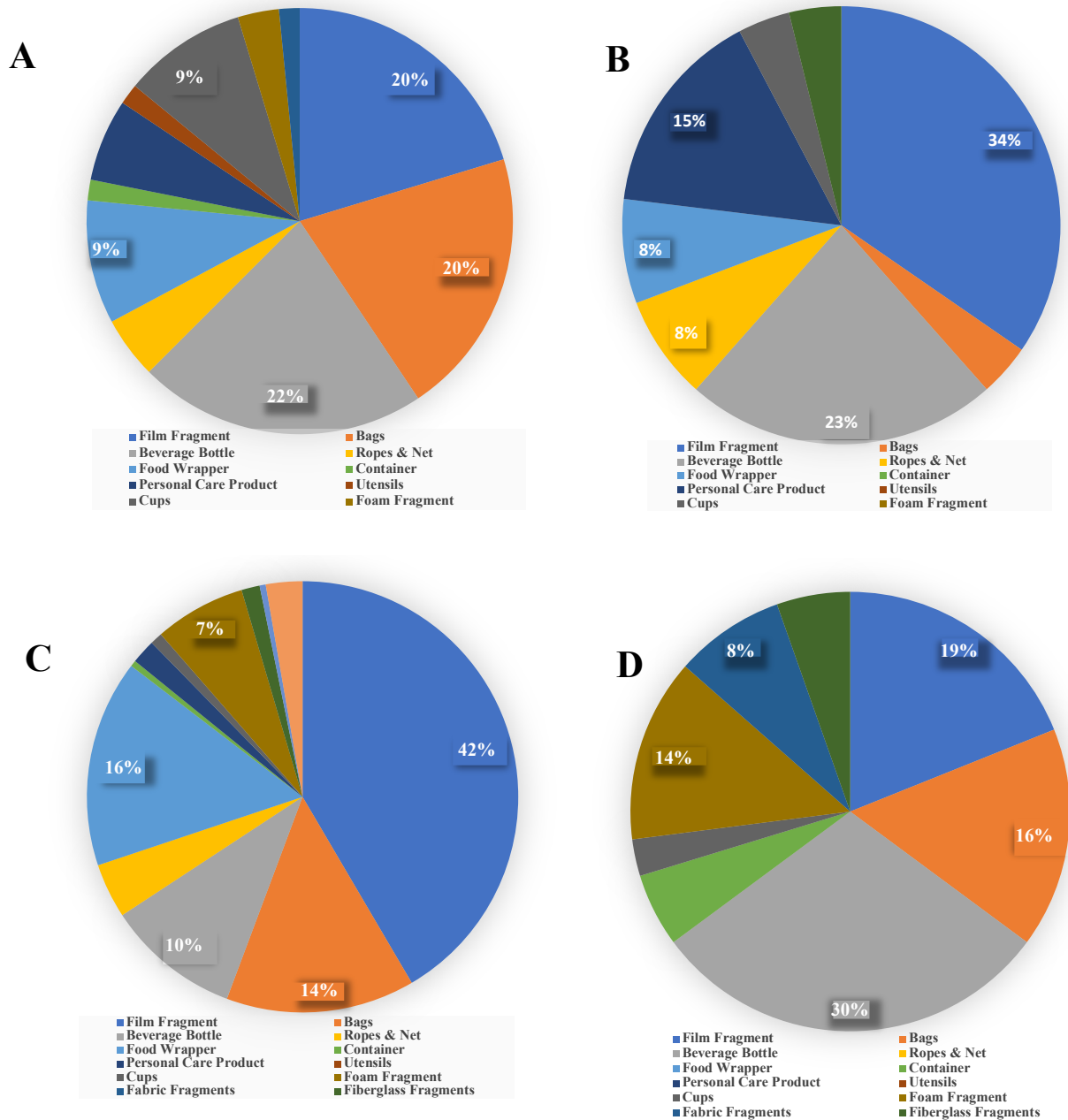


Figure 3: Composition of macroplastic litter in each site of SUCITAPPLAS. A. Cobeton Island, B. Lamangon Island, C. Condonga Island, D. Bilabid Island

Abundance of Macroplastics

Macroplastic abundance varied across the four sampling sites, suggesting site-variations level in pollution levels and potential plastic input sources. The overall counts and densities varied considerably even though all sites had the same sampled area (1,200 m²), indicating that local conditions have a substantial impact on plastic accumulation.

In terms of abundance and mass density, given the sampling area of 1,200 m² per site, Condonga Island recorded the highest count density of 0.18 items/m² and the highest number of macroplastics (n=219) among all sampling sites (Table 3). With a mean of 15.64±23.65, it also showed the highest variability, indicating an unequal distribution of macroplastics within the site. River inputs that carry plastic debris may be the cause of its high abundance.

The high standard deviation indicates that plastics are concentrated in specific areas, which may be impacted by geography, wind patterns, or water flow.

On the other hand, Lamangon Island recorded the lowest macroplastic count ($n = 26$) and density of 0.02 items/m^2 with a relatively low mean (2.00 ± 2.66). This suggests a comparatively cleaner environment, lower plastic inputs, better waste management, or more effective natural flushing. The lower variability further indicates a more even distribution of plastics across the site.

Table 3: Abundance of Macroplastics recorded per site.

Site	Features	Total Count	Total Area (m ²)	Density (items/m ²)	Mean \pm SD
Cobeton Island	Near coastal communities	64	1,200	0.05	4.57 ± 4.97
Lamangon Island	High tourism	26	1,200	0.02	2.00 ± 2.66
Condonga Island	Near a large river flowing through an urban area	219	1,200	0.18	15.64 ± 23.65
Bilabid Island	Less disturbed area	37	1,200	0.03	2.64 ± 3.29

Polymer Classification

The identified macroplastic debris comprised various major polymer types with notable differences in their abundance. Polyvinyl chloride (PVC) recorded the highest count ($n = 120$), suggesting its considerable presence in the study area. PVC is usually found in construction materials, pipes, and packaging, this indicates that infrastructure-related waste materials and urban runoff both contributed to its occurrence (Figure 4).

High-density polyethylene (LDPE), polyethylene terephthalate (PET), and polypropylene (PP) also occurred frequently. The prevalence of these materials in single-use packaging such as plastic bags, sachets and food wrappers suggests that consumer-related waste is a significant contributor to macroplastic pollution in the area.

The contribution of takeout and food service activities is indicated by the presence of Polystyrene (PS), which is usually found in foam packaging and disposable food containers. Its relatively moderate count is a reflection of its widespread use, and its tendency to fragment into smaller particles.

On the contrary, Polystyrene (PS) and Nylon (polyamide, PA) were found in lower quantities. Materials such as styrofoam and insulator boards are typically made up of polystyrene. Nylon is most commonly associated with fishing gear and synthetic textiles. They may be discarded less often because they are less abundant, or they may be more persistent and less likely to break down into observable macroplastic debris.

The “Others” category indicates the occurrence of less common composite materials, such as multi-layer plastics, in which classification into a single polymer group is difficult. These materials are usually persistent and non-recyclable, complicating waste management. Results show that the majority of macroplastic types consist of common thermoplastics, especially those used for packaging and short-term consumer applications. This emphasizes the major role of improper waste disposal, excessive use of single-use plastics and ineffective waste management systems in creating environmental pollution. Moreover, the high abundance of light polymers (e.g., HDPE, PET, and PP) indicates that buoyancy and transport processes (i.e., wind and water currents) affect their distribution and accumulation in the study area.

The macroplastic abundance was moderate for both Cobeton Island and Bilabid Island. The Cobeton Island had 64 items (0.05 items/m^2) and a mean of 4.57 ± 4.97 , while the Bilabid Island had 37 items (0.03 items/m^2) and a mean of 2.64 ± 3.29 . These values indicate that plastic pollution is present in both sites but in lower intensities than Condonga Island. The standard deviations are moderate and show some variability in distribution but not as marked as in Condonga Island.

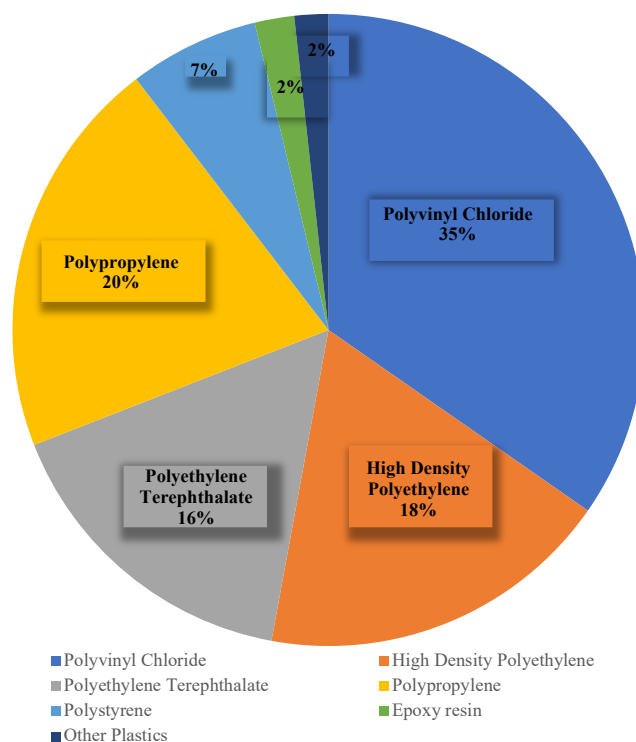


Figure 4: Polymer percentage composition of macroplastics collected from all sampling sites

Clean Coast Index (CCI) Analysis

As shown in Table 4, Cobeton Island (1.07), Lamangon Island (0.43), and Bilabid Island (0.62), based on the computed CCI are classified as “very clean”, while Condonga Island with CCI value of 3.65, is classified as “clean”. Despite the fact that coastal litter levels were typically low at all sampling sites, Condonga Island had a comparatively higher CCI score indicating more macroplastic accumulation in the island compared to other islands in the area.

Table 4: Cleanliness rating per sampling site

Sampling site	Total macroplastic count	Total Area (m ²)	CCI	Cleanliness Rating
Cobeton Island	64	1,200	1.07	Very clean
Lamangon Island	26	1,200	0.43	Very clean
Condonga Island	219	1,200	3.65	Clean
Bilabid Island	37	1,200	0.62	Very clean

Comparison of macroplastic density across sampling sites

A one-way analysis of variance (ANOVA) was performed to ascertain significant differences in macroplastic abundance across the four sampling sites (Table 5). The results showed a statistically significant difference between the sites ($F \approx 6.8$, $p < 0.001$). Conдона Island had significantly higher microplastic abundance than in Cobeton, Lamangon, and Bilabid Islands. This is probably because it is close to a river mouth, which is a major conduit for debris transported from upstream areas.

Table 5: One-way analysis of variance results for macroplastic counts among sites

Sampling site	Count	Mean \pm SD	F-value	p-value
Cobeton Island	64	7.11 \pm 4.82	6.8	<0.001
Lamangon Island	26	3.25 \pm 2.73		
Conдона Island	219	24.33 \pm 25.79		
Bilabid Island	37	6.17 \pm 3.02		

The result showed that macroplastic accumulation among sites was significantly different thus, a Tukey HSD post hoc test was conducted to determine which specific sites were different while keeping Type I error in check (Table 6).

Table 6: Tukey post hoc result

Site (1)	Site (2)	Mean Difference (1-2)	p-value	Decision
Cobeton	Lamangon	2.71	>0.05	Not significant
Cobeton	Conдона	-11.07	<0.05	Significant
Cobeton	Bilabid	1.93	>0.05	Not significant
Lamangon	Conдона	-13.78	<0.05	Significant
Lamangon	Bilabid	-0.78	>0.05	Not significant
Conдона	Bilabid	13.00	<0.05	Significant

After the one-way ANOVA, a Tukey HSD post hoc test was done to find out which sites were significantly different from each other. The results indicated that Conдона Island exhibited a significantly greater macroplastic abundance than Cobeton, Lamangon, and Bilabid ($p < 0.05$). Nonetheless, no significant differences were detected among Cobeton, Lamangon, and Bilabid, suggesting comparable levels of macroplastic accumulation across these locations.

DISCUSSION

The function of mangrove forests as effective retention zones for large plastic materials was demonstrated in this study through the presence and buildup of macroplastic in the mangrove ecosystem. Mangroves' complex root systems make it easier for plastic waste to be retained (Kathiresan & Bingham, 2001), which can then act as a long-term source of contamination in coastal food webs (de Oliveira Barbirato & Ferreira, 2021). Recent research by Navarro et al. (2023) stressed the presence of microplastics in bivalves inhabiting mangrove ecosystems, highlighting the possible ecological and human health consequences as well as the possibility of trophic transfer. As macroplastics undergo progressive weathering and fragmentation, the presence of these materials in mangrove environments is also ecologically significant. Over time, macroplastics are broken down into smaller pieces by physical, chemical, and biological processes such as UV radiation, wave action, and microbial activity, which ultimately result in the formation of microplastics (Yang et al., 2022; Zafiu et al., 2023; Liro et al., 2023).

Moreover, this study's findings show that, despite variations in the surrounding land use and human disturbance, macroplastic

pollution is found in all four mangrove sites. Site-specific variations in plastic abundance, mass density, and composition were a result of local human activity, hydrological processes, and environmental exposure. This conforms to the study of Fong et al. (2023) which recognized that the retention of land-based anthropogenic litter and trapping sea-based litter carried ashore by tidal and wave action were probably the causes of the high densities of macro-litter in the mangrove forests. Nonetheless, the fact that plastic waste is consistently present at every location emphasizes the essential function of mangrove forests as efficient catchment systems for plastic waste (Adyel & Macreadie, 2021; Cerri et al., 2025).

Conдона Island, which is near a large river that runs through an urban area, had the most plastic and the highest mass density of all the sites. The study of Cappa et al. (2023) in Cebu, Philippines specified that variability in plastic pollution was explained by landscape context, with mangroves in riverine environments having more plastic than those along the open coastline and proximity to rivers increasing plastic weight and abundance. Local and land-sourced litter varieties, like sachets and plastic bags, dominated the plastic market.

Moreover, the presence of fishing-related materials suggests that marine-based activities are also adding to the problem. Conдона Island which has the most abundant macroplastic with all the 14 types present in that area, suggests that this site has become a catchment of macroplastics from both land- and water-based sources, which causes the build-up in the mangrove forest. The fact that the area is near big river, riverine inputs are a big part of how plastic litter gets to the mangrove forest. Once plastics get to the coastal zone, they are easily trapped in the complex root systems of mangroves (He et al. 2024), which means they can build up even when there isn't much human activity nearby.

Cobeton Island, where the mangrove area is near coastal communities, also had a considerable number of plastic items, though it is way lower than the study of Van Bijsterveldt et al. (2021) in Java, Indonesia. The fact that plastic items like beverage bottles, plastic bags, food wrappers, and cups are the most common types of plastic at this site suggests that a lot of plastic comes from trash from nearby settlements. Likewise, Ubulom et al. (2023) confirmed that huge amounts of plastic bottles and sachets in the coastal area of Southeastern Nigeria were influenced by nearby communities. Moreover, Acot et al. (2022) asserted in the study in the beaches of Sarangani Bay that the density of macroplastic litter on urban beaches was found to be double that of rural beaches.

Lamangon Island, which is known as a tourist destination, had the lowest amount of plastic and mass density of all the sites. Fewer plastic items were observed, but there were still plastics related to consumers, like food wrappers, cups, and beverage bottles. During the sampling activity, signages around the area about proper waste management was noticed, as well as trash bins were installed strategically around the area. This was probably one reason why least macroplastics were collected in the area. Similarly, Cornejo et al. (2026) indicates that there may be other reasons for the high concentration of macroplastics in mountainous regions with very low population densities and high tourist throughout the winter and summer. On the contrary, Khadanga et al. (2022) emphasized that beachgoers or tourists are the main contributors to plastic pollution in the Gopalpur coast in the study during the post lockdown of Covid-19 pandemic. Further, Paulus et al. (2020) stated that plastic waste makes up most of the marine debris in the mangrove ecotourism area.

Bilabid Island, which was thought to be the least disturbed site, still had plastic trash on it, even though there wasn't much human activity nearby. The macroplastic litter collected in the area were mostly found on the roots and floor of the mangrove ecosystem. Dalu et al. (2025) affirmed that the accumulation and distribution

of macroplastics even in the least disturbed but vegetated areas could be driven by natural processes like rainfall and wind. Further, Gallitelli and Scalici (2024) found that higher plastic densities on vegetation than in adjacent water areas. The accumulation of wastes in the intertidal zone can be attributed by waves and current movements (Nevandhra et al., 2025) that could disperse and spread-out waste to some other areas. This finding shows that plastic pollution is not just a problem in one place; it can also affect areas that are far away or not disturbed as much because of regional-scale transport processes.

Plastic debris was consistently documented in mangrove forests across all four sites, regardless of variations in proximity to communities, tourism, river mouths, or disturbance levels. This pattern strongly supports the idea that mangroves are natural traps for plastic waste (Cerri et al. 2025; Kesavan et al. 2021). Mangrove ecosystems have extensive aerial root systems (Srikanth et al., 2016), pneumatophores (Numbere & Camilo, 2022), and low-energy hydrodynamic conditions (Kazemi et al., 2020) that slow down the flow of water and promote the retention and settling of macroplastic debris. Further, mangroves have the ability to stop plastic pollution from spreading into nearby marine environments by intercepting debris, giving them a dual role as an ecological sanctuary and likely a pollution sink (Navarro et al., 2023).

The mangrove structure retained both light items (like plastic bags and wrappers) and heavier debris (like fishing gear and containers). This shows that mangrove forests can hold onto plastics of different sizes and densities (Martin et al. 2019). Over time, plastics that are trapped may break down under environmental exposure (Dey et al. 2024). This adds to the plastic fragments that are seen at different sites. This trapping function may limit the immediate spread of plastics to nearby marine habitats, but it also leads to the long-term buildup of plastic waste in mangrove ecosystems (van Bijsterveldt et al. 2021), which could harm the plants and animals that live there.

The buildup of plastic trash in mangrove forests has important environmental implications. Trapped plastics can cover sediments (Martin et al. 2019), change the properties of the soil (Kumar et al. 2007), and stop roots from growing (van Bijsterveldt et al. 2021), which could impair the growth and regeneration of mangroves. Fishing-related trash is especially dangerous because it can get caught in mangrove roots and hurt animals that live there. The observed fragmentation of plastics in mangrove environments indicates that these habitats may serve as secondary sources of microplastics (Cappa et al., 2023; Maghsodian et al., 2022), which can be reintroduced into coastal waters during high tides or storm events.

CONCLUSION AND RECOMMENDATIONS

This study provides baseline data on macroplastic pollution in the mangrove ecosystems in different islands within SUCITAPPLAS. The findings show that macroplastic debris (>25 mm) is present across all sampling sites. Variations in abundance and Clean Coast Index (CCI) values show that conditions are generally "very clean" to "clean," but also show persistent plastic pollution. The predominant categories were film fragments and typical consumer-related plastics (such as bags, bottles, and wrappers), indicating the impact of daily human activities. Although these patterns are based on observed distribution data without direct measurement of transport or hydrodynamic drivers, spatial differences among sites suggest that locations with greater human activity area likely to exhibit higher macroplastic loads. The study area's mangrove ecosystems serve as sinks for macroplastic waste, underscoring their susceptibility to continuous plastic buildup and the possibility of long-term environmental persistence.

In order to track changes in abundance, composition, and spatial distribution over time, it is recommended to regularly monitor macroplastic pollution in mangrove ecosystems. To lessen land-based plastic inputs, localized waste management initiatives should be intensified, especially in Cobeton and Lamangon Islands. To address improper plastic disposal practices, community-based coastal cleanup initiatives and environmental awareness campaigns are also recommended.

To further understand transport pathways, fragmentation processes, and ecological impacts, future studies should combine hydrodynamic modeling with macro-and microplastic analysis.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

[Author 1 MMO]: Conceptualization, Methodology, Investigation, Resources Formal Analysis, Writing—original draft. **[Author 2 ESA]:** Investigation, Resources, Writing—review and editing, Supervision. All authors have read and agreed to the published version of the manuscript.

REFERENCES

- Abreo, N. A. S., Siblos, S. K. V., & Macusi, E. D. (2020). Anthropogenic marine debris (AMD) in mangrove forests of Pujada Bay, Davao Oriental, Philippines. *Journal of Marine and Island Cultures*, 9(1), 38-53. <https://jmic.online/issues/v9n1/3/>
- Acot Jr, F. T., Sajorne, R. E., Omar, N. A. K., Suson, P. D., Rallos, L. E. E., & Bacosa, H. P. (2022). Unraveling macroplastic pollution in rural and urban beaches in Sarangani Bay Protected Seascape, Mindanao, Philippines. *Journal of Marine Science and Engineering*, 10(10), 1532. <https://www.mdpi.com/2077-1312/10/10/1532>
- Adyel, T. M., & Macreadie, P. I. (2021). World's largest mangrove forest becoming plastic cesspit. *Frontiers in Marine Science*, 8, 766876. <https://doi.org/10.3389/fmars.2021.766876>
- Alkalay, R., Pasternak, G., & Zask, A. (2007). Clean-coast index—A new approach for beach cleanliness assessment. *Ocean & Coastal Management*, 50(5-6), 352-362. [10.1016/j.ocecoaman.2006.10.002](https://doi.org/10.1016/j.ocecoaman.2006.10.002)
- Braganza, P. A. T. (2017). Assessment of the implementation of the plastic bag reduction ordinance in Quezon City (2012-2016). *Philippine Journal of Public Administration*, 61(1-2), 20-42. <https://journals.upd.edu.ph/index.php/pjpa/article/view/6959>
- Cappa, P., Walton, M. E., Paler, M. K. O., Taboada, E. B., Hiddink, J. G., & Skov, M. W. (2023). Impact of mangrove forest structure and landscape on macroplastics capture. *Marine Pollution Bulletin*, 194, 115434. [10.1016/j.marpolbul.2023.115434](https://doi.org/10.1016/j.marpolbul.2023.115434)
- Cerri, F., Mohamed, S., & Galli, P. (2025). Mangrove forests as a natural trap for marine plastic litter: Insights from the Maldives. *Marine Pollution Bulletin*, 213, 117677. [10.1016/j.marpolbul.2025.117677](https://doi.org/10.1016/j.marpolbul.2025.117677)
- Cornejo, D., Martí, E., Margenat, H., Serra-Rada, J., Martínez, M., & Guasch, H. (2026). Tourism, waste management and macroplastic accumulation in headwater riparian-stream ecosystems. *Environmental Advances*, 100691. <https://doi.org/10.1016/j.envadv.2026.100691>

- Dalu, T., Oduro, C., Matsimela, R. M., Munyai, L. F., Wu, N., Moyo, S., & Cuthbert, R. N. (2025). Macroplastic distribution patterns and accumulation in an urbanised Austral subtropical river system. *Scientific Reports*, 15(1), 9231. <https://doi.org/10.1038/s41598-025-94282-w>
- de Oliveira Barbirato, J., & Ferreira, N. C. (2021). Accumulation on Mangrove Ecosystem and Their Interaction. *Humic Substances*, 111. <https://www.intechopen.com/chapters/76158>
- Dey, S., Veerendra, G. T. N., Babu, P. A., Manoj, A. P., & Nagarjuna, K. (2024). Degradation of plastics waste and its effects on biological ecosystems: A scientific analysis and comprehensive review. *Biomedical Materials & Devices*. 2(1), 70-112. <https://doi.org/10.1007/s44174-023-00085-w>
- EMB. (2018). Annual Accomplishment Report. EMB-DENR Environmental Education and Information Division. <https://eeid.emb.gov.ph/wp-content/uploads/2022/08/2018-EEID-accomplishment-EDITED.pdf>
- Fong, J., Lee, S. H. R., Sun, Y., Lim, C. L., Tan, Y. A. J., Tan, Y. H., & Neo, M. L. (2023). Litter traps: A comparison of four marine habitats as sinks for anthropogenic marine macro-litter in Singapore. *Marine Pollution Bulletin*, 196, 115645. [10.1016/j.marpolbul.2023.115645](https://doi.org/10.1016/j.marpolbul.2023.115645)
- Gallitelli, L., & Scalici, M. (2024). Conceptual model of global plants entrapping plastics. *Environmental Reviews*, 32(4), 470-484. <https://doi.org/10.1139/er-2023-0141>
- Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science advances*, 3(7), e1700782. <https://doi.org/10.1126/sciadv.1700782>
- He, Y., Lu, J., Li, C., Wang, X., Jiang, C., Zhu, L., ... & Li, D. (2024). From pollution to solutions: Insights into the sources, transport and management of plastic debris in pristine and urban rivers. *Environmental Research*, 245, 118024. <https://doi.org/10.1016/j.envres.2023.118024>
- Inocente, S. A. T., & Bacosa, H. P. (2022). Assessment of macroplastic pollution on selected tourism beaches of Barobo, Surigao Del Sur, Philippines. *Journal of Marine and Island Cultures*, 11(1), 203-214. <https://doi.org/10.21463/jmic.2022.11.1.14>
- Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *science*, 347(6223), 768-771. [DOI: 10.1126/science.1260352](https://doi.org/10.1126/science.1260352)
- Kasmuri, N., Tarmizi, N. A. A., & Mojiri, A. (2022). Occurrence, impact, toxicity, and degradation methods of microplastics in environment—a review. *Environmental Science and Pollution Research*, 29(21), 30820-30836. <https://doi.org/10.1007/s11356-021-18268-7>
- Kathiresan, K., & Bingham, B. L. (2001). Biology of mangroves and mangrove ecosystems. *Advances in Marine Biology*, 40, 81-251. [10.1016/S0065-2881\(01\)40003-4](https://doi.org/10.1016/S0065-2881(01)40003-4)
- Kazemi, A., Curet, O., Gómez, D., & Castillo, E. E. (2020). Energy Harvesting from the Tidal Currents Using a Mangrove-Like System. In *International Conference on Offshore Mechanics and Arctic Engineering*. American Society of Mechanical Engineers. Vol. 84416, p. V009T09A006. <https://doi.org/10.1115/OMAE2020-18894>
- Kesavan, S., Xavier, K. M., Deshmukhe, G., Jaiswar, A. K., Bhusan, S., & Shukla, S. P. (2021). Anthropogenic pressure on mangrove ecosystems: Quantification and source identification of surficial and trapped debris. *Science of the Total Environment*. 794, 148677. <https://doi.org/10.1016/j.scitotenv.2021.148677>
- Khadanga, M. K., Behera, A. K., Swain, G. K., Dora, D. P., Padhi, C. P., Mishra, R. K., ... & Patro, S. (2022). Evaluation of the status of marine plastic pollution along a tourist beach of Bay of Bengal during lockdown and post lockdown. *Marine pollution bulletin*, 182, 113970. [10.1016/j.marpolbul.2022.113970](https://doi.org/10.1016/j.marpolbul.2022.113970)
- Kumar, S., Hatha, A. A. M., & Christi, K. S. (2007). Diversity and effectiveness of tropical mangrove soil microflora on the degradation of polythene carry bags. *Revista de biología Tropical*. 55(3-4), 777-786. <https://www.scielo.sa.cr/pdf/rbt/v55n3-4/art04v55n3-4.pdf>
- Liro, M., Zielonka, A., & van Emmerik, T. H. (2023). Macroplastic fragmentation in rivers. *Environment International*, 180, 108186. [10.1016/j.envint.2023.108186](https://doi.org/10.1016/j.envint.2023.108186)
- Maghsodian, Z., Sanati, A. M., Tahmasebi, S., Shahriari, M. H., & Ramavandi, B. (2022). Study of microplastics pollution in sediments and organisms in mangrove forests: A review. *Environmental Research*. 208, 112725. <https://doi.org/10.1016/j.envres.2022.112725>
- Martin, C., Almahasheer, H., & Duarte, C. M. (2019). Mangrove forests as traps for marine litter. *Environmental Pollution*. 247, 499-508. <https://doi.org/10.1016/j.envpol.2019.01.067>
- Mensah, E. (2024). *Human health and environmental hazards associated with plastic waste: a review and spatial mapping in informal settlements of Kampala, Uganda* (Master's thesis, Tufts University). <https://www.proquest.com/openview/894688fd3345549f5c5939ce49a848e2/1?pq-origsite=gscholar&cbl=18750&diss=y>
- Napper, I. E., & Thompson, R. C. (2023). Plastics and the Environment. *Annual Review of Environment and Resources*, 48(1), 55-79. <https://doi.org/10.1146/annurev-environ-112522-072642>
- Navarro, C. K., Arcadio, C. G. L., & Bacosa, H. (2023). Mangrove Filters or Microplastic Traps? Insights from Microplastic Ingestion in *Polymesoda erosa* in Butuan Bay, Philippines. *CURRENT APPLIED SCIENCE AND TECHNOLOGY*, e0267224-e0267224. <https://doi.org/10.55003/cast.2025.267224>
- Nevandhra, A. P., Rijal, S. S., Sari, S. H., & Yona, D. (2025). Macroplastic Characteristics and Assessment of the Plastic Abundance Index (PAI) of Beach Sediments in Prigi Bay, East Java, Indonesia. *Applied Environmental Research*, 47(2). <https://doi.org/10.55003/cast.2025.267224>
- Numbere, A., & Camilo, G. (2022). *Growth, abundance, and diversity of black mangrove (Avicennia germinans) pneumatophores in deforested and sand-filled mangrove forest at Eagle Island, Niger Delta, Nigeria* (Version 2). Research Square. <https://doi.org/10.21203/rs.3.rs-1810526/v2>
- Ocean Conservancy. (2015). Stemming the tide: Land-based strategies for a plastic-free ocean. <https://www.greenpeace.org/static/planet4-southeastasia-stateless/2019/04/eae10551-eae10551-full-report-stemming-the.pdf>
- Our World in Data. (n.d.). Plastic pollution. Retrieved December 4, 2021, from <https://ourworldindata.org/plastic-pollution>

- Paculba, L. S. L., Mabida, R. C. A. C., Perico, G. C. M., Magdayo Jr, E. D., & Acot Jr, F. T. (2024). Macroplastic pollution in mangrove forests of Tangub City, Panguil Bay, Philippines. *Nusantara Bioscience*, 16(2), 251-262. <https://doi.org/10.13057/nusbiosci/n160212>
- Paler, M. K. O., Tabanag, I. D. F., Siacor, F. D. C., Geraldino, P. J. L., Walton, M. E. M., Dunn, C., Skov, M.W., Hiddink, J.G., & Taboada, E. B. (2022). Elucidating the surface macroplastic load, types and distribution in mangrove areas around Cebu Island, Philippines and its policy implications. *Science of the Total Environment*, 838, 156408. <https://doi.org/10.1016/j.scitotenv.2022.156408>
- Paulus, C. A., Soewarlan, L. C., & Ayubi, A. A. (2020). Distribution of marine debris in mangrove ecotourism area in Kupang, East Nusa Tenggara, Indonesia. *AACL Bioflux*, 13(5). <https://bioflux.com.ro/docs/2020.2897-2909.pdf>
- PhilAtlas. (n.d.). Surigao del Norte. Retrieved May 6, 2025, from <https://www.philatlas.com/mindanao/caraga/surigao-del-norte.html>
- PlasticsEurope. (2023). *Plastics – the fast facts 2023*. <https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2023/>
- Requiron, J. C. M., & Bacosa, H. P. (2022). Macroplastic transport and deposition in the environs of Pulaan River, Dapitan City, Philippines. *Philipp. J. Sci*, 151(3), 1211-1220. <https://doi.org/10.56899/151.03.33>
- Rochman, C. M. (2020). The story of plastic pollution. *Oceanography*, 33(3), 60-70. <https://doi.org/10.5670/oceanog.2020.304>
- Rhodes, C. J. (2018). Plastic pollution and potential solutions. *Science progress*, 101(3), 207-260. <https://doi.org/10.3184/003685018x15294876706211>
- Schachter, J., & Karasik, R. (2022). Plastic pollution policy country Profile: Philippines. *NI PB*, 22-10. <https://nicholasinstitute.duke.edu/sites/default/files/projects/Plastic-Pollution-Policy-Country-Profile-Philippines.pdf>
- Senate Economic Planning Office. (2017, November). *Philippine Solid Wastes at a Glance*. 2017. https://web.senate.gov.ph/publications/SEPO/AAG_Philippine%20Solid%20Wastes_Nov2017.pdf
- Srikanth, S., Lum, S. K. Y., & Chen, Z. (2026). Mangrove root: adaptations and ecological importance. 30(2), 451-465. <https://doi.org/10.1007/s00468-015-1233-0>
- Stenzel, M. H. (2026). The dark matter in water, air and land: from microplastic to invisible nanoplastics. *Materials Horizons* 13, 1628-1648. [10.1039/D5MH01544H](https://doi.org/10.1039/D5MH01544H)
- Ubulom, S. R., Yawo, O. J., & Akpan, U. E. (2023). Evaluating the Distributions and Impacts of Macroplastic Pollutants in Agansa Coastal Community, South Eastern Nigeria. *Journal of Global Ecology and Environment*, 18(2), 32-45. [10.56557/jogee/2023/v18i28301](https://doi.org/10.56557/jogee/2023/v18i28301)
- United Nations Environment Programme. (2009). *Marine litter: A global challenge*. <https://wedocs.unep.org/handle/20.500.11822/7787>
- van Bijsterveldt, C. E., van Wesenbeeck, B. K., Ramadhani, S., Raven, O. V., van Gool, F. E., Pribadi, R., & Bouma, T. J. (2021). Does plastic waste kill mangroves? A field experiment to assess the impact of macro plastics on mangrove growth, stress response and survival. *Science of the Total Environment*. 756, 143826. <https://doi.org/10.1016/j.scitotenv.2020.143826>
- World Bank. (2018). What a Waste 2.0: A global snapshot of solid waste management to 2050. <https://openknowledge.worldbank.org/entities/publication/d3f9d45e-115f-559b-b14f-28552410e90a>
- Yang, Z., Lü, F., Hu, T., Xu, X., Zhang, H., Shao, L., ... & He, P. (2022). Occurrence of macroplastics and microplastics in biogenic waste digestate: Effects of depackaging at source and dewatering process. *Waste Management*, 154, 252-259. [10.1016/j.wasman.2022.10.018](https://doi.org/10.1016/j.wasman.2022.10.018)
- Zafiu, C., Binner, E., Beigl, P., Vay, B., Ebmer, J., & Huber-Humer, M. (2023). The dynamics of macro-and microplastic quantity and size changes during the composting process. *Waste Management*, 162, 18-26. [10.1016/j.wasman.2023.03.002](https://doi.org/10.1016/j.wasman.2023.03.002)