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OCCURRENCE OF MICROPLASTICS IN THE SEDIMENTS ACROSS VARIOUS HABITATS WITHIN THE LAS PINAS PARANAQUE WETLAND PARK (LPPWP)

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This Special Project of **DAISYLEN E. SALVAN** titled: **"OCCURRENCE OF MICROPLASTICS IN THE SEDIMENTS ACROSS VARIOUS HABITATS WITHIN THE LAS PINAS PARANAQUE WETLAND PARK (LPPWP)"** is hereby accepted by the Faculty of Management and Development Studies, U.P. Open University, in partial fulfillment of the requirements for the degree **Master of Environment and Natural Resources Management (MENRM)**.

PEDCRIS ORENCIO, MAURP, MSC, PHD — 22 April 2026
Faculty-in-charge, ENRM 290 (Special Problem) — (Date)

KARL ABELARD EDBERTO L. VILLEGAS, JR., R.F. — 10 June 2026
Program Chair — (Date)

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Faculty of Management and Development Studies

25 June 2026
Date

DECLARATION

This is to certify that:

I. The special problem comprises only my original work towards the MENRM except were indicated in the Preface

II. Due acknowledgment has been made in the text to all other material used

III. The special problem is fewer than 25,000 words in length, exclusive of tables, maps, bibliographies and appendices.

<u>DAISYLEN ESCALANTE SALVAN</u>
Name

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Abstract

The Las Piñas–Parañaque Wetland Park is an ecotourism site and one of the two (2) remaining protected areas located in a highly urbanized city of Metro Manila, tagged as the *"Last Coastal Frontier"*. It holds the densest cover of mangrove within NCR, and is further recognized as an important migratory bird hotspot (Ramsar Site) or Wetland of International Importance. However, despite the area's ecological importance, LPPWP, faces multiple threats like chronic water-quality issues, habitat destruction, and wildlife disturbance. In many coastal habitats like the LPPWP, the presence of microplastics has emerged as a significant environmental threat due to the increasing population in nearby communities and various unregulated pollution sources.

This study aims to provide essential baseline information that can support and help in the updating of the protected area management plan for LPPWP, particularly in areas related to waste pollution, habitat conservation, and long-term ecological monitoring, considering that there is an information gap on the prevalence of existing microplastics within the area.

In this study, microplastics were found in all of the three (3) sampling stations representing various habitats in LPPWP. Fragments were the most common type of microplastic observed, accounting for 50% of the total MP load. The study revealed presence of PP (Polypropylene), PE (Polyethylene), and PTFE (Polytetrafluoroethylene, often Teflon) type of polymer plastics.

This finding indicates that the wetland is already being impacted by microplastic pollution, likely driven by continuous waste inflow from surrounding household communities and large industries. The origins of the microplastics across sediments were attributed to three (3) main sources: (a) linkage to waterways and river channels, (b) direct introduction by visitors, and (b) weathering breakdown of macro or meso plastics debris from nearby industrial areas. The result of the study highlights the urgent need for integrated management of plastic and targeted interventions for the protection of identified important habitats, as well as the existing biodiversity in the area. Some of the identified actions that can be taken into consideration of the management of LPPWP includes prioritizing strong waste-source reduction program; institutionalizing a Habitat Sediment Quality and Microplastics Monitoring Program through regular temporal sampling of sediments; strict implementation of RA 11898 Extended Producer Responsibility Act by integrating EPR-related requirements in business permit renewal of industries; promote waste diversion and recovery initiatives; and developing a GIS- based microplastic pollution zoning map.

Keywords: Microplastics, Wetland, Protected Area, Waste Pollution, Habitat, Biodiversity, Industries, Fragments, Pellets, Plastics, Threats, Management Strategy

I. INTRODUCTION

Plastics come in all shapes and sizes; those that are about the size of sesame seeds are known as microplastics. Microplastics are small plastic pieces less than five

(5) millimeters in size, which can be harmful to our ocean and aquatic life. The primary type of microplastics are used in cosmetics and care products. Secondary types are formed when larger materials break down into smaller fragments, which are then exposed to sunlight, wind, water, and undergo mechanical abrasion or weathering. (ERDB, 2023).

The Philippines ranked third as the most significant contributor of plastic litter into the ocean and number one emitter of plastic debris from riverine sources. Various studies in the country revealed that plastic litter is prevalent in estuaries and on beaches. (Navarro, et al. 2022). According to the study of Galgani et al. (2015), due to plastic abundance and durability it constitutes the majority of marine litter posing a significant threat to the environment. Microplastics have been found in the stomachs of various marine animals due to its composition that can be rapidly ingested. (ERDB, 2023). These examples represent a diverse range of organisms with varying feeding mechanisms, including detritivores, deposit feeders, and filter feeders (NOAA, 2015).

Philippines as a tropical country that hosts a wide variety of mangrove species, with poor plastic waste collections, and the absence of research programs on basic

plastic problems, has resulted in a limited understanding of the implications of microplastics to the environment (Onda, et al., 2020). These factors also contribute in the future. Coastal habitat like Mangrove supports biodiversity including fishes, mainly to the Philippines' mangrove forests as hotspots for microplastic accumulation crustaceans, seabirds and other benthic organisms. The exposure of these species to microplastics contaminants pose an emerging ecological hazard and threat. Microplastics embedded in sediment can alter sediment structure affecting filter-feeding species which can further result in bioaccumulation, biodiversity loss and impaired ecosystem services. These impacts extend beyond wildlife, as microplastics can enter the food chain and affect human health through the consumption of seafood.

The Las Pinas Paranaque Wetland Park (LPPWP), formerly known as the Las Pinas Paranaque Critical Habitat and Ecotourism Area (LPPCHEA) was the first established critical habitat in the Philippines, which is known to be habitat of various threatened wildlife species and has the densest cover of Mangrove in Metro Manila (LPPWP, 2019). As the last mangrove frontier in Metro Manila, the LPPWP's ecosystems, including mangroves and mudflats, are crucial for maintaining water quality by filtering pollutants and providing natural flood defenses. However, the park's ecological integrity is threatened by pollution, garbage deposition, and other anthropogenic activities. The park's water quality is under Class C based on DENR EMB Water Quality Classification. (DENR EMB, n.d.).

Based on the consolidated Trash Data Forms submitted by thousands of volunteers in LPPWP during the International Coastal Cleanup (ICC) activity last 20

September 2025 a total of 85, 617 pieces of trash items equivalent to 1,181 sacks were collected. The most common waste identified and recorded were plastic wastes composed of 16, 190 pcs of beverage bottles; 11, 410 pcs food wrappers; 8,100 pcs bottle caps; 4,660 pcs plastic bags; 3,188 pcs plastic cups and plates. (LPPWP ICC Data, 2025). Being part of Manila Bay, plastic waste from inland areas and the ocean accumulates in the Park's mangrove.

II. REVIEW OF LITERATURE

Biodiversity in mangroves of the Philippines

According to Cuenca (2015) the mangrove ecosystem houses different flora and faunal species that dwell in various niches such as the surface, underneath the substrate, on the trees and under the water. These organisms with varying niches play significant roles and functions within the mangrove ecosystem. As for the faunal species, it serves as the nesting grounds for hundreds of bird species. Meanwhile, it also serves as a home to a wide variety of species of reptiles, amphibians, mammals, fishes, crabs, shrimps, mollusks and other invertebrates. (Garcia et. al., 2013).

Associated habitats to mangroves: mudflats

The mudflats/ tidal flats are characterized by unvegetated and exposed substrates with sandy and muddy sediments that undergo regular tidal inundation. (Aldea, 2022; Laffoley & Grimsditch, 2009). Although there are only a few studies, many of these habitats have already been lost due to anthropogenic activities such as land reclamation, coastal erosion and other pressures from coastal development. Compared to the mangrove forests, mudflats and saltmarshes are barely recognized by the communities and stakeholders leading to its limited conservation efforts (Aldea, 2022). Despite the lack of support, these ecosystems are hosts diverse communities of wildlife. For various species of fish, mangroves serve as nurseries and feeding grounds. Further, it provides livelihood for the coastal communities. They also play a crucial role of filtering pollutants, sediments, and excess nutrients from the coastal waters. They act as filters that absorb nutrients such as nitrogen and phosphorus, which reduces risk of eutrophication and algal blooms. On a related note, these ecosystems serve as carbon sinks by sequestering the carbon dioxide from the atmosphere and storing it in the form of organic carbon that helps in climate change mitigation. (Sespene et. Al., 2016; Barbier, 2019; Laffoley & Grimsditch, 2009). The establishment of Marine Protected Areas is part of the conservation effort for these ecosystems. MPAs are guided by various laws and regulations, such as the National Integrated Areas System (NIPAS) Act or ENIPAS Act as ammended and the Fisheries Code of the Philippines.

Manila bay and LPPWP

Manila Bay is surrounded by diverse ecosystems including wetland habitats. Wetlands are important habitat that provides various ecosystem services. In the context of Manila Bay, wetland ecosystems such as LPPWP play crucial roles to its ecology. For instance, mangrove forests in wetland habitats play a vital role in stabilizing shorelines, providing habitat for various marine and terrestrial species. Tidal flats, on the other hand, provide feeding and resting grounds for migratory birds and support a variety of small aquatic organisms. However, anthropogenic activities posed significant threats to both the ecological integrity of Manila Bay and the wetland habitat of LPPWP.

The poor water quality of LPPWP can be attributed to being a catch basin to all wastes and pollutants due to inadequate management of wastes coming from domestic, commercial, and industrial activities wastewater discharges. (ERDB, 2021).

Legal basis of LPPWP management

On April 22, 2007 the LPPWP was established as a critical habitat through Presidential Proclamation No. 1412. The area was the first critical habitat established in the Philippines. It is a wetland in the coastal area of the Metro Manila located between the cities of Las Pinas and Paranaque fronting Manila Bay. It was declared as a critical habitat primarily to conserve it and protect threatened local and migrant wildbirds. These include the endangered Chinese Egret and the rare Pied Avocet and Gray-tailed Tattler. These birds are among the twenty-nine (29) migratory wild bird species that normally visit the country during the freezing winter months of the northern hemisphere flying through the East Asian-Australasian Flyway (EAAF). Proclamation 1412 also aims to protect the vulnerable Philippine Duck. It is one of the fifteen (15) resident wild bird species that have made LPPWP their home. Both local and foreign wild bird have attracted local and foreign wild bird enthusiasts and ecotourists. In 2004, about 5,000 heads of both migrant and resident birds were counted. Population size and species diversity of wildbirds in LPPWP, however, seems to vary with time. While official reports put the number of migrant and resident species found in LPPWP a total of 175 species, the Wild birds Club of the Philippines reported in 2005 that for the period January 2003 to June 2005, a total of 104 species were sighted in LPPCHEA with 91 species found in the mudflats and 13 species in the coastal lagoons. More than enhancing the sceneries of the coastal seascape of Manila Bay and their significance to ecotourism, these wild birds contribute to the enhancement of the coastal ecosystem functions in the area as shelter, feeding and breeding grounds of fish, crabs and other marine life. These numerous birds contribute to the dispersal and fertilization of the LPPWP vegetation the most prominent of which are the mangroves that likewise serve as buffer of horizontal and vertical infrastructures against storms or strong winds, traps for eroded soil and home of various wildlife species. (LPPWP, 2019).

In 2018, the LPPWP was legislated as a Protected Area under the ENIPAS lawThe area is under the jurisdiction of the Department of Environment and Natural Resources - National Capital Region and managed by its Protected Area Management

Board (PAMB) composed of multi-sectoral body from relevant National Government Agencies (NGAs), Local Government Units (LGUs), Non-Government Organizations (NGOs), Private Sector, Academe, and other stakeholders.

Coastal biodiversity assessment and contingent valuation study in LPPWP

In a coastal biodiversity survey done in LPPWP in 2024 under the Foreign-Assisted and Special Projects Services (FASPS) a, a total of 25 species of below-water macrofauna was observed. This was composed of 20 fish species, three (3) crustaceans, and two (2) polychaetes. Most of these species, particularly fish species such as the Blue-spot Mullet (Crenimugil seheli) locally as Kapak and the Blackchin Tilapia (Sarotherodon melanotheron) locally known as Tilapia Arroyo, are major target species with significant commercial value amongst local fisherfolks either for sustenance or for selling. Interestingly, shrimp and tilapia larvae/fingerlings have been observed and caught within the mangrove stands of LPPWP, some of which were even present in standing water that have been trapped due to receding tides. These findings highlight the LPPWP wetland ecosystem's role as a critical habitat and refuge for a diverse array of below-water macrofaunal and macrobenthic communities. Likewise, this also highlights the value of the wetland ecosystem, particularly mangrove forests, in providing essential supporting services that maintain the productivity of fisheries in the area. (Ancog, R., Gamido, R. M., & De Ramos, et al., 2024).

Currently, the study of Bendaño et al. (2017) is one of the most comprehensive listings of below-water macrofauna species that can be found in Manila de Bay. They reported a total of 146 species of fish and invertebrates caught during their trawl survey. Of the top 50 species in terms of biomass, nearly 44 fish species were collected in Manila and Cavite with relative biomass (combined values of demersal and pelagic species) ranging from 1% to 30%.

For Direct Use values, LPPWP offers substantial economic benefits through its rich marine ecosystems and recreational opportunities. It serves as a critical resource for the local fishery sector, generating an estimated annual value of PHP 245,000 to PHP 27 million from fish, shellfish, and mollusks. This direct benefit not only supports families and businesses but also sustains local economies and contributes to food security across Metro Manila. Aside from this, recreational activities in LPPWP add approximately Php 942,381 annually to its economic value. These ecosystem services emphasize the importance of LPPWP in supporting the local economy and preserving biodiversity, highlighting its potential for educational and eco-tourism initiatives. Meanwhile, LPPWP's indirect use value, including the prevention of coastline erosion, provision of nursery grounds, and climate regulation, contributes to environmental stability and disaster mitigation. The economic value of these services is estimated at approximately PHP 13.7 million (USD 245,620.96), highlighting the LPPWP's role in enhancing urban resilience against climate adversities without direct consumption of resources. This is particularly critical given Metro Manila's vulnerability to climate change. Thus, this highlights the significant economic benefits of maintaining the ecological integrity of LPPWP. (Ancog, R., Gamido, R. M., & De Ramos, et al., 2024).

Vulnerability assessment of LPPWP

LPPWP is found in the western side of the Cavite-Manila Coastal Road, bounded on the north by Paranaque River and on the south by Las Pinas River. The LPPWP landmass comprises Freedom Island on the north and the Long Island in the south separated from the Metro Manila mainland by a vast mudflat expanse which submerges with seawater during high tide. LPPWP becoming a garbage sink is inevitable given its location in between the mouth of Paranaque River immediately in its northern boundary and the mouth of Las Pinas River immediately in its southern boundary. However, other possible sources of solid wastes are rivers in Cavite draining to Manila Bay south of the Cavite City peninsula as well as Pasig River where all types of solid wastes are carried from the severely polluted San Juan River to Manila Bay. The presence of a garbage dump near the bank of Las Pinas River about half a kilometer from Long Island, exacerbates the solid waste problem in the area. The mountain of solid waste that accumulates in LPPWP is astounding as seen by thenaked eyes. This is not surprising given both the location of LPPWP vis-à-vis three nearby major rivers as well as the statistical data on uncollected solid waste in Metro Manila, including the Las Pinas-Paranaque coastal barangays. (LPPWP, 2021).

Aside from Paranaque River, Las Pinas River, and Zapote River the protected area is drained by seven (7) major rivers from 26 catchments including Pasig River (NCR), Pampanga River (Nueva Ecija, Pampanga and Bulacan), Talisay River (Bataan), Mecauayan river (Bulacan), Navotas-malabon-tullahan-tenejeros river (NCR), Imus River (Cavite) and Maragondon River (Cavite). All of the above major rivers are sources of solid wastes that are transported into various parts of Manila Bay. With regards to solid wastes volume that are carried into LPPWP, the only reliable empirical data are the garbage collected during coastal clean ups. (LPPWP, 2021).

In 2025 International Coastal Cleanup (ICC), a global initiative to collect and document coastal trash, a total of 18, 352 sacks of trash were yielded, whereas1,181 sacks came from LPPWP. (DENR NCR, 2025). In Metro Manila alone, based on data from the MMDA, about 8,000 tons of solid waste are generated per day of which only 85% is collected for transport to garbage disposal sites. However, in a survey of residents in the Las Pinas and Paranaque coastal barangays, government collection efficiency for solid wastes is lower at only 59.84% meaning only about 60% of the population dispose of their garbage through the government collection system. Of the total population, 12% rid their garbage by burning, 12% throw their garbage directly into Manila Bay and 4% in the nearby dumpsite, 9 % throw them anywhere while 3% simply leave their garbage in any public corner. Multiplying the population in the coastal barangays at the LPPWP boundary (i.e. 7,995 residents) with the average solid waste generation per capita (0.597 kgs per day) and multiplying the result with 12% of residents throwing their garbage directly into Manila Bay is a simple method of providing the probable volume of wastes being thrown directly into LPPCHEA from the coastal barangays alone. It is 572.76 kgs per day. (LPPWP, 2021).

Constructed wetlands as a nature-based solution

Microplastics pollution is one of the major concerns for water quality affecting ecosystem and human welfare. Nature-based solutions like constructed wetlands, act as passive filters: vegetation, soils, and microbial communities within wetlands can trap and retain microplastics in sediments and plant biomass. Some studies report removal efficiencies above 99% for larger particles in stormwater contexts, indicating that wetland systems could be integrated or restored as part of microplastic mitigation strategies in coastal parks like LPPWP. (OECD, 2021).

III. STATEMENT OF THE STUDY

The LPPWP being part of Manila Bay is surrounded by three (3) river systems, including Paranaque River, Zapote River, and the Las Pinas river. Aside from these rivers, Manila Bay is drained by seven major rivers from 26 catchments, which makes the LPPWP highly vulnerable to anthropogenic activities such as improper waste disposal since all pollutants coming from these rivers end up in it.

Plastic waste being one of the most prevalent wastes contributing to marine litter in LPPWP faces growing environmental concern. Despite the role of mangroves in the area as critical coastal buffers and biodiversity hotspots, and the mudflats as a breeding ground of wildlife, there is limited research on the extent of microplastic accumulation in this area. This study aims to address the knowledge gap on the occurrence of microplastics across different habitats in LPPWP and its potential implications for biodiversity in the area.

It is essential to investigate their occurrence by considering exposure levels and potential pathways of bioaccumulation. By assessing the presence of microplastics in the area, the findings are expected to contribute to a more comprehensive understanding of microplastic pollution in coastal habitats and support evidence-based management and policy decisions to mitigate ecological risks in Philippine mangrove environments and wetland habitats.

IV. OBJECTIVES OF THE STUDY

The primary objective of the study is to systematically assess the occurrence of microplastics in the sediments of various important habitats in LPPWP to provide science-based recommendations for habitat conservation and management. Specifically, it aims to:

1. To collect sample sediment and analyze the prevalence and distribution of microplastics in the mangrove, mudflat, and shoreline sediments of LPPWP through sediment sampling;
2. To physically characterize microplastics by color, size, shape, and polymer type using prescribed analytical techniques and chemical characterization through laboratory analysis; and
3. To analyze the potential risks of microplastics to the existing wildlife by considering their exposure pathways, how they accumulate in the sediments, and impacts by predicting which particles organisms are most likely to encounter or ingest.

V. RATIONALE

Over the previous years, microplastic pollution in coastal and other aquatic systems has become an emerging issue. There is considerable interest in understanding the impacts of microplastics on aquatic wildlife, as the impacts remain poorly understood. (Thompson et al. 2004, Browne et al. 2007).

The LPPWP being located in a highly urbanized area known for its high population density and is surrounded by various pollution sources is tagged as the “Last Coastal Frontier of Metro Manila” and recognized as an important migratory bird hotspot (Ramsar Site) and serves as a vital habitat for a wide variety of threatened and vulnerable wildlife species as a legislated Protected Area.

Given the area’s ecological importance, this study aims to provide essential information that can support and help in the updating of the protected area management plan for LPPWP, ensuring that microplastic considerations are effectively integrated into future conservation and protection strategies.

All plastic size categories when spread in the environment have various adverse effects on the environment. Particularly, those microplastics which can be rapidly ingested by a wide range of marine animals mistaken it for food particles. This incidence can cause internal injuries, blockages that can reduce their ability to eat, leading to starvation and death.

In a Coastal Biodiversity survey done in LPPWP in 2024 under the Foreign-Assisted and Special Projects Services (FASPS), a total of 25 species of below-water macrofauna composed of 20 fish species, three (3) crustaceans, and two (2) polychaetes were observed. Further, based on the recent quarterly Bird Monitoring record of LPPWP, there are 175 species of birds that can be found in the area of which

25 are endemic, 72 migrant, and 51 resident birds. These studies support that LPPWP is an important habitat to various wildlife species that can be affected by microplastics threat.

Investigating the occurrence, abundance, and polymer types of microplastics within the mangrove and intertidal mudflats of LPPWP which is identified as a significant threat to both marine and wildlife is essential to incorporate appropriate conservation measures. Particularly, by quantifying the plastics abundance, characterizing microplastic presence (color, and polymer type) and evaluating microplastic risk to wildlife and existing habitat it will gain understanding on the complexity of microplastics that can pose risks.

VI. SCOPE AND LIMITATIONS

This study focused on assessing the distribution and prevalence of microplastics in the mangrove, mudflats, and shoreline sediments of LPPWP, which threaten both marine and wildlife populations and survival. It involves the collection and analysis of sediment samples to determine the concentration, characteristics of microplastics, as well as to identify potential sources and transport pathways. The study also evaluates the potential risks to habitats and associated organisms and provides recommendations for management and policy interventions.

The research is limited to testing of soil sediment samples only and does not include the collection and testing of water and biotic samples, as the sampling was restricted to a specific period. Further, sampling sediment collection was conducted during the wet season (September – October 2025), considering that it is the most ideal time for collection since heavy rainfall and strong runoff transport more plastics from surrounding areas into the wetland. This period captures the peak influx and accumulation of trash in the area based on the consolidated trash data information of LPPWP every year. Findings are site-specific to LPPWP and may not be generalized to the entire Manila Bay.

VII. DESCRIPTION OF THE STUDY AREA

Figure 7.1. Boundary Map of LPPWP.

LPPWP formerly known as Las Pinas Paranaque Critical Habita and Ecotourism Area is a coastal wetland located within the Manila Bay area and a legislated protected area under Republic Act No. 11038, also known as the Expanded National Integrated Protected Areas System (ENIPAS) Act of 2018. Aside from being a protected area, it was declared as the 6th Ramsar Site in the Philippines under the Ramsar Convention through Presidential Proclamation No. 1412. LPPWP has a total area of 181.63 hectares composed of mosaic habitat, including beach forest, saltmarshes, lagoons, 36 hectares of mangrove, and 111.67 hectares of mudflats.

It is divided into two main islands: Freedom Island located on the side of Paranaque City and Long Island situated in the city of Las Pinas. Moreover, it has two

(2) major management zones namely (1) Strict protection zone and (2) Multiple-Use Zone. The latter is further divided into (a) Recreational zone and (b) Sustainable Use Zone.

Strict Protection Zone is devoted to habitat restoration. biodiversity enhancement and research, thus public access to said areas is strictly limited. The mangrove areas, salt marshes and mud flats (north and south lagoons) are all part of the Strict Protection Zones. In the MUZ, the stretch of the Long Island, except the mangrove areas and lagoons, and certain portions of Freedom Island are designated as Recreational Zones wherein visitors are given free access to this area.

The various habitats in LPPWP support a wide range of biodiversity. There are about 23 species of mangrove in the area including Nilad, Bungalon, and Bakawan. This serves as the spawning, nursery feeding and temporary shelter for wildlife species. Further, the Mudflat serves a vital resting, breeding and feeding ground of wild birds consisting of macroinvertebrates. (LPPWP, 2019).

VIII. METHODOLOGY

The study employed a rapid assessment approach following the prescribed methods by the National Oceanic and Atmospheric Administration (NOAA): Laboratory Methods for the Analysis of Microplastics in the Marine and Coastal Environment (2015), and the procedures of Microplastics Extraction developed by Besley et. al (2017), with some modifications testing its applicability to provide baseline information since there is no current study of MP pollution.

Figure 8.1 Process flow of microplastics sampling and processing.

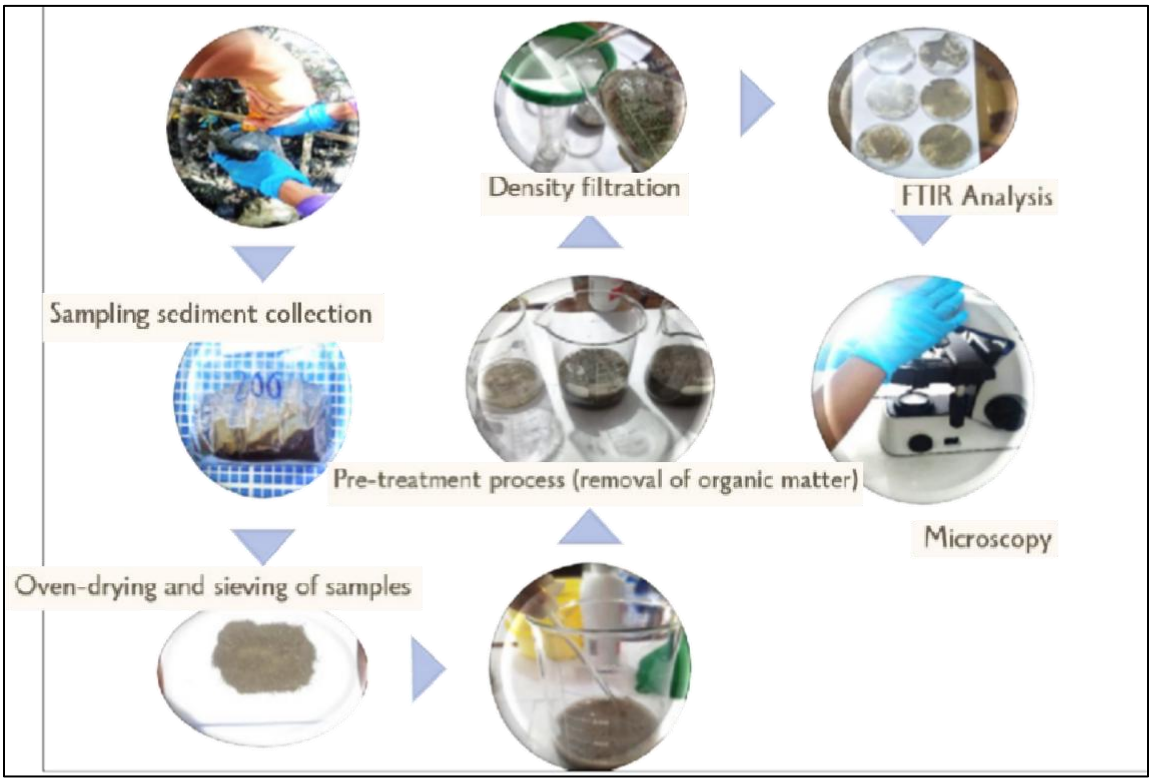


Table 8.1

General Description of the three selected sampling sites within LPPWP

Station	Area Description	General Condition	Ecosystem Services
Mangrove	Forms continuous and patchy stands of trees	Moderately to highly disturbed; dense root systems trap sediments, organic matter, and anthropogenic debris including plastics; functions as a sediment and microplastic sink	Composed of mangrove trees mostly *Avicennia* with some *Rhizophora* species. Some benthic invertebrates (crabs) juvenile fish, arthropods, and serves as feeding and roosting habitat for resident and migratory waterbirds.
Mudflat	Largest habitat with extensive intertidal area exposed during low tide	Open with high tidal influence; subject to sediment pollutant; acts as a dynamic accumulation and redistribution zone for microplastics	Benthic macrofauna (bivalves, gastropods), crustaceans, microphytobenthos, foraging grounds for migratory and resident shorebirds
Shoreline	Narrow continuous strip along the water's edge	Exposed and disturbed; influenced by wave action, tidal flushing, and direct anthropogenic inputs; acts as a transition and	Opportunistic fauna (small crustaceans, gastropods), fish larvae, algae, and transient use by birds and other wildlife

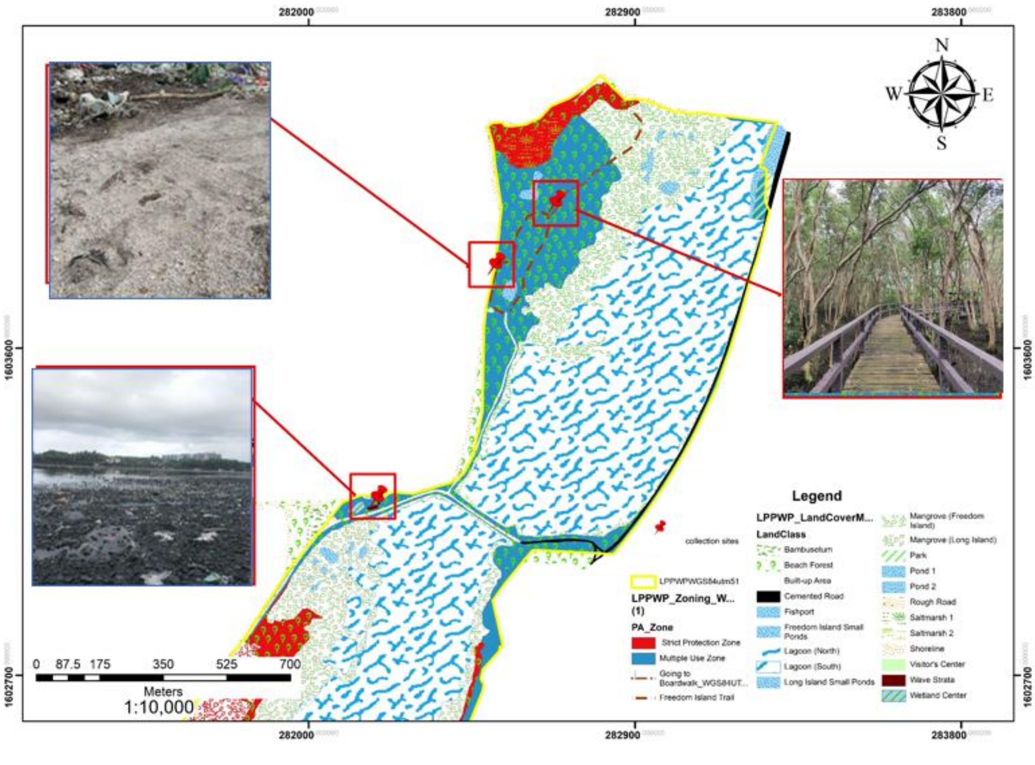
		transport zone for plastics	

Sampling Stations

Microplastics were sampled from the surface sediments at three (3) different stations representing various important habitats in the area: Station 1 Mangrove Area, Station 2 Mudflat area, and Station 3 the shoreline area.

The sampling sites were selected based on their potential for pollution pathway accumulation. The reduced water velocity in these locations promotes the deposition and retention of microplastics, making them suitable for assessing the extent of microplastic contamination.

Figure 8.2. Map of sampling stations.



Sediment collection

Sampling sediment collection was conducted during the wet season (September – October 2025), considering that it is the most ideal time for collection since heavy rainfall and strong runoff transport more plastics from surrounding areas into the wetland. This period captures the peak influx and accumulation of trash in the area based on the consolidated trash data information of LPPWP every year.

Samplings were carried out in the identified sampling sites using a quadrat of 50 cm × 50 cm. For each zone, a total of 200 grams of soil sediment samples were taken using a metallic spoon to collect soil within the sampling square with 0-100 mm to 100-200 mm depth. The collected samples were labeled and stored in Ziplock to prevent contamination.

Figure 8.3. Soil sampling collection.

Figure 8.4. Measuring soil depth.

Figure 8.5. Collected sediments within 0-100 mm, and 100-200m.

Processing of Sediment Samples

A combination of density separation method and laboratory analysis was employed in this study to account for the presence of microplastics within selected habitats in LPPWP.

Visual Inspection

The sediment samples were oven-dried at 60°C for 48 hours. The sediment samples were then sifted through standardized sieves with progressively smaller openings. microplastic. The assessment of the suspected microplastics was done by visual inspection. The sediment particles that were visible to the naked eye larger than 5mm (macroplastics) were manually eliminated and discarded. Meanwhile, the sediments obtained from sieving (estimated with a fraction less than 5 mm) were retained for microplastic extraction through density separation method.

Density Separation

To extract the plastic by the Density Separation method, a fully saturated sodium chloride (NaCl) solution was prepared by dissolving 71.78 grams of NaCl in 190-ml distilled water (total of 38% solution). For each sample, a 50-g homogenized sediment sample was subjected to WPO by mixing with 50 ml 30% hydrogen peroxide.

The mixture was stirred for 5 min and then left to stand for 1 h to allow the sediments to settle at the bottom. The addition of hydrogen peroxide was repeated until bubbling was no longer observed. A water bath (room temperature) was also used every time the bubbling becomes too violent. Approximately a total of 100–200 ml of hydrogen peroxide was used to completely remove the organic matter from the sample.

Figure 8.6. Process of density separation method.

After settling, the liquid on top was decanted and filtered using gravity filtration. The sediment was then mixed with 100 mL of saturated NaCl solution to extract the microplastics. The mixture was stirred for approximately 1 minute and was left to stand for 6 hours, allowing the soil sediments to settle to the bottom. The liquid on top of the sediment was decanted. The density separation was done for another two rounds using the same sediment sample with fresh NaCl solution. After filtration, the pieces of filter paper were covered with a paper towel, and left to dry for 2 days, for inspection.

Microscopic examination

After the pre-treatment process, the samples were transported to Calayan Educational Foundation, Incorporated – Medical Technology Laboratory to observe for the presence of microplastics using a Microscope. The identification of microplastics was done by classifying five types of microplastics namely films, fragments, fibers, foams, and pellets. Identification of microplastic types was also carried out based on type, color and size using a microscope (Olympus CX23) with 10x-40x magnification.

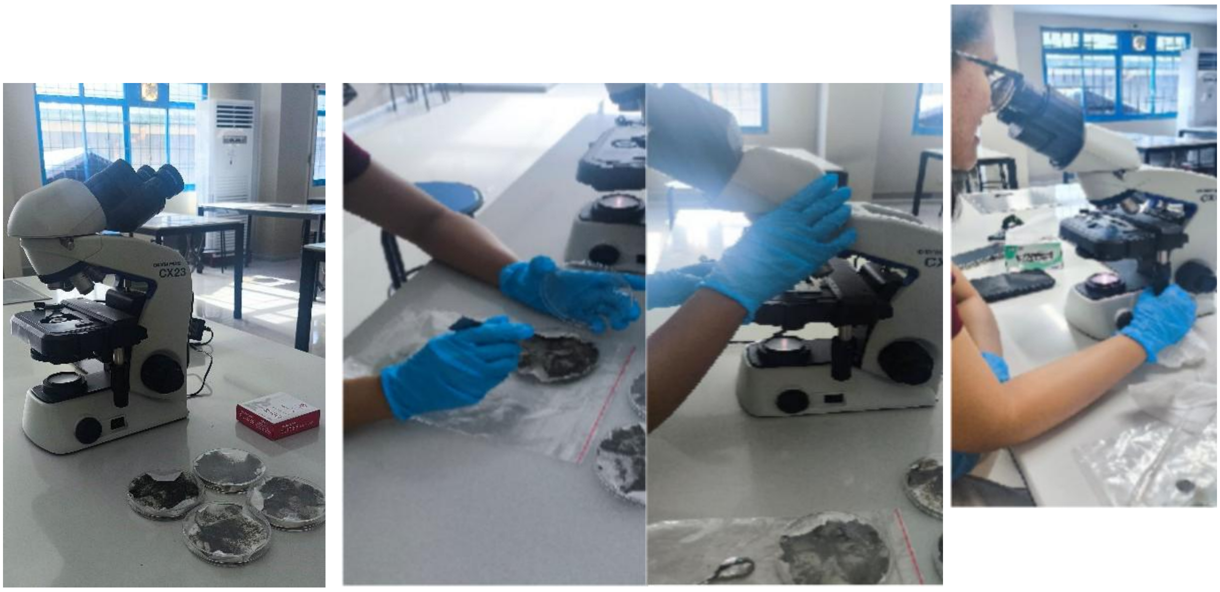


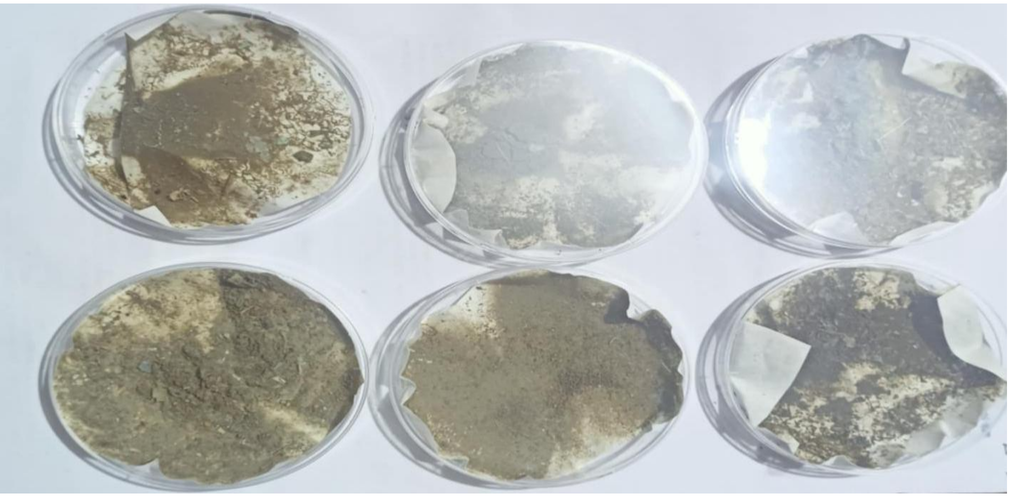
Figure 8.7. Observation of samples in the laboratory using microscope with 40x magnification.

ATR- FTIR Spectroscopy

Ideally, chemical confirmation of 100% of all particles (e.g., via FTIR) visually identified is recommended to ensure accurate identification. However, due to constraints in sample volume, instrument availability, and analysis time, a subsampling approach was applied in this study. A representative subset of 30% of the particles was selected for spectroscopy-based confirmation. Subsamples were selected using a stratified random approach based on particle size, color, and morphology to ensure they reflected the diversity of the full dataset.

For the processing of sediment samples through the use of FTIR spectroscopy, the pre-treated sediment samples were transported to the One-stop Laboratory Services of the Department of Science and Technology (DOST) in Los Banos, Laguna, for spectral analysis test. The result of the spectral scanning of the sediments were used to compare spectrum with microplastics using Handbook of Fourier Transform Raman and Infrared Spectra of polymers by Kuptsov and Zhizhin and Online Base Spectra developed by Wiley and Sons.

Figure 8.8. Pieces of filter paper transferred to petri dish and transported to laboratory for analysis.



Data Analyses

The study used statistical analysis, One-way ANOVA, to compare the mean values of counted microplastic between each sampling sites and depth-level. ANOVA was used to determine statistically significant differences between the means of independent groups.

Furthermore, the T-test (Post Hoc Test) was employed to analyze data in each sampling site collected at varying depth-level to identify which specific groups differ from each after a significant result in One-way ANOVA.

The total number of pair-wise comparisons was calculated using MS Excel Data Analyzer with this formula:

$$\textbf{Number of comparisons} = \frac{K(K-1)}{2}$$

K = the number of groups

Bonferroni correction: To control for a higher risk of Type I errors from multiple comparisons, a Bonferroni correction is often applied to the alpha level.

$$\textbf{New alpha level} = \frac{Original\ Alpha}{Number\ of\ comparisons}$$

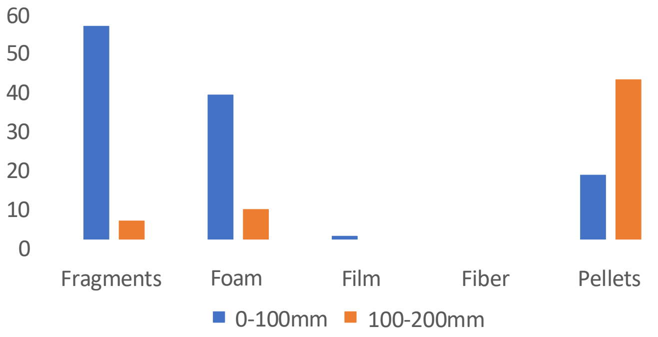
T-test formula:

- $t = \dfrac{(x_1 - x_2)}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$
- x_1, x_2 = means of the two groups
- s_p = pooled standard error
- n_1, n_2 = sample sizes of the two groups

IX. RESULTS

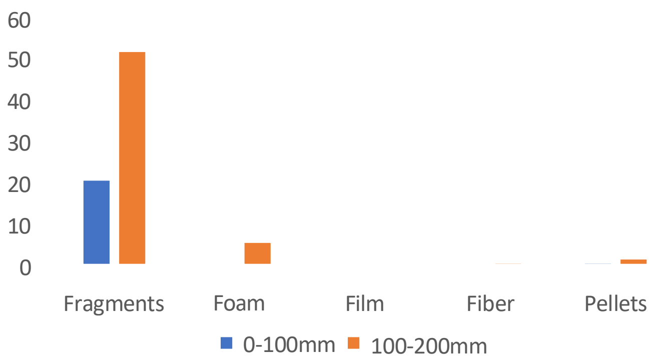
Percent Distribution of Microplastics within the three (3) sampling sites across different habitats in LPPWP

Figure 9.1. Distribution of MP in Mangrove.



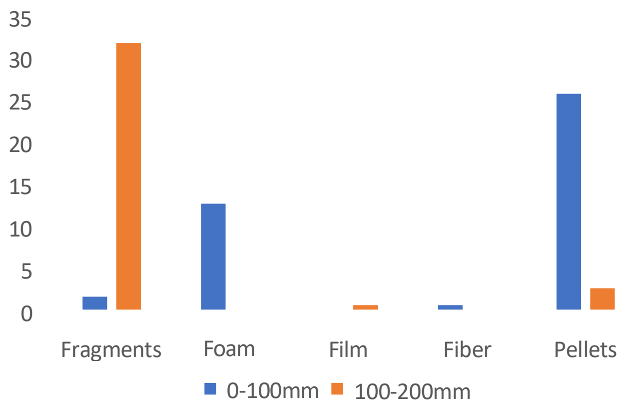
Station No. 1 located in the Mangrove area; a total of 176 particles were counted from the samples from 0-100mm and 100-200 mm soil depth. This was composed of 63 fragments, 48 plastic foams, 2 film, 2 fibers and 61 pellets type of plastic materials.

Figure 9.2 Distribution of MP in Mudflats.



Station No. 2 located in Mudflat area, a total of 83 particles were counted from the samples from 0- 100mm and 100-200 mm soil depth. This was composed of 73 fragments, 6 plastic foams,1 fiber and 3 pellets type of plastic materials.

Figure 9.3. Distribution of MP in Shoreline.

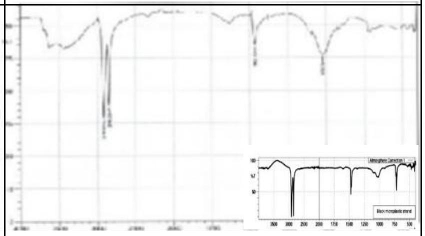
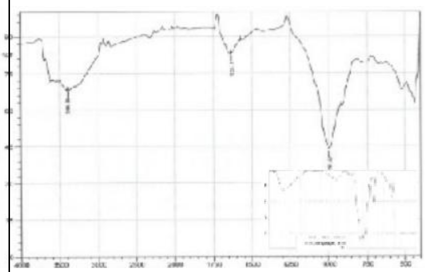
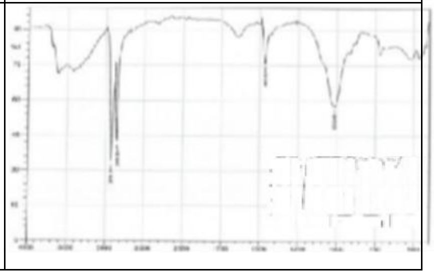


Station No. 3 located in Shoreline area, a total of 83 particles were counted from the samples from 0- 100mm and 100-200 mm soil depth. This was composed of 34 fragments, 13 plastic foams, 1 film, 1 fibers and 29 pellets type of plastic materials.

FTIR Analysis of Sediment samples

Table 9.1

FTIR Spectra Analysis of Microplastics

Sample	Key FTIR peaks (cm^{-1})	Polymer / material	Evidence (peaks/features)	Confidence	FTIR Results
A	2915, 2848, 1470, 1375 (possible), 720	Polyethylene (PE) or Polypropylene (PP)	Strong wave CH stretching at ~2915 & 2848; bending at ~1470 and rocking at ~720	Medium–High	
B	1250–1150 (broad C–F region) , 600–650 (CF_2 bend)	Fluoropolymer (e.g., PTFE / perfluorinated sulfonic acid membrane)	Strong stretching region; weak CH signals 450 to 600	Medium	
C	2915, 2848, 1470, 1000–1100 (broad)	Polyethylene (film-grade) — possibly oxidized PE or EVA (less likely)	CH stretches and bends match PE a 1000–1100 band	Medium	

(Comparative Reference Source: Handbook of Fourier Transform Raman and Infrared Spectra of Polymers by Kupstov and Zhizhin)

(A) Characteristics of sample stretches at 2951 and 2848 together with bending bands at 1470 and 720 cm. (B) Spectrum wave between 1,250 to 1150 cm^{-1} and low bending at 600-650 cm^{-1} (C) and spectra waves similar also to polyethylene but shows sign of weathering or degradation.

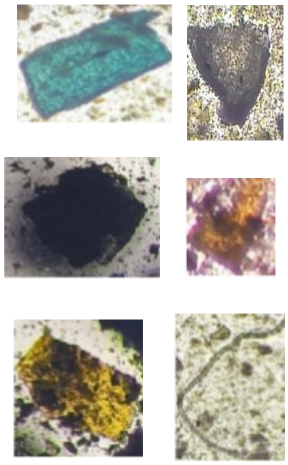
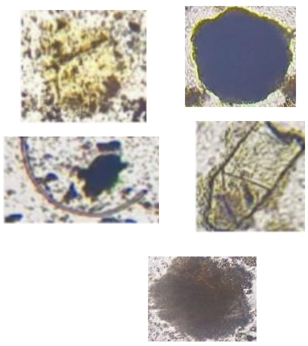
X. ANALYSIS AND DISCUSSIONS

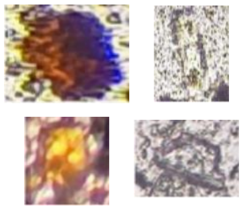
Physical Characterization

The identification of microplastics was done by classifying five types of microplastics namely films, fragments, fibers, foams, and pellets. Microplastic particles were counted in a "zigzag" pattern from left to right. The data was processed using ImageJ Processing Software to account for the particle size and area measurements. The data were displayed in the form of tables and images which were analyzed descriptively. Tabulated below is the summarized data of the particles.

Table 10.1.

Classification of microplastics observed based on physical characteristics.

Component	Type	Shape	Color	Photo
Station 1: MANGROVE	Plastic films, Foamed plastic, Filaments, Fibers	Flat, irregular, subrounded, irregular, elongated, broken edges	Blue, Transparent, opaque, yellow, elongated, yellow, grey	
Component	**Type**	**Shape**	**Color**	**Photo**
Station 2: MUDFLATS	Plastic films, Foamed plastic, Fibers	Subrounded, elongated, irregular, broken edges	Yellow, Opaque, Elongated, Transparent, Gray	

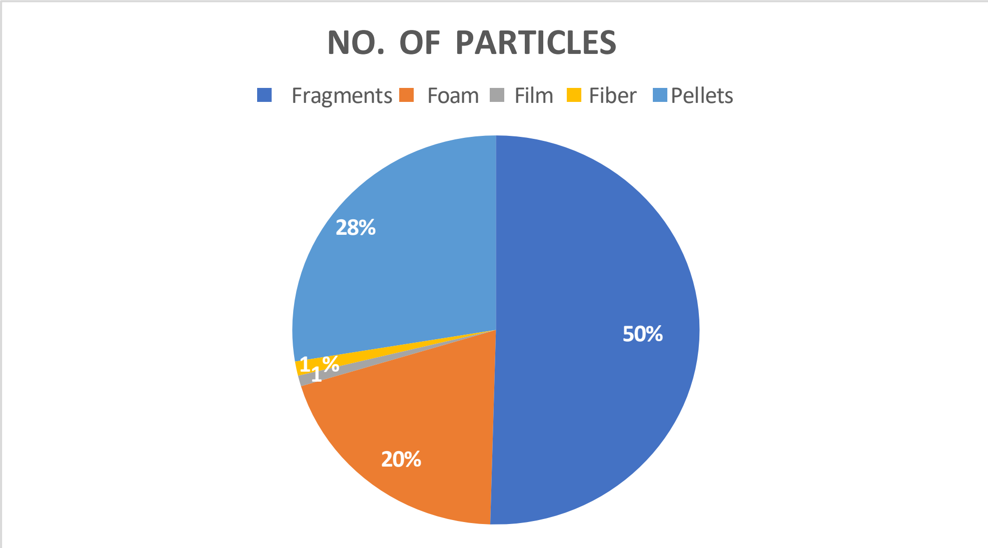
Component	Type	Shape	Color	Photo
Station 3: SHORELINE	Plastic fragments, Fibers filaments, Pellets	Subrounded, irregular, elongated, broken edges	Red, Transparent, yellow, crystalline	

(Comparative Reference used: Field Manual on Microplastics by National Environmental Science Program)

The microscope examination showed that particles collected from the three stations shared similar physical characteristics. Across all sites, the observed microplastics were generally small (mostly <250 μm), and displayed a range of shapes, including flat, irregular, sub-rounded, and elongated forms. Their colors were also diverse, with particles appearing blue, transparent, opaque, yellow, gray, red, and crystalline, reflecting diverse sources and degradation processes within the wetland park.

Presented in the figure below is the percentage of each identified type of microplastics in all sampling sites in LPPWP.

Figure 10.1 Percent distribution of five (5) identified microplastics



Fragments were the most abundant shape, accounting for 50% of the total microplastics. The highest abundance of microplastics was observed in the mangrove area, which was dominated by fragments and pellets. Fragments likely resulted from the breakdown of larger hard plastic objects e.g. bottles or containers, packaging materials, and household waste (Wootton et al. n.d.), which enter the wetland through waterways and storm drains. These fragments were identified as polypropylene (PP) which was the most abundant polymer type identified in the sample sediment. Meanwhile, pellets come from small particles of raw materials in industrial plastic production in nearby industrial buildings in the wetland. (Wootton et al. n.d.). This dominance is consistent with microplastic pollution in urban coastal ecosystems since it is well-known for high population and high industrial activities that can contribute to the plastic pollution.

The third type of microplastics identified was foam constituting 20% of the total microplastics. This category includes expanded plastic foam materials like foam cups, packaging, and insulation. These particles are lightweight and will compress if squeezed. (Wootton et al. n.d.) Further, this waste could be linked to the presence of nearby Saprahan and Mussel Culture in the area. The particles of Film and Fiber identified was low in quantities, though constituting only 1% of the total microplastics, suggesting degradation of plastic bags and thin-film packaging.

The majority of microplastics fell within the <250 μm size class, indicating advanced fragmentation and prolonged weathering within the wetland environment. Smaller particles are more easily transported by tidal currents, and their accumulation in sediment reflects the low-energy, depositional nature of LPPWP zones such as mangrove areas and mudflats.

The most common colors were black, transparent, blue and yellow. Blue fibers are often linked to synthetic clothing materials, while black fragments may originate from rubber, tires, or burnt plastic debris. Transparent particles, usually from polyethylene bags and packaging. (Wootton et al. n.d.)

The abundance and shape distribution observed in LPPWP are comparable to findings from other studies in adjacent habitats to LPPWP like the Preliminary Study on Microplastics in Bivalves from Bacoor Bay, Cavite, an area affected by intense urban and household waste input. In this study, microplastics were found in all three species tested, such as mussels, oysters, and clams. Most particles identified were fibers and fragments, consistent with urban plastic sources such as clothing fibers, packaging, and degraded consumer goods. This similarity highlights the widespread influence of domestic wastewater and urban runoff in microplastic contamination patterns.

Chemical Characterization

FTIR Spectra Analysis

Although visual sorting was used to identify potential microplastics, not all particles that appear plastic are truly synthetic, particularly at smaller size classes. Best approach for chemical verification of particles is 100%. However, this was not logistically feasible for the study due to the large number of particles and limited access to FTIR Laboratory. As a result, only a subsample of 30% of the particles was subjected to confirmation analysis.

In this study, subsamples were selected to represent the full range of colors, morphotypes, and size categories observed in the entire dataset. Nonetheless, the use of subsampling introduces some uncertainty, which should be considered when interpreting microplastic abundance and composition.

The study also employed Spectra Comparison and Verification using Online Spectra Base from John Wiley & Sons, Inc. and Handbook of Fourier Transform Raman and Infrared Spectra of Polymers by Kupstov and Zhizhin. The results of FTIR analysis of the samples were compared to the spectra of various types of plastic compounds to identify what type of plastics were present in the area. Based on the available references, Polyethylene peaks between 2950 to 3000 cm; PTFE from 450 peaks to 500 and weakens at 550, PP peaks between 2900 to 2950 and weakens and drops at 2950 forward. Comparing this to the results of spectral scanning of samples, the spectra from the first characteristics samples stretch at 2951 and 2848 together with bending bands at 1470 and 720 cm1. This spectrum is consistent with that of Polyethylene or Polypropylene (PP) group. Next one, spectrum wave is between 1,250 to 1150 cm^{-1} and low bending at 600-650 cm^{-1} which is consistent with fluorinated polymer (PTFE). The third and last spectra, waves at Spectra, waves at 2915 similar also to polyethylene but shows sign of weathering or degradation since there is a flattened features within the wave of spectra. The spectra analysis reveal possibilities of PE, PP and PTFE type of polymer in the sample.

Data Analyses – ANOVA Tests

For the analysis of data, the study used statistical analysis, One-way ANOVA, to compare the mean values of microplastic between each sampling stations and interpret results.

Table 10.2

Summary Data Analysis of Variance.

SUMMARY						
Groups	**Count**	**Su m**	**Averag e**	**Variance**		
Station 1	6	352	58.6667	4065.466667		
Station 2	6	166	27.6667	1534.266667		
Station 3	6	156	26	839.2		
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	4061.78	2	2030.89	0.946222977	0.4102	3.68232
Within Groups	32194.7	15	2146.31			
Total	36256.4	17				

Based on the tabulated data above, since the P-value is less than 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted. Hence, there is a significant difference between the three sampling stations. The one-way ANOVA revealed a statistically significant difference in microplastic abundance among the three sampling stations with P-value < 0.05). This indicates that the overall microplastic levels vary across habitat types.

Table 10.3.

Summary Data of T-Test using Post-Hoc Test.

Sampling depth	P Value (T Test)	Significance
S1.1 VS S2.1	0.141042976	No
S2.1 VS S3.1	0.554802578	No
S3.1 VS S1.1	0.244996862	No
S1.2 VS S2.2	0.975816547	No
S2.2 VS S3.2	0.682435515	No
S3.2 VS S1.2	0.661310315	No

TEST	ALPHA
ANOVA	0.05
Post-Hoc Test (Bonferroni Corrected)	0.008333333

Meanwhile, although ANOVA results revealed significant difference of microplastics occurrence across habitats, the T-test using Post Hoc Bonferroni-corrected comparisons revealed no significant pairwise differences among the sampling depths used. This suggests that while the general trend indicates greater microplastic trapping in other habitat types, the variability within stations, sampling depth, and the conservative nature of the Bonferroni correction prevented the detection of statistically significant pairwise differences.

Table 10.4

Potential pollution sources of plastics according to type.

Fragments	Breakdown of larger hard plastics such as bottles, containers, packaging materials waste from visitors or may be transported through waterways and river systems from nearby households.
Pellets	Spillage or leakage of raw materials from nearby industrial plastic production facilities within Manila bay.
Foam	Foamed plastics, possibly linked to fishing activity or mussel culture within Manila Bay.
Film	Degradation of plastic bags, food wrappers, and other thin-film packaging from nearby households and industries transported through waterways and river systems.
Fiber	Wear and tear of synthetic fabrics, ropes, nets, or textile-related waste from fishing-related activities.

The findings of the study were used to infer the potential sources of plastic pollution affecting the wetland. The table provides indicative interpretations linking observed microplastic types to known pollution pathways in and around the site. These interpretations serve as preliminary insights rather than definitive source apportionment, underscoring the need for more comprehensive analyses in the future, such as hydrology and runoff-influence studies to better trace microplastic transport mechanisms.

Fragments and films, which typically result from the breakdown of larger rigid plastics (for example, bottles, food containers, and common packaging materials), may originate from visitors given that LPPWP is a well-known ecotourism site in Metro Manila. They may also come from nearby households and industries, with wastes carried through connected river systems such as the Las Piñas, Parañaque, and Zapote Rivers that are connected to the LPPWP. Pellets, on the other hand, are likely linked to leakage or accidental release of raw plastic materials from industrial facilities around Manila Bay. Foamed plastics may be associated with mussel culture practices in the area, where floatation devices made of foam are commonly used which you can see in the photo presented here. Meanwhile, fibers likely stem from the shedding of synthetic textiles, the wear of ropes and nets, and other fishing-related activities that continuously contribute to the fine thread-like debris found in the sediments.

Table 10.5.

Risk assessment of microplastics in LPPWP.

Habitat / Station	Dominant Microplastics	Possible reason for accumulation	Exposed Wildlife	Risk/Pathway
Station 1: Mangrove	Fragments, Pellets, Foams	Root entrapment, sediment retention	Mudskippers, crabs, mollusks, benthic worms, herons, egrets,	Sediment ingestion, foraging, trophic transfer
Station 2: Mudflat	Fragments	Fine sediments trap small particles	Wading birds, benthic infauna, polychaetes	Surface feeding, sediment filtering
Station 3: Shoreline	Fragments, Pellets, Foams	Wave deposition, runoff inputs	Small fish, surface-feeding waterbirds birds	Direct ingestion, (confusion with food)

Marine Biodiversity		
Fish, Crustaceans, and polychaetes	Blue-spot Mullet/Kapak and Blackchin Tilapia (Sarotherodon melanotheron), shrimp	20 fish species, three (3) crustaceans, and two (2) polychaetes
Plankton	Bacillariophyceae (diatoms), Cyanophyceae (cyanobacteria), and Dinophyceae (dinoflagellates)	21 genera
Phytoplankton	Dinoflagellate: Protoperidinium, Diatoms: Chaetoceros, Rhizoxolenia, Pleurosigma, Biddylphia, Skeletonema	
Zooplankton	copepoda (calanoid, cyclopoid, harpacticoid), cladocera, ciliate, mollusca, and rotifera	14 taxa
Macrobenthos	Annelida, Arthropoda, and Mollusca (Mollusks: 13 bivalves and 4 gastropods)	19 species
Waterbirds	Black-winged stilt (Himantopus himantopus); Egrets and terns, ittle egret, Nankeen night heron, Black-crowned night heron, sandpipers, greenshank and etc.	258 individuals, 27 spp
Terrestrial Biodiversity		
Arthropods	Collembola (springtails), Hymenoptera (ants and wasps), Isopoda (woodlice), and Acari (mites)	139 morphospecies
Amphibains	Common tree frog, Crab-eating frog, Cane toad	3 spp
Volant mammals	esser short nose fruit bat, greater musky fruit bat	2 spp

The biodiversity data presented on the left were based on studies conducted in LPPWP from 2023 to 2024, demonstrating that the mosaic habitat of LPPWP supports a wide range of wildlife, including fish, crustaceans, polychaetes, plankton and zooplankton, macrobenthos, waterbirds, arthropods, amphibians, and mammals. In contrast, the table on the right shows the indicative species potentially affected by microplastic exposure or ingestion, inferred from their feeding behaviours and known exposure pathways.

While this provides an initial assessment of risk, further investigations such as biota testing are necessary to validate these assumptions.

Microplastics entrapped within mangrove roots pose risks to mollusks, crabs, benthic organisms, and waterbirds due to sediment ingestion, foraging activities, or trophic transfer. In the mudflats, where microplastics become embedded in fine sediments, benthic fauna and waterbirds that feed on surface sediments are likewise vulnerable. Along the shoreline, microplastics deposited by waves and runoff may be ingested by small fish and other surface-feeding organisms, as well as waterbirds that may mistake these particles for food. This highlights the need for continued monitoring and targeted studies to better understand exposure pathways and ecological impacts within the LPPWP ecosystem.

XI. RECOMMENDATION AND CONCLUSION

The origins of the microplastics across sediments in various habitats in LPPWP may be attributed to three (3) main sources: (a) linkage to waterways and river channels, (b) direct introduction by visitors, and (b) weathering breakdown of macro or meso plasics debris from nearby industrial areas. The result of the study highlights the urgent need for integrated management of plastic and targeted interventions for the protection of identified important habitats as well as the existing biodiversity in the area. (Gregory and Andrady, 2003).

To provide a science-based guidance for management and policy interventions aimed at reducing microplastic pollution and enhancing habitat protection in LPPWP, based on the findings of this study the following are key measures that can be incorporated into the updating of the protected area management plan:

Waste-source reduction program

Management should prioritize stronger source-reduction and monitoring interventions to address the increasing presence of microplastics across its habitats, including the installation of waste interception systems such as trash traps or river booms along major river inlets that discharge into the wetland. Such collaboration may be formalized through a Memorandum of Agreement (MOA/MOU), which is feasible given that the LGUs are active PAMB members.

Habitat Sediment Monitoring Program

Institutionalize a Habitat Sediment Quality and Microplastics Monitoring Program through regular temporal sampling of sediments and selected biota to track microplastic loading, assess ecological risks, and evaluate the effectiveness of management interventions over time.

Strict implementation of EPR for business and industries through LGUs and Barangays

Support EPR implementation by integrating EPR-related requirements in business permit renewal (e.g.) proof of compliance from DENR-EMB, certification of enrollment under a Producer Responsibility Organization (PRO), and submissions of waste diversion, plastic recovery, and audit reports into their BPLO system to ensure that only compliant establishments are granted permits.

Promote waste diversion and recovery initiatives by establishing plastic take-back programs in barangays, installing plastic recovery bins in coastal and riverside areas near LPPWP, and partnering with PROs for localized plastic recovery efforts.

Develop a GIS-based microplastic pollution zoning map for LPPWP

To strengthen future monitoring, it is also recommended to develop a GIS-based microplastic pollution zoning map for LPPWP, incorporating habitat type and sediment characteristics. Mapping microplastic distribution across mangrove structural zones (seaward edge, mid-zone, landward zone) can guide targeted clean- up efforts and habitat restoration priorities. Future research may adopt a temporal sampling combined with artificial intelligence (AI) and machine learning techniques to model microplastic transport and accumulation pathways. AI-based models integrating tidal data, sediment dynamics, and land-use patterns could predict microplastic hotspots and accumulation trends over time, supporting proactive management.

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