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IDENTIFICATION OF MARINE DEBRIS ON MARANNU BEACH PASIMARANNU VILLAGE, SINJAI REGENCY

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Abstract

Marine debris has become one of the most significant environmental challenges affecting coastal ecosystems, particularly in developing coastal regions where fisheries, tourism, and human settlements coexist. This study aimed to identify the composition, size distribution, biomass, and spatial distribution of marine debris on Marannu Beach, Pasimarannu Village, Sinjai Regency. Field sampling was conducted in May 2025 using the line transect method recommended by NOAA. Three sampling stations were established, each consisting of three transects and three 10 × 10 m quadrats. All collected debris was classified according to material type (plastic, wood, glass, rubber, textile, metal, and expanded polystyrene), size category (mega, macro, and meso), and total weight. Oceanographic parameters, including currents, waves, and tides, were obtained from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) to support interpretation of debris accumulation patterns. The results demonstrated that plastic was the dominant debris type at all sampling stations, reflecting the substantial influence of fisheries, tourism, and domestic activities on coastal pollution. Macro-debris represented the predominant size category, indicating that most waste entered the coastal environment before undergoing fragmentation. In contrast, wooden debris contributed the greatest biomass despite being less abundant than plastics. Variations among sampling stations were closely associated with differences in surrounding land use and hydrodynamic conditions, particularly current direction, wave height, and tidal fluctuations. These findings indicate that marine debris accumulation on Marannu Beach is controlled by the interaction between anthropogenic activities and oceanographic processes. Therefore, integrated coastal waste management, continuous environmental monitoring, community participation, and improved solid waste management systems are essential to reduce marine debris pollution and support sustainable coastal ecosystem conservation.

Keywords: Coastal Pollution; Marine Debris; Oceanography; Plastic Waste; Shoreli

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INTRODUCTION

Marine debris has become one of the most pressing environmental issues affecting coastal and marine ecosystems worldwide. Rapid population growth, urbanization, increasing consumption of single-use plastics, and inadequate waste management systems have significantly increased the amount of waste entering aquatic environments (United Nations Environment Programme [UNEP], 2021). Indonesia, as the world's largest archipelagic country with more than 17,000 islands and an extensive coastline, is particularly vulnerable to the accumulation of marine debris. Earlier global assessments ranked Indonesia among the countries contributing the highest amount of plastic waste entering the oceans, primarily due to mismanaged solid waste from densely populated coastal areas (Jambeck et al., 2015). Although national policies and waste reduction programs have been strengthened in recent years, marine debris continues to pose serious environmental, ecological, and socio-economic challenges (Cordova et al., 2021).

Marine debris consists of any persistent manufactured or processed solid material that is intentionally or unintentionally discarded, disposed of, or abandoned in marine and coastal environments (UNEP, 2021). The debris originates from both land-based and ocean-based activities, including domestic waste, tourism, fisheries, transportation, aquaculture, and

industrial activities. Among these materials, plastic dominates global marine litter because of its durability, low production cost, lightweight properties, and extremely slow degradation process (Galgani et al., 2022). Unlike biodegradable materials, plastic waste may persist for hundreds of years while continuously fragmenting into smaller particles known as microplastics, thereby increasing its ecological risks (Borrelle et al., 2020).

The movement and accumulation of marine debris are strongly influenced by hydrodynamic processes, including tides, ocean currents, waves, and wind patterns. Consequently, coastal areas often function as accumulation zones where floating debris transported from rivers and offshore waters is deposited (Silmarita & Fauzi, 2019). River systems represent one of the primary pathways transporting land-based waste into marine environments, particularly in developing countries where waste management infrastructure remains limited (Meijer et al., 2021). Therefore, coastal pollution frequently reflects not only local waste generation but also regional watershed characteristics and oceanographic processes.

Marine debris has extensive ecological consequences for coastal ecosystems. Plastic debris may entangle marine mammals, sea turtles, seabirds, and fish, while smaller fragments are frequently ingested by marine organisms, causing internal injuries, reduced feeding efficiency, reproductive impairment, and mortality (Kühn et al., 2015; UNEP, 2021). In addition, accumulated debris negatively affects critical coastal habitats such as coral reefs, mangrove forests, and seagrass meadows by reducing light penetration, limiting photosynthesis, and physically damaging habitat structures (Lamb et al., 2018). Microplastics also serve as vectors for toxic chemicals and pathogenic microorganisms, potentially transferring contaminants throughout marine food webs and eventually reaching human consumers through seafood (Galgani et al., 2022).

Beyond ecological impacts, marine debris also generates substantial economic and social losses. Coastal tourism destinations suffer from reduced aesthetic value, decreased visitor satisfaction, and increased beach cleaning costs when waste accumulates along shorelines (Beaumont et al., 2019). Fisheries experience reduced productivity because discarded plastics damage fishing gear, increase operational costs, and decrease fish habitat quality. Furthermore, floating debris may interfere with navigation safety and coastal infrastructure, while unmanaged waste can become breeding sites for disease vectors that threaten public health (UNEP, 2021). Consequently, marine debris has become a multidisciplinary issue involving environmental sustainability, coastal management, economic development, and community welfare.

Indonesia has responded to this challenge through various national initiatives aimed at reducing marine plastic pollution, including the National Plan of Action on Marine Debris and commitments to substantially reduce marine plastic leakage. Nevertheless, effective implementation requires reliable scientific information regarding the composition, abundance, distribution, and sources of marine debris at local scales (Cordova et al., 2021). Field-based monitoring remains essential because characteristics of marine debris vary considerably among coastal regions depending on population density, land use, tourism intensity, fisheries activities, and hydrodynamic conditions. Such information provides an evidence-based foundation for designing appropriate waste management strategies and evaluating policy effectiveness.

Marannu Beach, located in Pasimarannu Village, Sinjai Regency, South Sulawesi, represents one of the coastal areas potentially affected by marine debris accumulation. The beach supports multiple human activities, including small-scale fisheries, coastal tourism, marine transportation, and community settlements. These activities potentially contribute locally generated waste, while regional currents and seasonal monsoon circulation may transport additional debris from surrounding coastal areas. Consequently, accumulated

marine debris threatens the ecological integrity of the coastal ecosystem, decreases environmental quality, and reduces the attractiveness of the beach as a tourism destination. Plastic waste, in particular, poses long-term environmental risks because of its persistence and potential fragmentation into microplastics, whereas glass, metal, rubber, and other hazardous materials may create physical hazards for both marine organisms and coastal communities.

Despite the increasing concern regarding marine debris in Indonesian coastal environments, scientific information concerning the composition and characteristics of marine debris on Marannu Beach remains very limited. Most previous studies have focused on heavily urbanized coastal regions, whereas relatively little attention has been given to smaller coastal communities such as Pasimarannu Village. Baseline information regarding the types, abundance, spatial distribution, and dominant sources of marine debris is critically needed to support evidence-based coastal management and community-based conservation initiatives. Identifying marine debris composition also provides valuable insight into dominant pollution sources and facilitates the development of targeted waste reduction programs involving local governments, coastal communities, tourism stakeholders, and fisheries sectors. Therefore, this study aims to identify and characterize marine debris on Marannu Beach, Pasimarannu Village, Sinjai Regency. The findings are expected to provide scientific evidence supporting sustainable coastal management, strengthen environmental awareness among local communities, and contribute to Indonesia's broader efforts in reducing marine debris pollution and protecting coastal ecosystem resilience.

METHOD

This This study was conducted in May 2025 at Marannu Beach, Pasimarannu Village, Sinjai Regency, South Sulawesi, Indonesia. The study area was divided into three sampling stations representing different coastal characteristics, and the location of each station was determined using a Global Positioning System (GPS). The distribution of sampling stations is presented in Figure 1. Marine debris sampling followed the line transect method recommended by the National Oceanic and Atmospheric Administration (NOAA, 2023), in which a 100-m transect was established perpendicular to the shoreline from the intertidal zone toward the terrestrial area. Each station consisted of three transects with three sampling replicates, and every transect was subdivided into three quadrats measuring 10 × 10 m. All marine debris within each quadrat was collected manually using protective gloves, placed into collection bags, cleaned with freshwater to remove sediments, and subsequently sorted according to material type (plastic, glass, metal, rubber, wood, textile, and styrofoam) and size category (mega-, macro-, and meso-debris) following internationally accepted marine debris classification protocols (Cheshire et al., 2009; NOAA, 2023; UNEP, 2021). Each debris category was weighed using a digital balance (10–50 kg capacity), while all field observations were systematically recorded for subsequent analysis.

The collected data were analyzed using descriptive quantitative approaches to determine the composition, abundance, biomass, and spatial distribution of marine debris. Total abundance and total mass of each debris category were calculated following the procedures described by Djaguna et al. (2019), while the average abundance and average weight were obtained by dividing the cumulative values by the total number of transects surveyed. Spatial distribution of marine debris was expressed as debris density (kg m^{-2}) using the equation proposed by Kungskulniti et al. (2018):

$$S = \frac{W(kg)}{A}$$

Where S represents marine debris density (kg m^{-2}), W is the total debris weight (kg), and A is the sampled area (m^2). This analytical approach enables standardized comparisons among sampling stations and provides reliable ecological information regarding the intensity of marine debris accumulation, which is essential for evaluating coastal pollution status and supporting evidence-based coastal management and marine conservation programs (Ryan et al., 2020; UNEP, 2021).

RESULT AND DISCUSSION

Oceanographic Conditions and Marine Debris Accumulation

The distribution of marine debris on Marannu Beach was strongly influenced by local oceanographic conditions, particularly currents, waves, and tidal dynamics. Current data obtained from BMKG during May 2025 indicated a dominant southeast-to-south current direction with velocities ranging from 3.23 to 4.97 m s^{-1}. Such current velocities are sufficiently strong to transport floating debris, especially low-density materials such as plastic bags, plastic bottles, and expanded polystyrene (styrofoam), toward the shoreline. Ocean currents are recognized as one of the principal drivers controlling the transport pathways and accumulation hotspots of marine debris because they continuously redistribute floating materials across coastal environments (van Sebille et al., 2020; Meijer et al., 2021). Consequently, the observed accumulation pattern at Marannu Beach reflects not only local waste generation but also debris transported from adjacent coastal areas through regional hydrodynamic processes.

Wave conditions during the study period remained relatively low, ranging between 0.281 and 0.398 m. Moderate wave energy generally promotes shoreline deposition because wave forces are insufficient to transport accumulated debris back into offshore waters. Similar findings have been reported in tropical coastal environments where relatively calm sea conditions facilitate continuous accumulation of floating litter within the intertidal zone (Ryan et al., 2020). The slight increase in wave height recorded during the second half of May likely contributed to the redistribution of floating debris among different coastal sectors rather than removing accumulated waste entirely. Likewise, semidiurnal tidal characteristics observed throughout the study enhanced the periodic transport and retention of debris along the beach. Repeated tidal inundation increases the probability of debris deposition at the high-tide line, producing characteristic accumulation belts commonly observed in tropical sandy beaches (UNEP, 2021).

Composition of Marine Debris

Plastic represented the dominant debris category across all sampling stations, demonstrating that anthropogenic activities remain the primary source of coastal pollution at Marannu Beach. The highest proportion of plastic debris occurred at Station 1, corresponding to the fishing harbor, where intensive fishing operations, household activities, and daily community interactions generate substantial quantities of disposable plastic materials such as bottles, food packaging, ropes, and shopping bags. Station 2, located near recreational facilities and gazebos, also exhibited a similarly high proportion of plastic waste, reflecting the contribution of tourism activities and inadequate visitor waste management. These findings are consistent with numerous studies indicating that plastics account for more than 70–80% of marine debris worldwide because of their low density, durability, and resistance to degradation (Borrelle et al., 2020; Galgani et al., 2022).

Wood constituted the second largest debris category, particularly at Station 3 located directly along the shoreline. Unlike plastics, wooden debris originates from both anthropogenic and natural sources, including damaged fishing equipment, construction

materials, driftwood transported by rivers, and broken coastal vegetation. The relatively high abundance of wooden debris suggests that hydrodynamic transport processes, especially currents and wave action, contribute substantially to the delivery of terrestrial materials into coastal ecosystems. Similar observations have been documented in tropical islands where floating woody materials accumulate naturally within sheltered coastal environments (UNEP, 2021).

Glass, rubber, textiles, metals, and expanded polystyrene were detected at all sampling stations but contributed considerably lower proportions than plastics and wood. Glass fragments mainly originated from beverage containers discarded by visitors, whereas rubber debris consisted primarily of footwear, tires, and fragments of fishing equipment. Textile waste was associated with discarded clothing and fishing materials, while metal debris predominantly comprised beverage cans and corroded household materials. Although these categories were less abundant, they still pose ecological risks because sharp glass fragments may injure beach users, metals may release hazardous compounds through corrosion, and synthetic textiles may progressively fragment into microfibers that contaminate coastal food webs (UNEP, 2021; Galgani et al., 2022).

Size Distribution of Marine Debris

Marine debris size classification revealed a clear dominance of macro-debris across all sampling stations, followed by meso-debris, whereas mega-debris represented only a small fraction of the total debris collected. The predominance of macro-sized materials indicates that waste entering the coastal environment remains largely intact before undergoing physical fragmentation. Macro-debris generally consists of bottles, food containers, plastic packaging, fishing gear, wooden fragments, and other visible solid waste generated directly by human activities (Cheshire et al., 2009). Similar dominance of macro-debris has been widely reported for tropical beaches where recreational use and fisheries represent the major sources of coastal litter (Ryan et al., 2020).

The presence of substantial quantities of meso-debris suggests that fragmentation processes are actively occurring along Marannu Beach. Continuous exposure to ultraviolet radiation, mechanical abrasion by waves, and repeated tidal movement gradually break larger debris into progressively smaller particles. These fragmented materials present greater ecological concern because they are more readily ingested by fish, crustaceans, mollusks, seabirds, and other marine organisms, thereby facilitating the transfer of plastic-associated contaminants through marine food webs (Borrelle et al., 2020; Galgani et al., 2022). In contrast, mega-debris occurred infrequently because large objects are generally removed by local communities, transported elsewhere by strong currents, or occur outside the relatively limited sampling area.

Debris Mass and Spatial Distribution

Although plastic dominated numerically, wooden materials contributed the greatest proportion of total debris mass across the three sampling stations. This finding demonstrates the importance of distinguishing between abundance and biomass when evaluating marine debris. Plastics typically possess relatively low density and therefore dominate item counts, whereas wood contributes disproportionately to total mass because of its higher density and larger dimensions. Similar discrepancies between numerical abundance and biomass have been reported in coastal debris assessments globally (Ryan et al., 2020). Consequently, assessments based solely on item counts may underestimate the ecological importance of heavier debris categories.

Spatial distribution analysis further demonstrated that debris density varied among sampling stations according to surrounding land use and coastal characteristics. The fishing harbor exhibited the highest density of plastic debris, reflecting intensive fisheries-related

activities and domestic waste generation. Recreational areas accumulated mixed debris associated with tourism, whereas the open shoreline contained greater quantities of driftwood and natural materials transported by marine currents. These spatial differences indicate that marine debris accumulation at Marannu Beach results from the interaction between local anthropogenic activities and regional hydrodynamic forcing rather than a single pollution source. Similar relationships between land use, coastal hydrodynamics, and debris distribution have been documented in numerous coastal ecosystems throughout Southeast Asia (Meijer et al., 2021; Cordova et al., 2021).

Overall, the results demonstrate that plastic remains the dominant pollutant in terms of abundance, whereas wood contributes the largest biomass within the coastal environment. Oceanographic processes including currents, waves, and semidiurnal tides play a fundamental role in controlling the transport, deposition, and redistribution of marine debris, while human activities associated with fisheries, tourism, and coastal settlements provide the primary sources of waste entering the marine environment. These findings highlight the urgent need for integrated coastal waste management strategies involving improved solid waste infrastructure, community participation, routine coastal clean-up programs, and continuous environmental monitoring to reduce marine debris accumulation and preserve the ecological integrity of Marannu Beach (UNEP, 2021; Borrelle et al., 2020; Galgani et al., 2022).

CONCLUSION

This study demonstrated that marine debris accumulation on Marannu Beach, Pasimarannu Village, Sinjai Regency, is strongly influenced by both anthropogenic activities and local oceanographic processes. Plastic was identified as the most abundant debris category across all sampling stations, indicating that fisheries, tourism, and domestic activities constitute the primary sources of coastal pollution. Macro-sized debris dominated the size distribution, suggesting that most waste entered the marine environment as intact materials before gradually fragmenting into smaller particles through physical weathering. Although plastics dominated numerically, wooden materials contributed the largest total biomass, highlighting the importance of evaluating both debris abundance and mass when assessing coastal pollution. Spatial variations in debris composition and density reflected differences in surrounding land use, while current direction, wave conditions, and semidiurnal tidal dynamics played important roles in transporting and concentrating marine debris along the shoreline. The findings emphasize that effective mitigation of marine debris requires integrated coastal management involving source reduction, improved waste management infrastructure, regular beach clean-up programs, environmental education, and long-term monitoring based on standardized scientific methods. Such measures are essential to protect coastal biodiversity, maintain ecosystem services, and support the sustainable management of coastal resources in Marannu Beach and other similar tropical coastal environments.

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