High Macroplastic Abundance in the Seagrass Beds of North Sulawesi, Indonesia

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ABSTRACT

Seagrass meadows are ecologically and economically important but are now facing the issue of plastic pollution. This study identified 1,288 macroscopic-sized marine debris in seagrass beds in eastern and western Minahasa peninsula, North Sulawesi, Indonesia. Of this number, majority (853) are macroplastics, 564 plastic items were recovered from the western region while only 289 items from the eastern region. Macroplastics (>20mm) were the most prevalent debris (46-83%) with mean weight per unit area higher in the east coast (41±21 g/m^{-2}) compared to the west coast (17.6±9.8g/m^{-2}) of the peninsula. Among the plastic types (PL), a total of 17 types were found in the two regions, of which 16 types were found in the western region while only 7 in the eastern region. Plastic bags and small bottles dominated the macroplastics sampled from the study area, both in terms of percentage and density. Other debris types included cloth, rubber, glass, ceramics, and metals varied in terms of their proportions and density across the sampling stations. Further research is needed to understand the spatial and temporal variations of plastic abundance in North Sulawesi's seagrass beds.

Keywords: debris, coastal, plastics, seagrasses, waste

INTRODUCTION

Anthropogenic marine debris, particularly plastic pollution, has emerged as a significant environmental concern globally (Li et al., 2016; UNEP 2018; Smith et al., 2019). Seagrass meadows, known for their ecological and economic importance, are increasingly becoming sinks for plastic waste, posing potential threats to these fragile ecosystems (Orth et al., 2006). Indonesia, with its extensive coastline and large population, has been identified as one of the top contributors to plastic pollution in the world's oceans (Van der Reis & Sperfeld, 2018). The seagrass beds of North Sulawesi, Indonesia, play a crucial role in coastal ecosystem dynamics, supporting diverse marine life and providing numerous ecological services but are threatened due to plastic pollution (Syakti & Muthalif, 2017; Bonanno & Orlando-Bonaca, 2020). Understanding the extent and characteristics of anthropogenic marine debris in these seagrass habitats is essential for effective conservation and management efforts.

Preliminary studies have indicated that macroplastic debris constitutes a significant proportion of the anthropogenic items found in seagrass meadows worldwide due to their capacity to serve as sinks of plastic debris (Sanchez-Vidal et al., 2021; Unsworth et al., 2021; Krishnan, 2021). These larger plastic items can cause entanglement and physical damage to seagrass plants, affecting their growth and overall health (Bonanno & Orlando-Bonaca, 2020). A number of studies have also shown that fishes (Bucol et al., 2020) and macroinvertebrates (Remy et al., 2015) in seagrass beds ingest microplastics.

The aim of this study is to quantify and characterize anthropogenic marine debris within selected seagrass beds in North Sulawesi, Indonesia. By examining the types, abundance, and distribution of marine debris, we can gain insights into the potential impacts on seagrass ecosystems and identify priority areas for remediation and conservation efforts. The specific objectives of this research are to assess the composition, abundance, and distribution of macroplastic and mesoplastic debris within seagrass beds in both the eastern and western regions of the Minahasa peninsula in North Sulawesi.

MATERIALS AND METHODS

The research was conducted over a 3-day period, from November 28-30, 2022. Seagrass sampling took place in multiple locations along the coast of North Sulawesi. Six stations were selected, with three located in the western part of North Sulawesi and three in the eastern part. The geographical coordinates of the eastern stations were: E1 (1°19'36.2" N, 125°03'57.1" E), E2 (1°17'40.3" N, 125°04'01.4" E), and E3 (1°13'51.5" N, 125°02'52.8 E). In the western area, W1 was positioned at (1°34'16.6" N, 124°48'17.3" E), W2 at (1°33'01.0" N, 124°48'48.2" E), and W3 at (1°25'43.8" N, 124°43'41.1" E). The research locations are depicted in the provided map (Fig. 1). The western coast of North Sulawesi, specifically stations 1 and 2, share similar location characteristics as they are in close proximity to each other. Both stations have sandy and rocky substrates and are characterized by the presence of *Enhalus acoroides* and *Syringodium isoetifolium* seagrass species. Additionally, mangroves line the shoreline in both stations. Station 3, on the other hand, has a sandy and slightly muddy substrate and is home to *Thalassia hempricii* and *Syringodium isoetifolium* seagrass species based on morphological identification.

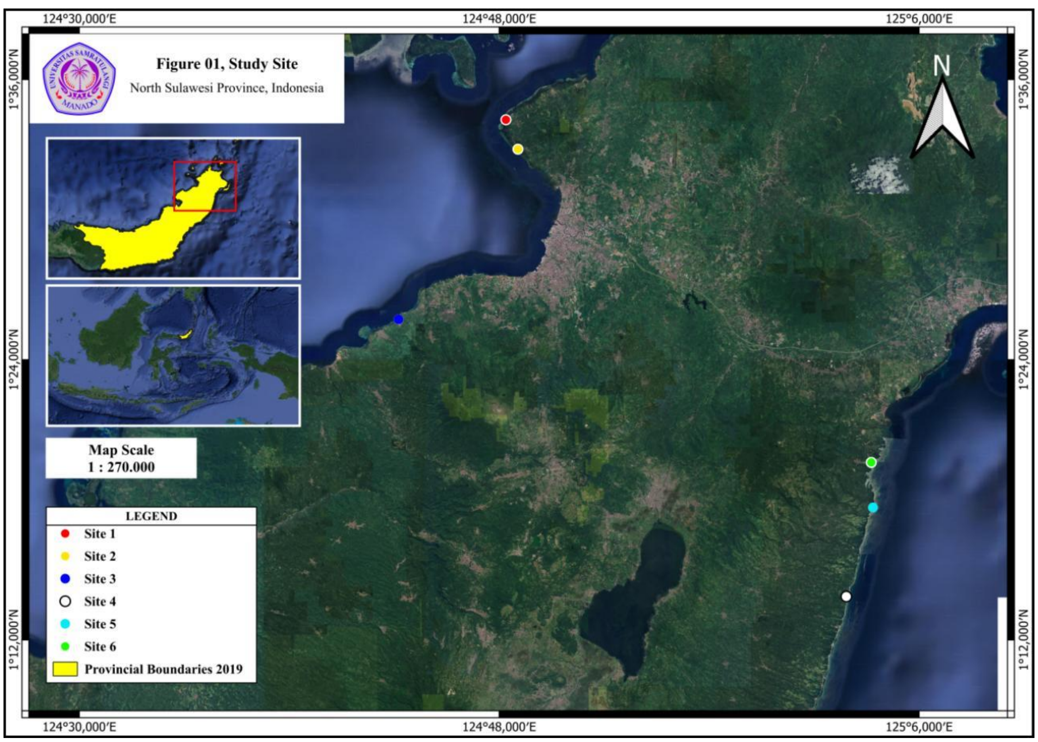

Fig. 1 Study site showing the location of the sampling stations.

Sampling

Sampling followed the NOAA (National Oceanic and Atmospheric Administration) method, which involved establishing a 50-meter long and 2-meter wide transect line within the seagrass area. Marine debris within the transect area was collected and placed into net bags. Subsequently, the debris from each station was sorted, identified, and quantified following the guidelines outlined by the Ministry of Environment and Forestry (KLHK), including weight and quantity calculations.

Data Analysis

The composition of waste is expressed as a percentage (%), which represents the weight of each waste type relative to the total weight of waste within the transect.
Percentage (%) = (X / Total weight of waste) * 100; where X is the weight of waste per type.

Anthropogenic debris density is calculated by dividing the amount of waste per type by the overall transect area. Waste density is reported in units of the amount of waste per item/m^2.

To compare the composition and density of waste in the seagrass meadows between sampling locations, a Kruskal-Wallis test was conducted using the rstatix package while t-test was used to compare between the two regions using in R (R Core Team, 2022).

RESULTS AND DISCUSSION

This study examined a total of 1,288 macroscopic-sized marine debris in seagrass beds in eastern and western Minahasa peninsula, North Sulawesi, Indonesia. Of this number, majority (853) are macroplastics, 564 plastic items were recovered from the western region while only 289 items from the eastern region. Across all stations and regardless of the region, macroplastics predominate the marine debris in terms of proportions, ranging from 46.5 to 83.4% followed by glass and ceramics (0-43.9%), and metal (0-20.4%) while the other categories such as cloth and rubber were all below 20% in all stations (Figure 2).

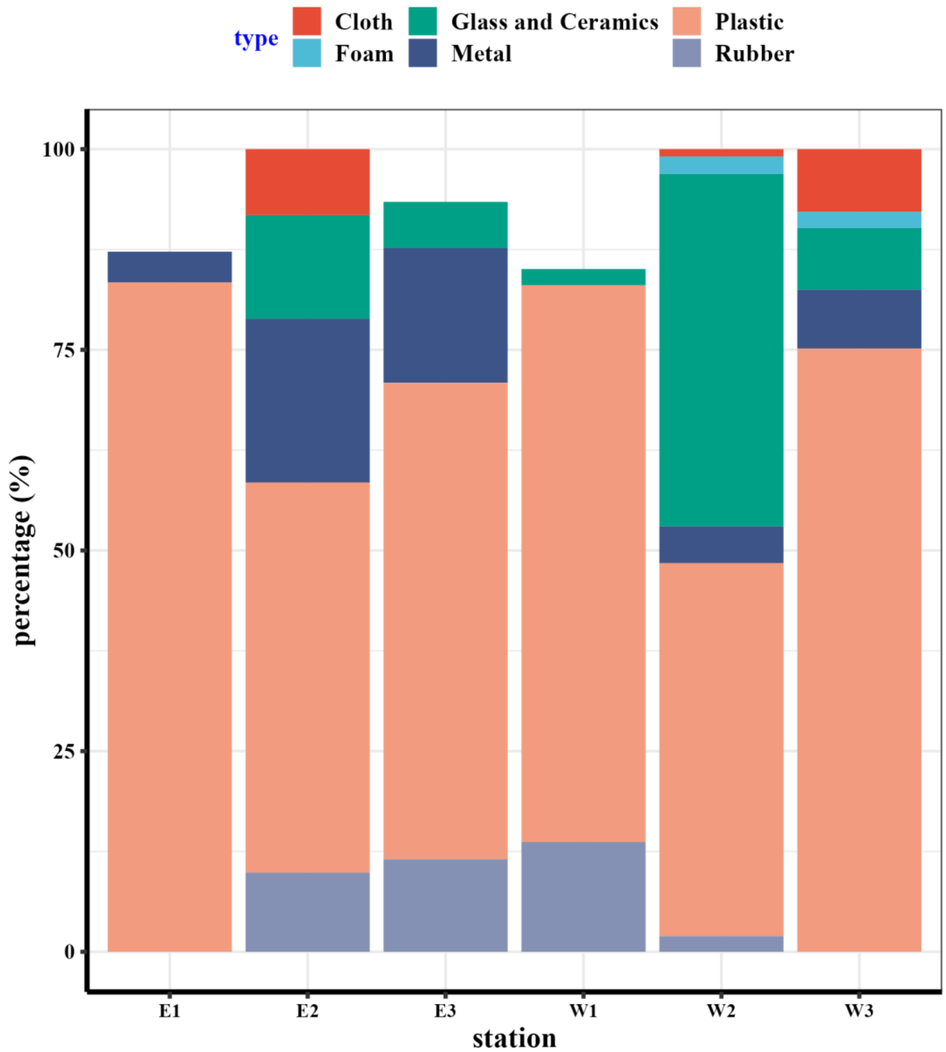

Fig 2. Composition of marine debris across sampling sites in North Sulawesi (E1-3, eastern side and W1-3 side of the peninsula).

Overall, in terms of the density of marine debris (Figure 3), plastic wastes consisted the highest contribution. The eastern stations had higher mean density of 24.36 (6.0 SE) items/m^2 in contrast to that of the western stations with mean value of only 10.5 (3.08 SE) items/m^2. This difference is statistically significant between the eastern and western regions (t-test, $P < 0.05$). Other types of waste included fabrics, rubber, glass & ceramics, metal, and cloth, all of which were of low density in the seagrass beds (all <7 items/m^2.

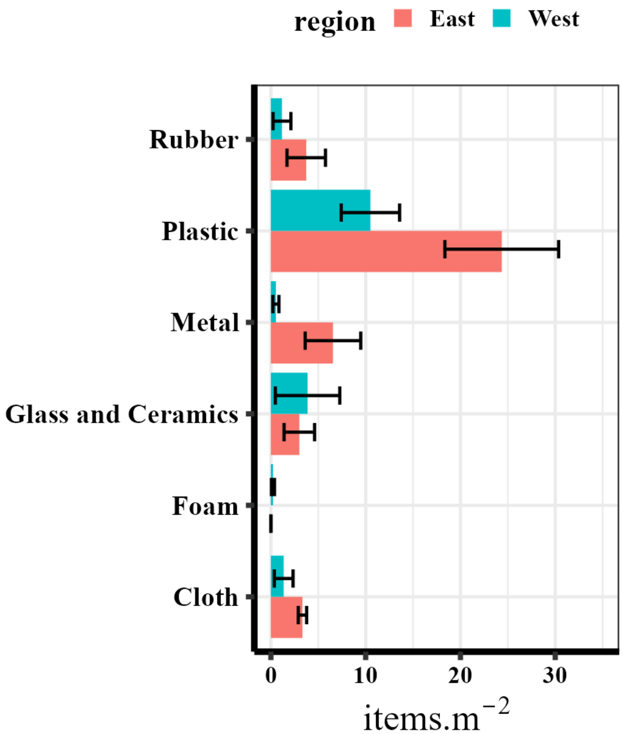

Fig 3. Density of marine debris in the sampling sites of Minahasa peninsula (Error bars indicate Standard Error).

Based on the 24 categories of plastic types (PL) described based on Lasut et al. (2021), 17 categories were determined by this study, with 16 categories found in the western region while only 7 in the eastern region. The eastern region, however, had the highest density in terms of plastic type dominated by plastic bags with 7.57±2.92 (SE) items/m^2 followed by small bottles (7.33±0.44 items/m^2) while the western region only had the highest plastic density of 1.8 items/m^2 (Figure 4). These major plastic types differ significantly between the east and west regions (t-test < 0.05).

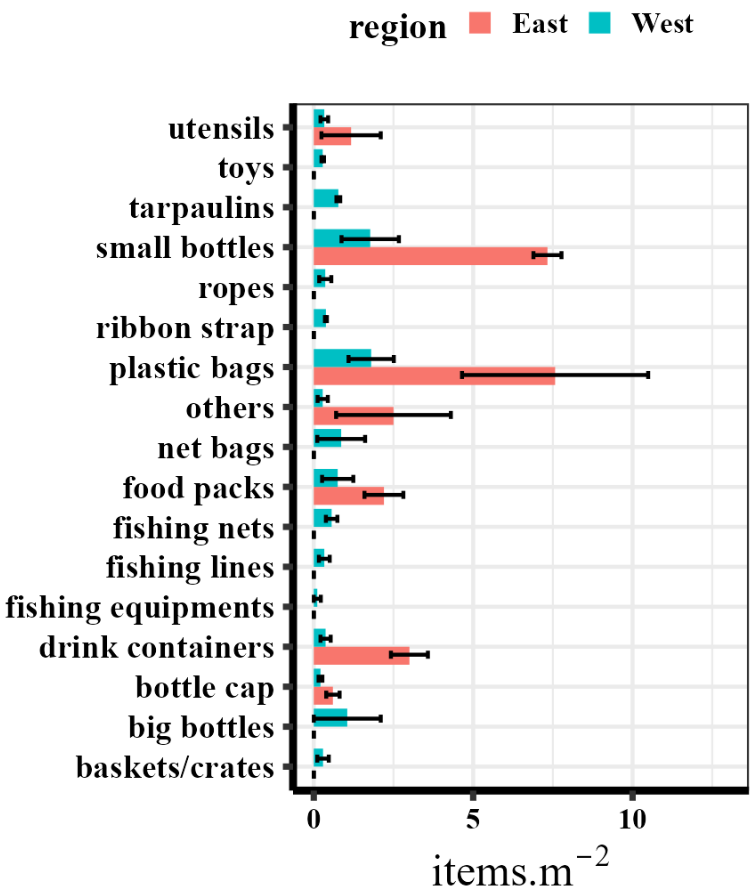

Fig 4. Density of macroplastic types in the sampling sites of Minahasa peninsula (Error bars indicate Standard Error).

This study surveyed the marine anthropogenic debris found in the seagrass beds of the two regions (east and west sections) of the Minahasa peninsula. Our results show a higher mean density of plastic debris in our sampling sites compared with a previous study in Manado Bay (Lasut et al. 2021, reported 6.25-9.18 fragments/m^2) and in neighboring Asian countries such as that of Gaboy et al. (2022) in Iligan Bay, Philippines, and other locations worldwide, such as Portugal (Cozzolino et al., 2020). Rasyid et al. (2022) also found that macroplastics dominated the marine debris they quantified.

Several factors may have contributed to the high levels of plastic pollution in the seagrass beds of North Sulawesi. First, the region is densely populated, with over 2.6 million people living in the province of North Sulawesi (BPS, 2020). This high population density leads to increased waste generation, much of which is not properly managed and ends up in the environment. Second, the region is home to several major ports, which are a source of marine plastic pollution. Third, the region is also experiencing rapid economic growth. This growth has led to increased coastal development, which can also contribute to marine plastic pollution. These factors are consistent with what is known in the literature (e.g., Chen et al., 2019).

The high levels of plastic pollution in the seagrass beds of North Sulawesi are a threat to the marine ecosystem and human health. Plastic pollution can harm marine life by entanglement, ingestion, and smothering (Bonanno & Orlando-Bonaca, 2020). It can also degrade marine habitats, such as coral reefs and seagrass beds, which are important for biodiversity and fisheries (Anjana et al. 2020). In addition, plastic pollution can accumulate in the food chain, potentially contaminating seafood and posing a risk to human health (AlMamun et al., 2023).

To address the problem of plastic pollution in the seagrass beds of North Sulawesi, it is important to take steps to reduce the amount of plastic waste that is generated and to improve waste management practices (Mueller et al., 2022). This could include initiatives such as reducing the use of single-use plastics, improving recycling and waste collection, and raising awareness about the impacts of plastic pollution. In addition, it is important to protect and restore marine habitats, such as coral reefs and seagrass beds, which can help to filter plastic pollution from the water column. This study provides valuable information on the status of plastic pollution in the seagrass beds of North Sulawesi. This information can be used to develop and implement strategies to address the problem of plastic pollution in this important marine ecosystem.

In conclusion, this study reveals the presence of anthropogenic marine debris, particularly plastic pollution, in the seagrass beds of North Sulawesi, Indonesia. The mean weight per unit area of macroplastics varied between the east and west coasts, indicating potential differences in debris accumulation patterns. In addition to plastics, other types of debris such as cloth, rubber, glass, ceramics, and metals were also observed. To fully comprehend the extent and dynamics of plastic abundance in North Sulawesi's seagrass beds, further research is necessary, particularly focusing on spatial and temporal variations. This information is vital for developing effective mitigation and conservation strategies to protect the ecologically and economically valuable seagrass ecosystems in the region. It is anticipated that the findings of this research will contribute to the existing knowledge on the abundance and characteristics of anthropogenic marine debris in the seagrass beds of North Sulawesi. Furthermore, this study will provide valuable information for policymakers, researchers, and local communities to develop effective strategies for managing plastic pollution and conserving the vital seagrass ecosystems in the region.

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