

Impact of wet and dry seasons on marine macro and meso debris distribution in Manado Bay, Indonesia

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Abstract. Nowadays, marine debris can be found all over the world, including in Indonesia. In Manado City, debris deposits increase every year because there are no debris nets on the river estuaries. The waste from settlements can enter the marine environment through rivers, city drainage, marine activities, and even tourist activities. The existence of waste has become a major threat that has a very negative impact on marine resources, the ecosystem, the economy, and social life. The present study aims to identify the impact of seasonal variation on macro and meso debris distribution in Manado Bay. This study was conducted in August 2021 (east season) and January 2022 (west season). Meso-debris (0.5-2.5 cm) and macro-debris (> 2.5 cm) were collected from five beaches in Manado Bay during the flood and ebb tide periods. Macro and meso fragments consisting of nine materials were found on five beaches, namely plastic (PL), glass and ceramic (GC), foam (FP), paper and cardboard (PC), metal (ME), cloth (CL), rubber (RB), wood (WD) and others (OT). Plastic products are the main type, accounting for about 70-80%. This study shows that, spatially, debris was clustered at the mouth of the bay and near the river, especially on Sindulang Beach, Bailang Beach, and Talawaan Bajo Beach. Temporally, the macro- and meso-debris in the five locations reveal weight and density increased during wet season, with around 18% compared to the dry season.

Key Words: ecosystem, marine debris, marine environment, plastic, seasonal variation.

Introduction. Nowadays, debris can be found in the environment all over in the world, including in the marine environment. The presence of marine debris can seriously impact aquatic life and humans. Marine debris is commonly found in the form of plastic, glass, ceramics, foam, metal, rubber, wood, paper and styrofoam, which take a long time to decompose (NOAA 2013). Approximately 80% of marine debris comes from land and is carried by rivers and enters the sea (Jambeck et al 2015). Anthropogenic activities play a significant role as a primary source of increasing marine debris. These activities include fishing activities, activities in urban settlements (runoff is carried away during heavy rains), ship activities, and offshore oil mining and beach recreation (Cheshire et al 2009). Ferreira et al (2011) reported that, after debris enters the marine environment, hydrodynamic factors such as currents, tides, and waves direct its dispersion in the seas and bays.

The assessment of marine debris abundance and composition can be performed using beach litter. Valuable information, such as the plastic type, quantity, size, and source, is necessary to enact efficient management strategies. Research on marine debris has been conducted on many coastal areas around the globe. An important area is represented by the beaches around Manado Bay, North Sulawesi. Manado Bay is located in the north of Sulawesi Island, Indonesia. Manado is well-known for its beautiful coral reefs and diverse marine life, making it a popular tourist destination. However, with the increase in tourism and economic development, the amount of marine debris in the area has also increased. An increase in the population of 0.47 % per year in Manado City has

been linked with a rise in the amount of waste in Manado (BPS 2021). Based on data from the National Waste Management Information System (SIPN 2021), the increase in the amount of debris in Manado City from 2020 to 2021 amounted to 2,555 tons. Most of the waste was composed of food waste (47.7%), followed by plastic waste at 19.48%. The marine debris poses significant environmental concerns, as it can harm marine life, disrupt ecosystems, and negatively impact coastal economies that rely on tourism and fishing (Wilcox et al 2016; Rial et al 2017).

The present study aims to assess the variation of marine debris in Manado Bay in two ranges of sizes, macro (> 2.5 cm) and meso (0.5-2.5 cm), based on different seasons (dry and wet) and tidal condition (flood and ebb). In this study, the selected locations were Sindulang Beach, Bailang Beach, Tasik Ria Beach, Malayang Beach, and Talawaan Bajo Beach. These locations are near rivers, recreational areas, fishing activities, and densely populated areas. Based on the findings of the study, a baseline management plan can be developed to address the issue of marine debris in Manado. This plan includes implementing strict waste management regulations, raising awareness among local communities and tourists, and organizing regular beach clean-up activities.

Material and Method

Description of the study sites. This study was conducted in August 2021 (east season) and January 2022 (west season) on 5 beaches in Manado Bay and its environs: Talawaan Bajo Beach, Bailang Beach, Sindulang Beach, Malayang Beach, and Tasik Ria Beach (Figure 1).

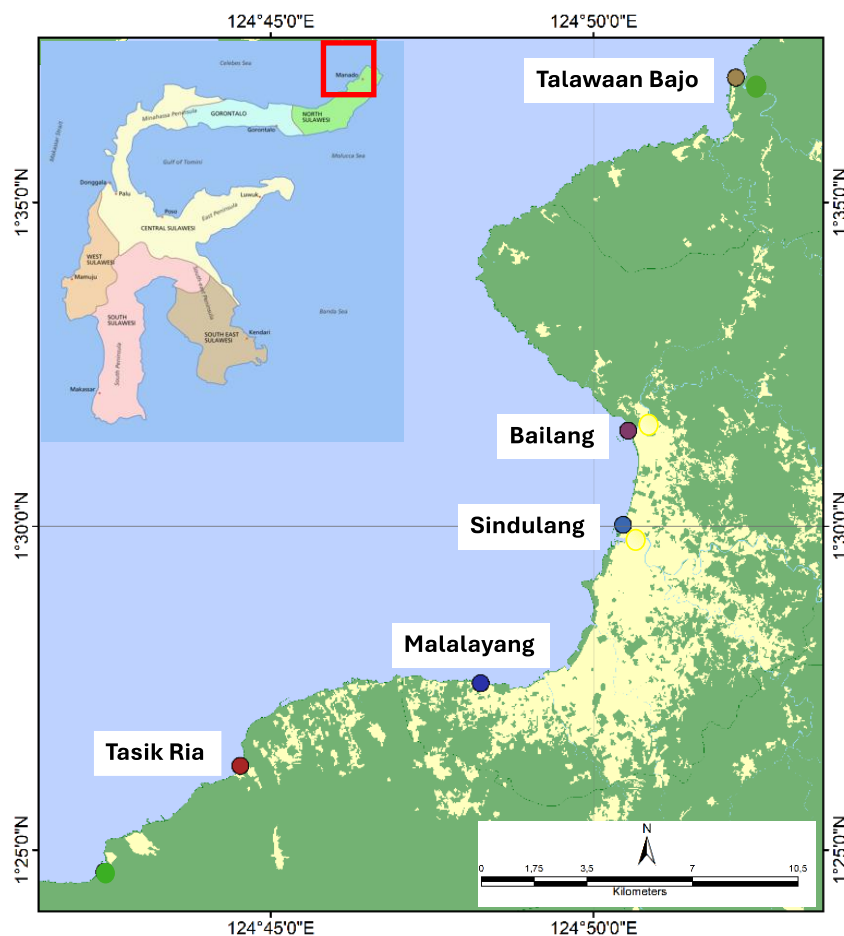


Figure 1. The location of Manado Bay, North Sulawesi, Indonesia.

The locations represented areas near streams and rivers, recreation areas, fishing areas, and areas with dense populations. Talawaan Bajo Beach is 25.4 km from the center of

Manado City. This location is used as a place for recreation and fishing activities. The Talawaan Bajo River flows into this beach with a river discharge of $22.46 \text{ m}^3 \text{ s}^{-1}$ (PSDA 2017). Bailang Beach is 10 km from the center of Manado City. This beach has a sandy substrate and is directly next to the Bailang River, with a river discharge of $313.90 \text{ m}^3 \text{ s}^{-1}$ (PSDA 2017). Bailang Beach is not only a tourist destination but also a vital hub for the local fishing community.

Sindulang Beach is 4.7 km from the city center, and this location is used as a recreation area, fishing activities, transportation route, beachside culinary spot, and port. Sindulang Beach has a sandy substrate and is adjacent to the Tondano River, with a river discharge of $291.12 \text{ m}^3 \text{ s}^{-1}$ (PSDA 2017). Malalayang Beach (around 5 km from the city center) is a peri-urban area and also a tourism area; it is allocated for fishing and access to the sea. Tasik Ria Beach is a popular destination for tourists in Manado and is located 21.6 km from the city center. Tasik Ria Beach is the perfect place to unwind and enjoy the natural beauty of Manado.

Meso-debris and macro-debris were collected during flood and ebb tide periods, using the Guidelines for Beach Litter Monitoring of the Ministry of Environment and Forestry Republic of Indonesia (KLHK 2020) which adopted the guidelines of Cheshire et al (2009). The study began with the determination of a transect area that was 100 m long, parallel to the shoreline, and 20 m wide. The transect was divided into five lanes, namely A, B, C, D, and E, perpendicular to the coastline, each 20 m apart. Each lane was placed in 1 quadrat measuring $5 \times 5 \text{ m}$, with a different position in each lane. This was intended to represent the waste condition at each study site. In each quadrat, 25 parts of a sub-quadrant size of $1 \times 1 \text{ m}$ were created, and five units were selected randomly and coded as A1, A2, A3, A4, and A5. The quadrat was positioned in the same place during the ebb and flood tide periods. Visible debris collection included deposited debris at the top of sediment and floating debris on the surface of water. Furthermore, the debris was quantified by abundance into 9 types (plastic, foamed plastic, cloth, paper and cardboard, metal, rubber, glass and ceramics, wood, and others). The classification of the marine debris adopted the guidelines of Cheshire et al (2009).

Results and Discussion. The marine debris found in Manado Bay and its environs was dominated by macro-debris. The same result was also reported by Pane et al (2020) and Lasut et al (2021). The total amount of macro-debris during the east season was 1451 items. During the west season, there were 1161 items. The total amount of meso-debris during the east season was 584 items and that during the west season was 254 items. This is because the production of macro-sized waste is much greater than that of meso-sized waste, and the breakdown of macro-waste into smaller pieces takes a long time. In general, the greatest amount of marine debris was found in Talawaan Bajo Beach, Bailang Beach, and Sindulang Beach. The differences in the amount of waste found at each location could be influenced by several factors, including land use, inputs from the river, marine activities, tourism activities, and the influence of ocean currents, which act to transport marine debris. Settlement anthropogenic activities and tourism activities influence the accumulation of marine debris in the area (Pawar et al 2016; Syakti et al 2017). The flow current has an essential role in influencing the distribution of marine debris (Moore et al 2001). During the east season, the current in Manado Bay moves to the north of the bay (Yohanlis & Putri 2021), and Talawaan Bajo Beach yielded the most macro-debris compared to the west season. During the west season, the current in Manado Bay only moves at the mouth of the bay (Yohanlis & Putri 2021), and this causes Bailang Beach to accumulate a larger amount of macro-debris compared to the east season. Based on the direction of the current movement in this season, Sindulang Beach should also accumulate more garbage than in the east season. However, the results found were different. Before the sampling was carried out, high waves occurred, which caused the waste that had accumulated on the beach to be transported far from the transect location. The comparison of debris based on the total amount Manado Bay and its environs can be seen in Figure 2.

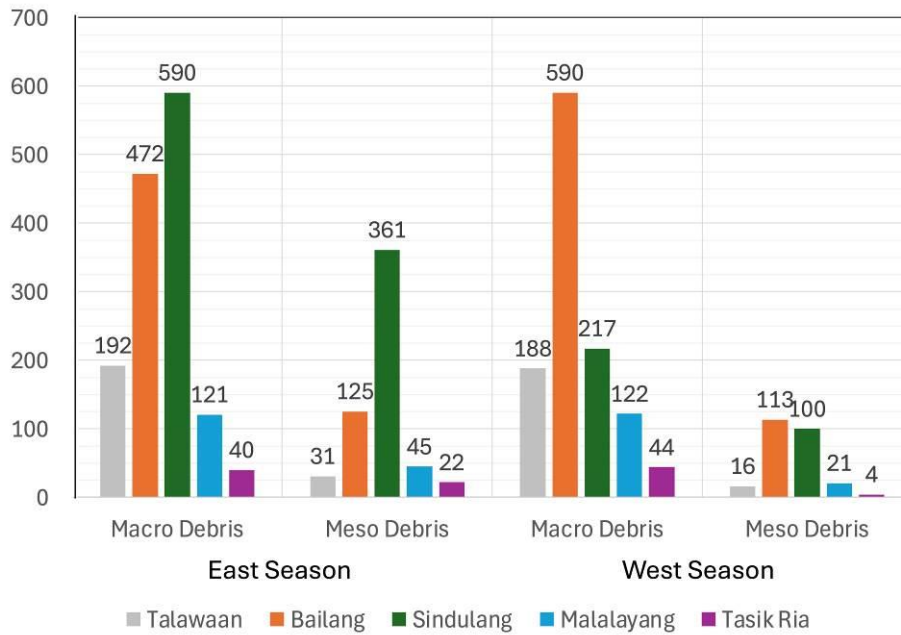


Figure 2. Comparison of debris based on total amount.

Characteristics of marine debris. The size of the marine debris found in the five research locations was divided into three categories, namely small (< 2.5 cm), medium (≥ 2.5 cm; ≤ 10 cm), and large (> 10 cm; ≤ 1 m) (Figure 3).

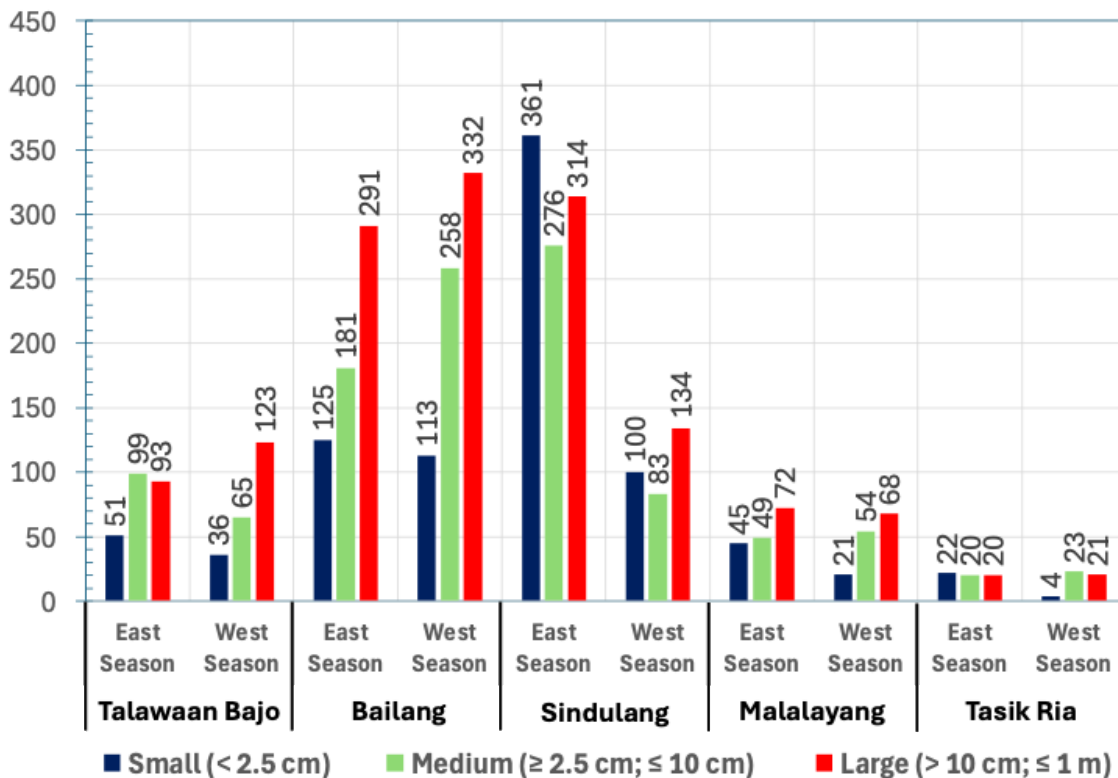


Figure 3. Size distribution during east season and west season.

The small category was included in the meso-debris group, while the macro-debris group included the medium and large classes. Marine debris sizes can vary depending on the conditions of the waste entering the sea and the length of time for which the debris has been fragmented. Medium and large sizes of waste are more commonly found because

these sizes are encountered more often in daily life, and the breakdown of large pieces of waste into smaller pieces takes a long time. The size and buoyancy of each type of debris can affect the distribution of the debris. Debris with a larger size and buoyancy can be dispersed further than small-sized waste, because small waste tends to sink before spreading far into the sea (Fazey & Ryan 2016). Small-sized waste can be sourced from the location itself, while relatively large debris can be obtained from the location or from sources far from the area based on its ability to collect waste. The difference in the number of sizes in each category is related to the number of types of waste found.

The effect of seasonal variation in composition and density of marine macro-debris. During the east season, the total weight of macro-sized waste obtained at the five research locations at flood tide was 5.18 kg and that at ebb tide was 15.65 kg (Table 1). There was a decrease in the weight of waste in the west season. The total weight of waste during the flood and ebb tide conditions was 2.19 kg and 10.73 kg, respectively. The weight of waste found during ebb tide conditions was much higher than during flood tide conditions. This is related to the density of the type of waste found. Debris collected at flood tide tends to float on the surface, while, at ebb tide, the waste is deposited on the sediment's surface. Tides can cause the mass movement of water, which plays a role in distributing marine debris. Waste that has a low density can be transported or float more efficiently, while waste with a high density will be deposited in coastal sediments. According to Constantino et al (2019) and Juliandri et al (2020), currents and tides are the main factors influencing the distribution of debris along the coast, and Faizal et al (2021) added that the effect of tidal current is increased during the ebb tide period, when a large amount of debris is transported and accumulates on the coastline.

Table 1

The total weight of macro and meso debris during east and west season

Station	Weight of macro debris (g)		Weight of meso debris (g)	
	Flood	Ebb	Flood	Ebb
<i>East season</i>				
Talawaan Bajo	-	1,875.80	-	56.70
Bailang	651.10	8,937.38	8.50	40.40
Sindulang	2,827.20	3,464.10	12.30	11.70
Malalayang	1,356.70	1,091	66.90	15.30
Tasik Ria	348.80	288.60	12.20	1.20
<i>West season</i>				
Talawaan Bajo	645	2,909.60	0.80	1.90
Bailang	894.80	2,462.10	4.50	22.20
Sindulang	392.50	4,184.12	66.50	64.0
Malalayang	237.60	961.30	-	40.20
Tasik Ria	27.70	218.50	-	6.60

During the east season, the greatest weight of marine debris during flood tide was found at Sindulang Beach (2,827.20 g) and the lowest was found at Tasik Ria Beach (348.8 g), while, during ebb tide, the highest was found at Bailang Beach (8,937.38 g) and the lowest at Tasik Ria Beach (288.6 g) (Table 1). During the west season, the greatest weight of marine debris during flood tide was found at Bailang Beach (894.8 g) and the lowest at Tasik Ria Beach (348.8 g), while, during ebb tide, the highest was found at Sindulang Beach (4184.12 g) and the lowest was found at Tasik Ria Beach (218.5 g). The weight of the waste found at each location does not represent the waste density at that location. For example, during the west monsoon, the highest total weight of waste (low tide) was found on Sindulang Beach, but the highest density of waste was found on Bailang Beach.

Marine debris was found at all five beaches in Manado Bay, consisting of nine types: plastic, foamed plastic, cloth, paper and cardboard, metal, rubber, glass and ceramics, wood, and others. The spatial distribution of the composition and density of

macro-debris in each location during the east and west season can be seen in Figure 4 and Figure 5, respectively.

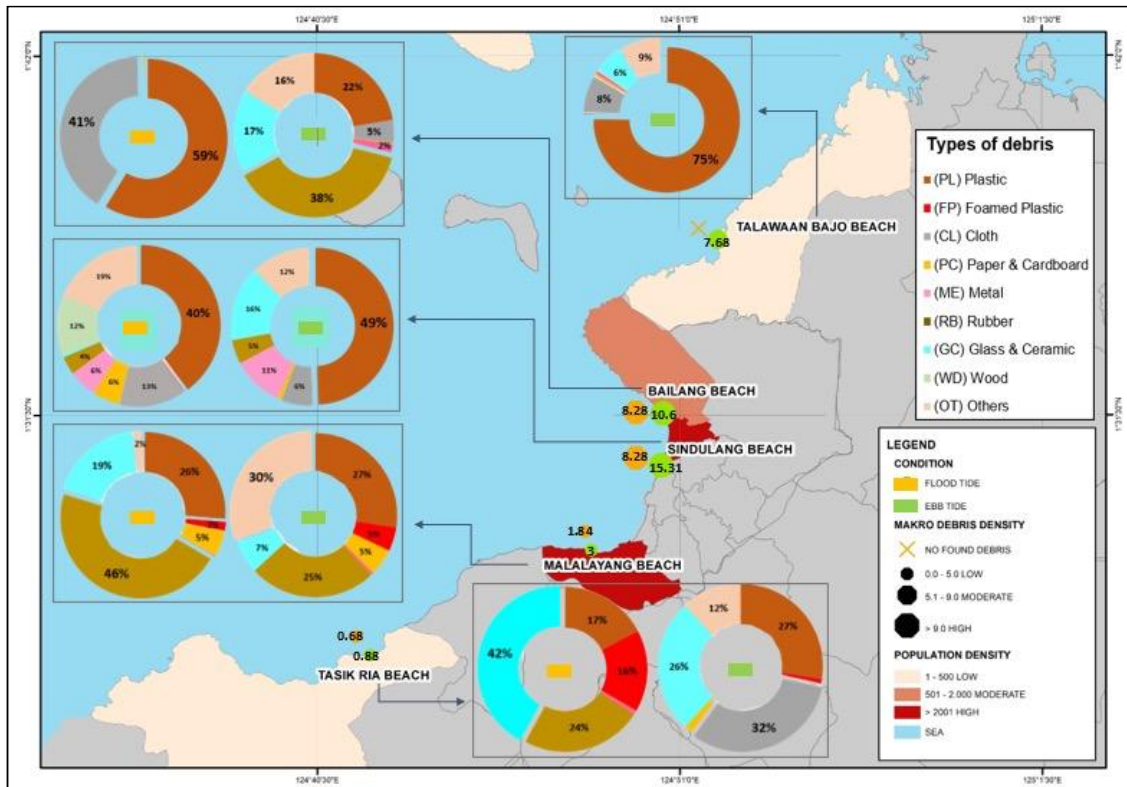


Figure 4. Macro-debris composition and density during east season.

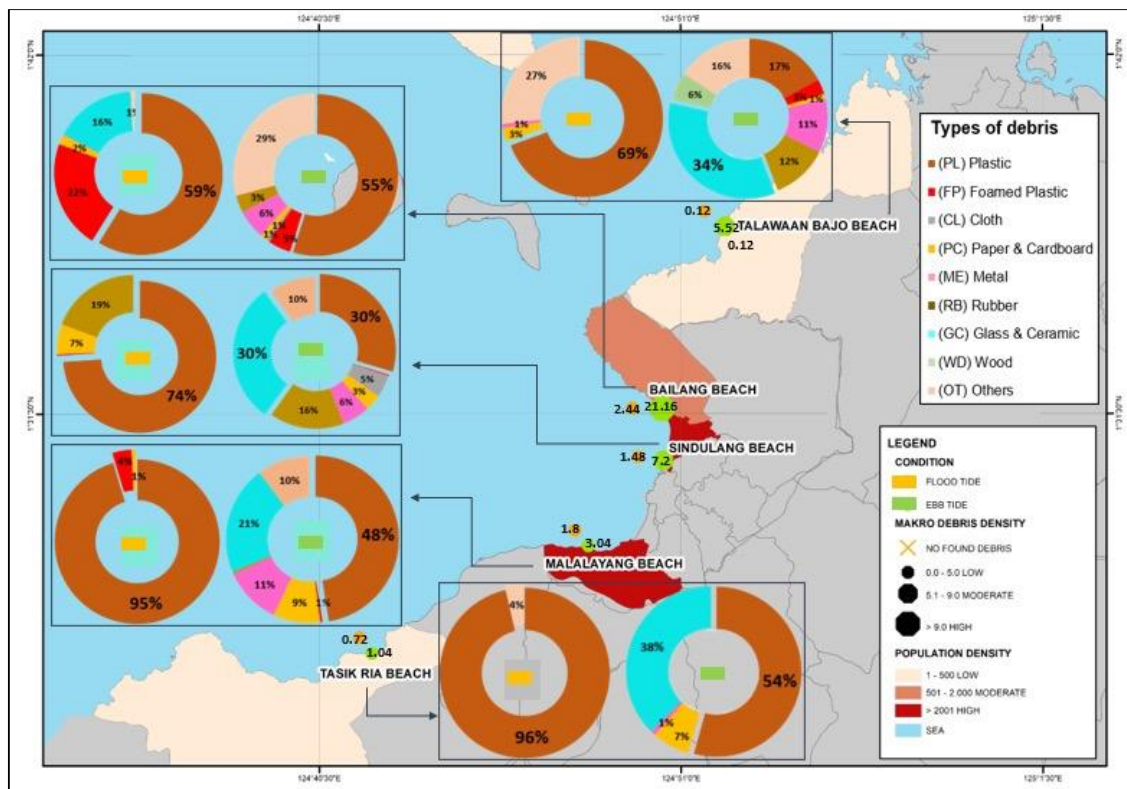


Figure 5. Macro-debris composition and density during west season.

Based on the composition of the waste found, plastic waste is the dominant waste type found in the macro-waste category during the east and west seasons. Plastic is the most

common type of waste, ranging from 70 to 85%. Plastic has a relatively low density and high buoyancy and is difficult to decompose, causing plastic marine waste to be found in many areas. The difference in material composition in the east and west season is clearly visible at Malalayang Beach and Tasik Ria Beach. At Malalayang Beach, during the west season, the plastic type during flood and ebb tide conditions increased by 69 and 21%, respectively. At Tasik Ria Beach, during the west season, the plastic type during flood and ebb tide conditions increased by 79 and 27%, respectively.

The macro-debris density in Manado Bay and its environs during the east season ranged from 0.68 to 8.28 items m^{-2} for flood conditions, while that for ebb conditions was between 0.88 and 15.31 items m^{-2} (Table 2). During the west season, it ranged from 0.12 to 2.44 items m^{-2} for the flood conditions, and that for ebb conditions was between 1.04 and 21.16 items m^{-2} . The density of waste in Manado Bay increases during the west monsoon. This is due to increased rainfall during this season, which causes river water discharge to increase and allows more waste from settlements to be carried to the sea. The density of marine debris per type shows an increase in the density of plastic and metal materials during the west season due to high river discharge. This pattern is typical of the spreading of tropical river waters (Tarya et al 2018).

Table 2

The density of macro and meso debris during east and west season

<i>Station</i>	<i>Density of macro debris (item m^{-2})</i>		<i>Density of meso debris (item m^{-2})</i>	
	<i>Flood</i>	<i>Ebb</i>	<i>Flood</i>	<i>Ebb</i>
<i>East season</i>				
Talawaan Bajo	-	7.68	-	1.24
Bailang	8.28	10.60	0.52	4.48
Sindulang	8.28	15.31	7.04	7.40
Malalayang	1.84	3.00	0.28	1.52
Tasik Ria	0.68	0.88	0.36	0.52
<i>West season</i>				
Talawaan Bajo	1.32	7.32	0.24	0.40
Bailang	2.44	21.16	1.80	2.68
Sindulang	1.48	17.20	1.32	2.68
Malalayang	1.80	3.48	-	0.84
Tasik Ria	0.72	1.04	-	0.16

Sindulang Beach, Bailang Beach, and Talawaan Bajo Beach have a higher solid waste density. According to Lasut et al (2021), the most significant contributor to waste in Manado City is residential areas with 65.68%, followed by traditional markets with 8.12%, commercial centers with 5.65%, and regional waste with 2.4%. This is also supported by research by Andrades et al (2016) and Bergmann et al (2017), which stated that most marine debris come from land-based sources, especially in densely populated settlements. Waste situated around the beach is assumed to have been carried away from residential areas, indicated by the large amount of packaging waste for daily activities and equipment found. Human activities play an essential role in contributing to waste entering the environment. Apart from land sources, marine activities can also contribute to marine debris Cheshire et al (2009). In these three locations, waste from fishing equipment was also found. We assumed that the waste at this location did not only come from land but also the sea, although in very small proportions.

The effect of seasonal variation in composition and density of marine meso-debris. The spatial distribution of the composition and density of the meso-debris at each location during east and west season can be seen in Figure 6 and Figure 7, respectively.

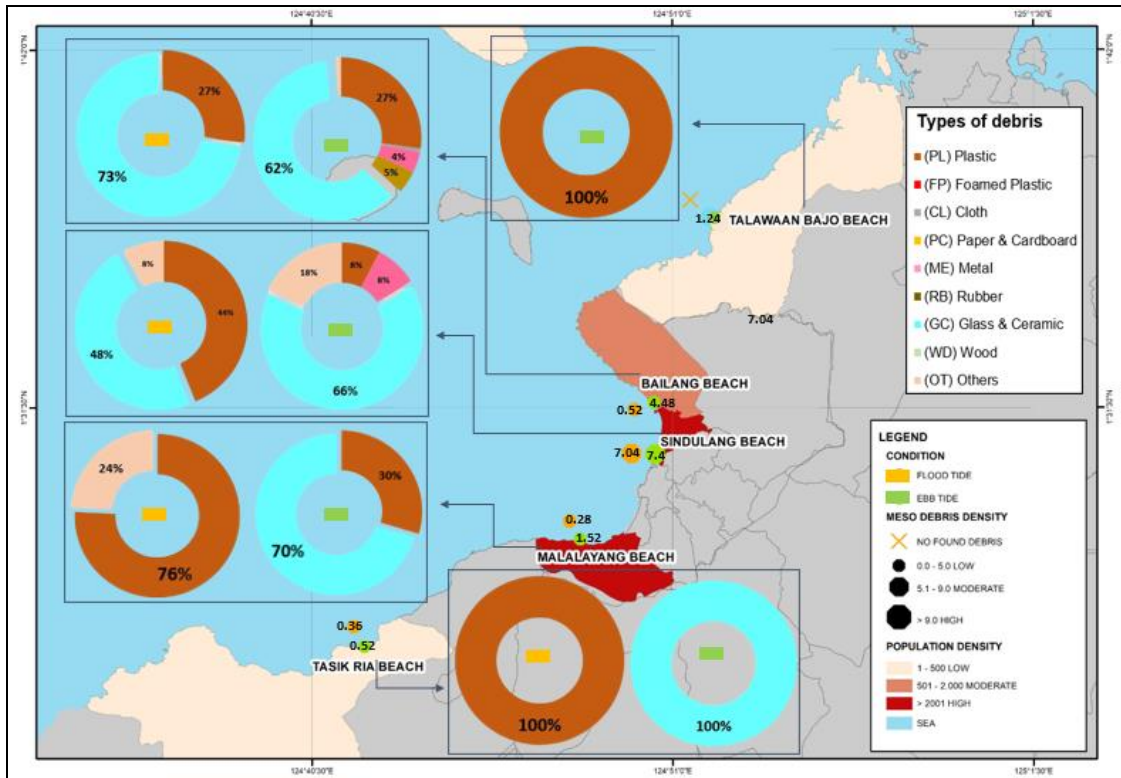


Figure 6. Meso-debris composition and density during east season.

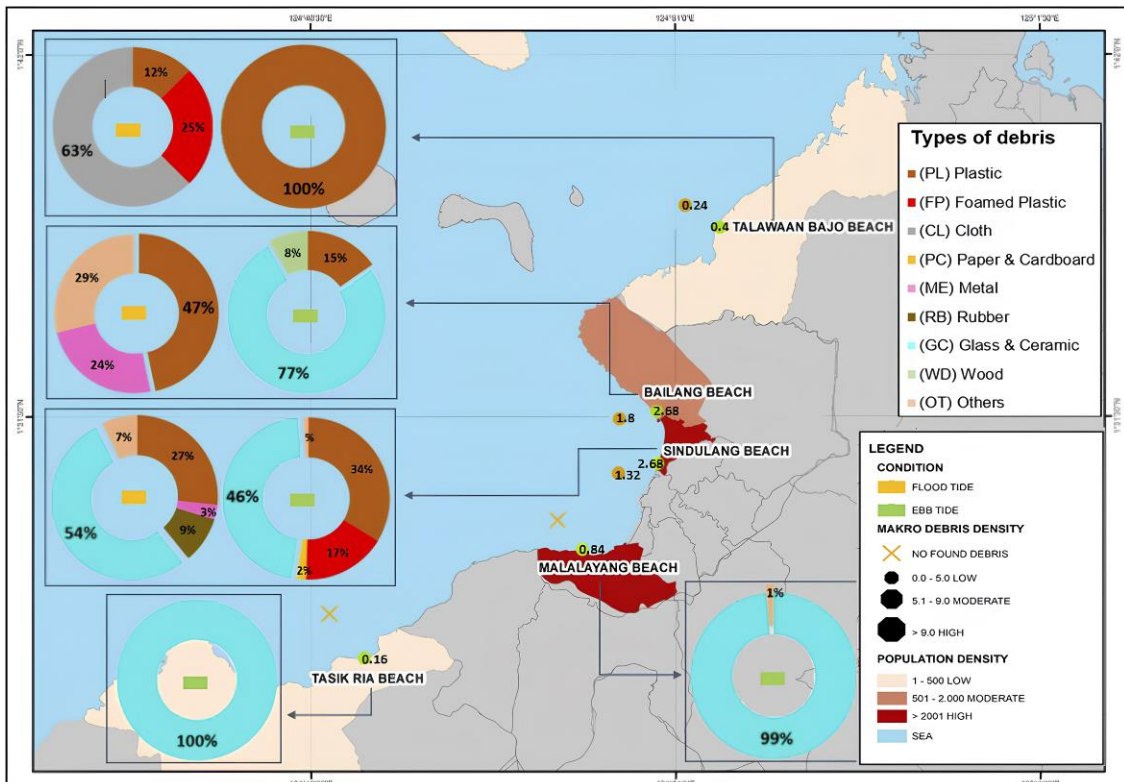


Figure 7. Meso-debris composition and density during west season.

Meso-debris was found at all five beaches in Manado Bay, consisting of 9 types: plastic, foamed plastic, cloth, paper and cardboard, metal, rubber, glass and ceramics, wood, and others. During the east season, the total weight of meso-sized waste obtained at the five research locations at flood tide was 99.9 g and that at ebb tide was 125.30 g. The highest weight of marine debris during flood tide was found at Malalayang Beach (66.90

g) and the lowest at Bailang Beach (8.5 g), while, during ebb tide, the highest was found at Talawaan Bajo Beach (56.7 g) and the lowest at Tasik Ria Beach (1.2 g). During the west season, the total weight of meso-sized waste at flood and ebb tide was 71.8 g and 135.3 g, respectively. The greatest weight of marine debris during flood tide was found at Sindulang Beach (66.5 g) and the lowest at Talawaan Bajo Beach, while, during ebb tide, the highest was found at Sindulang Beach (64.4 g) and the lowest at Talawaan Bajo Beach (1.9 g). The meso-debris density in Manado Bay and its environs during the east season ranged from 0.28 to 7.04 items m⁻² for flood conditions, while that for ebb conditions was between 0.52 and 7.40 items m⁻² (Table 2). During the west season, it ranged from 0.24 to 1.80 items m⁻² for flood conditions, while that for ebb conditions was between 0.16 and 2.68 items m⁻². An increase in the weight and density of waste in the west season only occurs at ebb tide. A comparison of the weight and density of meso-waste is relatively difficult to perform based on differences in tidal and seasonal conditions.

Conclusions. Macro-debris and meso-debris were found on five beaches consisting of nine types of materials, namely, plastic, glass and ceramics, foamed plastic, paper and cardboard, metal, cloth, rubber, wood, and others. Plastic items were the dominant type, representing approximately 70-80%. Spatially, debris was clustered at the mouth of the bay and near the river, and there was a large amount of activity, especially on Sindulang, Bailang, and Talawaan Bajo. Temporally, seasonal differences affect the debris deposit area according to the flow direction in the season. During the wet season, the density of marine debris increases significantly, with an estimated 18% rise compared to the dry season. The weight and density of marine debris are highest at Sindulang and Bailang during west season. In addition, the study has also highlighted the need for continued research and monitoring of marine debris in Manado. This will help track the progress of the management plan and identify any new or emerging issues. It will also provide valuable data for future decision-making processes.

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Conflict of interest. The authors declare that there is no conflict of interest.

References

- Andrades R., Martins A. S., Fardim L. M., Ferreira J. S., Santos R. G., 2016 Origin of marine debris is related to disposable packs of ultra-processed food. *Marine Pollution Bulletin* 109(1):192-195.
- Bergmann M., Lutz B., Tekman M. B., Gutow L., 2017 Citizen scientists reveal: marine litter pollutes Arctic beaches and effects wildlife. *Marine Pollution Bulletin* 125(1-2): 535-540.
- Badan Pusat Statistik (BPS), 2021 [Manado regency in figures]. BPS-statistics of Manado regency, Manado, 365 pp. [in Indonesian]
- Cheshire A. C., Adler E., Barbière J., Cohen Y., Evans S., Jarayabhand S., Jeftic L., Jung R. T., Kinsey S., Kusui E. T., Lavine I., Manyara P., Oosterbaan L., Pereira M. A., Sheavly S., Tkalin A., Varadarajan S., Wenneker B., Westphalen G., 2009 UNEP/IOC guidelines on survey and monitoring of marine debris. UNEP Regional Seas Reports and Studies, No. 186, IOC Technical Series No. 83, 120 pp.
- Constantino E., Martins I., Salazar Sierra J. M., Bessa F., 2019 Abundance and composition of floating marine macro litter on the eastern sector of the Mediterranean Sea. *Marine Pollution Bulletin* 138:260-265.

- Faizal A., Werorilangi S., Samad W., Lanuru M., Dalimunte W. S., Yahya A., 2021 Abundance and spatial distribution of marine debris on the beach of Takalar Regency, South Sulawesi. IOP Conference Series: Earth and Environmental Science 763:012060.
- Fazey F. M. C., Ryan P. G., 2016 Debris size and buoyancy influence the dispersal distance of stranded litter. *Marine Pollution Bulletin* 110(1):371-377.
- Ferreira J. A., da Silva C. A., Resende A. T., 2011 [Clean bay project: monitoring of marine environments degraded by solid waste in Guanabara Bay, Rio de Janeiro, Brazil]. *Journal of Integrated Coastal Zone Management* 11(1):103-113. [in Portuguese]
- Jambeck J. R., Geyer R., Wilcox C., Siegler T. R., Perryman M., Andrady A., Narayan R., Law K. L., 2015 Plastic waste inputs from land into the ocean. *Science* 347(6223):768-771.
- Juliandri M. R., Radjawane I. M., Tarya A., 2020 Modeling the distribution of floating marine debris movement in tourism area in Pelabuhan Ratu Bay, West Java. *AACL Bioflux* 13(5):3105-3116.
- Kementerian Lingkungan Hidup dan Kehutanan (KLHK), 2020 [Guidelines for monitoring of beach litter]. Ministry of Environment and Forestry, Jakarta, 115 pp. [in Indonesian]
- Lasut M. T., Pane L. R., Doda D. V. D., Kumurur V. A., Warouw V., Mamuaja J. M., 2021 Seasonal variation of marine debris at Manado Bay (North Sulawesi, Indonesia). IOP Conference Series: Earth and Environmental Sciences 744:012038.
- Moore C. J., Moore S. L., Leecaster M. K., Weisberg S. B., 2001 A comparison of plastic and plankton in the North Pacific central gyre. *Marine Pollution Bulletin* 42(12):1297-1300.
- National Oceanic and Atmospheric Administration (NOAA), 2013 Programmatic environmental assessment (PEA) for the NOAA Marine Debris Program (MDP). 168 pp.
- Pane L. R., Pelle W. E., Undap S. J., Rumampuk N. D. C., Warouw V., Mamuaja J. M., Lasut M. T., 2020 [Type, composition, and density of marine litter in Manado Bay during rainy season]. *Aquatic Sciences and Management* 8(1):1-7. [in Indonesian]
- Pawar P. R., Shirgaonkar S. S., Patil R. B., 2016 Plastic marine debris: sources, distribution and impacts on coastal and ocean biodiversity. *PENCIL Publication of Biological Sciences* 3(1):40-54.
- Pengelolaan Sumber Daya Air Wilayah Sungai Tondano-Sangihe-Talaud-Miangas (PSDA), 2017 [Water resource management of Tondano-Sangihe-Talaud-Miangas watershed]. The Ministry of Public Works and Housing of Indonesia, Jakarta, 328 pp. [in Indonesian]
- Rial D., León V. M., Bellas J., 2017 Integrative assessment of coastal marine pollution in the Bay of Santander and the Upper Galician Rias. *Journal of Sea Research* 130:239-247.
- Sistem Informasi Pengelolaan Sampah Nasional (SIPN), 2021 [National waste management information system. Manado City waste data for 2021]. Available at: <https://sipsn.menlhk.go.id/sipsn/>. Accessed: June, 2023. [in Indonesian]
- Syakti A. D., Bouhroum R., Hidayati N. V., Koenawan C. J., Boulkamh A., Sulistyio I., Lebarillier S., Akhlus S., Doumenq P., Wong-Wah-Chung P., 2017 Beach macro-litter monitoring and floating microplastic in a coastal area of Indonesia. *Marine Pollution Bulletin* 122(1-2):217-225.
- Tarya A., Hoitink A. J. F., Van der Vegt M., van Katwijk M. M., Hoeksema B. W., Bouma T. J., Lamers L. P. M., Christianen M. J. A., 2018 Exposure of coastal ecosystems to river plume spreading across a near-equatorial continental shelf. *Continental Shelf Research* 153:1-15.
- Wilcox C., Mallos N. J., Leonard G. H., Rodriguez A., Hardesty B. D., 2016 Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife. *Marine Policy* 65:107-114.
- Yohanlis A. D., Putri M. R., 2021 Characteristics of surface currents in Manado Bay, North Sulawesi, Indonesia. *Borneo Journal of Marine Science and Aquaculture* 5(1):42-52.

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