Seasonal variation of marine debris at Manado Bay (North Sulawesi, Indonesia)

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Abstract. Marine debris has become a global concern due to its impact on marine ecosystems. These materials generally come from land and are deposited to marine environment through different agent of carrier. Many efforts are being made to monitor the dynamics of the debris including their presence and their variability in relation to seasons. The latter are assumed from the facts that the presence of the debris is mainly affected by the waves, speed, and direction of ocean currents in the area of interest. In this study, variation of debris in dry and wet season at Manado Bay was assessed by using a shoreline technique. Two locations are selected, Bailang and Malalayang beach. The samplings were conducted in August 2019 (represent dry season) and January 2020 (represent wet season). Several parameters are examined during the sampling; they are: amount of material, type of debris, composition, and spatial density of each type for macro-size (>2.5 cm) and meso-size (0.5–2.5 cm). The results showed that there was variation on composition and density, but the types of debris remain unchanged. Our present study concluded that variation in the season do not affect the variability of marine debris in Manado Bay.

Keywords: Bunaken; Indonesia; marine debris; plastic; seasonal variation

1. Introduction
Waste has become a global problem nowadays. It can be found everywhere and has a huge impact on the environment both on land and in the ocean [1–5]. Marine debris is found in or near the ocean and are originated from land which are resulted from human activities. They enter marine environment through rivers, drainage channels, and are also carried by visitors of a beach [6–9], and their fate is influenced by waste management activities on land [2, 5]. Most of marine debris is very harmful to the marine resources, ecosystem, economy and social life [1, 10].

In 2016, Indonesia became the country with the world largest mismanaged plastic waste [4.3 million metric ton (Mt)] from the total of 9.1 Mt waste production [11]. It has increased from 3.22 Mt in 2010
In order to prevent it to worsen, Indonesian government has issued a regulation in 2018 through a Presidential Decree Number 83 which governs Marine Debris Management. The regulation aims to establish strategies, program and activities in the form of a national action plan in handling marine debris from 2018 to 2025. One of the activities implemented is monitoring, which includes monitoring marine debris in Manado Bay. The Bay is located in northern part of Sulawesi Island, Indonesia. The area of the bay is very strategic because it is in the middle area of world coral triangle and has the Bunaken National Park as the outer part [5] and also an area of an important traditional fishing for the locals.

Bunaken National Park, one of the three Unesco’s biosphere reserves in Indonesia, which is known for its coral reefs [5] faces a threat of marine debris which could be brought by current from Manado Bay, originated from Manado city. In January to April 2018, garbage removed from Bunaken Island (one of five islands in Bunaken National Park) weighed up to 3 tons [13]. Meanwhile, according to Central Bureau of Statistics [14] the number of domestic and foreign visitors in Manado has reached 1,739,729 people. This expected to be a threat to Manado Bay and Bunaken National Park which the quantity of garbage can increase and will have a negative impact on the residence, and in particular to the marine environment [5], in addition to other impacts cause by liquid waste [15].

One of the efforts in monitoring marine debris in Manado Bay is by accessing their presence and dynamics in the sea. In general, the dynamic of marine debris, its existence and variation, are closely related to seasons, tides, wave, current speed and direction, oceanography and meteorology factors and fishing activities [16–20]. The monitoring is very important to reduce ecological threat that could possibly occur [3, 21].

The study aimed 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) by using different parameter (type, amount, composition, density) and shoreline technique (assessment of shoreline segments). The study was an integral part of the research conducted by Pane et al. [22] and is part of marine debris monitoring program in Manado Bay waters and around Bunaken National Park funded by the Ministry of Environment and Forestry of the Republic of Indonesia.

2. Material and methods

2.1. Study site

The observation was conducted in Manado Bay, North Sulawesi, Indonesia. Two locations were selected as sampling sites. The first location is Malalayang Beach, geographically located at 1º27′36,0″ N and 124º48′15,0″ E. The beach is located at the southern part of the bay and is facing north. The substrates consist of sands with gravel, and beach faces north, sandy beach mixed with gravel, and slope range 82.3 to 84.1°, and is bordered by vegetation to the land. The second location is Bailang Beach, located in 01º31′32,0″ N and 124º50′32,0″ E. It lies on the northern part of the bay and faces west. It has a muddy substrate type and slope range of 82.3º to 84.1°, bordered by vegetation to the land (figure 1).

Manado Bay is open sea water facing west toward Sulawesi Sea, which is on the western side of northern part of Sulawesi Island. Part of northern side of the bay is included in Bunaken National Park area which is known for its high biodiversity and is diving site [5]. Based on its position, Manado Bay forms a water-front city toward Manado city. Malalayang Beach (around 5 kms from the city center) is a peri-urban area and also a tourism area; it is allocated for fishing and access to the sea. The source of debris generally comes from the sea, and they are stranded by current and waves. Bailang Beach (around 4 km from the city center) is an urban area of Manado city and is not intended for tourism, so there is only for fishing and also access to the sea. The presence of debris in this area is basically from the sea and also Bailang River which is situated next to the sampling site.

The selection of the location was done by following the Guidelines for Monitoring Coastal Waste published by the Ministry of Environment and Forestry of Republic of Indonesia [23] which adopted the guidelines of Cheshire et al. [24] and Lippiatt et al. [10]. The guidelines require, among other things, that location should be accessible throughout the year or season (for continuous monitoring), sandy or gravel substrates, there are no breakwaters, jetties, docks or other structures, has a gentle to moderate
slopes, there is no clean-up activities around the area during sampling, and there is now waste management facilities at the location. Since 2017, both beaches have been designated to be permanent observation locations for marine debris monitoring in Manado Bay [25].

2.2. Sampling time and technique
The marine debris sampling was carried out once in each season, on July 19th and 20th 2019 for dry season and on January 24th and 25th 2020 for wet season. The differences between those two seasons are based on the average monthly precipitation which reached 17.66 cm in July and 33.11 cm in January. Debris sampling in both seasons was carried out at the same location and with similar sampling procedure.

Sampling was conducted by using the guidelines of marine debris quantification published by Ministry of Environment and Forestry of the Republic of Indonesia [23] which has been used nationally in Indonesia since 2017. This method was adapted for the condition in Indonesian waters from the method issued by NOAA [10]. Observation was made during low tide using shoreline technique on macro- (>2.5 cm) and meso-debris (0.5–2.5 cm) waste materials. Sampling area on the coast was defined at the length of 100 m parallel to the coastline; the first line was established at the nearest part of the water; and it was 20 m wide. Sampling area was divided into 5 lanes (perpendicular to the coastline), each 20 m apart. A quadrate (5 m², 2 replicates) was placed on each lane. This 5 m² quadrate was then divided into 25 small quadrates (1 m²), and 5 of these sub-quadrates were randomly selected and were further divided into 4 small parts (0.25 m²). These 4 parts were then labeled as section A, B, C and D. Section A is on upper left side facing the sea and the other parts (B, C, and D) were on the clockwise direction.

Sampling of the marine debris was done at 5 sub-quadrates (which has been divided into section A to D) in each lane. At section A, the surface of the sand was peeled off to the depth of 5-10 cm and all the
substrates was collected (together with marine debris) by using a scoop. All the sands in Section A were collected into 2 sieves at the same time. The 0.5 cm steel sieve (made of steel) was at the bottom to collect the meso-size debris and the 2.5 cm steel sieve was on the top to collect the macro-debris. All the collected debris that has been passed through 0.5 cm sieve was then put into plastic bags and labeled. The debris which was collected from 2.5 cm sieve was put into a plastic bag. Section B to C were also peeled to the depth of 5 to 10 cm, collected using a scoop, and put together with all the collected debris in Section A and labeled.

All the sampling bags were stored properly. They were classified, calculated, and weighed. The classification was carried using the guidelines from UNEP/IOC Guidelines on Survey and Monitoring of Marine Debris [24]. They were then weighed with a scale (to the accuracy of 0.1 g) and counted based on the type of materials. All the data were recorded in the datasheet.

2.3. Data analysis
The data obtained during the sampling was calculated based on the guidelines provided by Ministry of Environment and Forestry of Indonesia [23], by determining their composition and density of the debris material. The composition was calculated from the weight percentage of the debris for each type in total waste. Meanwhile, the density was calculated from the percentage of waste (fragment) per type in m$^2$.

The calculation for each size was performed differently. Statistical tests were applied, among others Kolmogorov-Smirnov test to find out the distribution of the data, Wilcoxon Signed Rank test was performed to find out the differences between season toward data that are not normally distributed, and paired T test for normally distributed data.

3. Results and discussions

3.1. Types of marine debris
Marine debris was found in Manado Bay, at both study sites, in both dry and wet seasons and both sizes. The debris consists of 9 types of materials, there are plastics (PL), glass and ceramic (GC), foamed plastic (FP), paper and cardboard (PC), metal (ME), cloth (CL), rubber (RB), wood (WD), and other (OT). There was only a slight variation occurred in the number of types based on season for both sizes.

The number of debris items for macro size in Malalayang Beach for dry and wet season were 25 and 24, respectively; while in Bailang Beach 33 and 32. The meso-size in Malalayang Beach for dry and wet season were 17 and 17, and for Bailang Beach were 24 and 22.

Marine debris found during the study was classified according to UNEP/IOC Guidelines on Survey and Monitoring of Marine Debris [24]. They were plastic materials, glass and ceramic materials, foamed plastic, metal, rubber materials, cloth materials and others. The plastic materials include bottle caps & lids (PL01), bottles < 2 L (PL02), jerrycans (PL03), straws (PL04), drink package rings (PL05), food containers (PL06), plastic bags (PL07), cigarettes butts & filters (PL11), monofilament line (PL18), strapping (PL21), fiberglass fragments (PL22), and other plastics (PL24). Glass & ceramic materials include construction materials (GC01), bottles (GC02), cups (GC03), and glass fragments (GC07). Foam packing (styrofoam) (FP04) was classified into foamed plastic. Paper & cardboard materials were cups and drink containers (PC03), and other paper & cardboards (PC05). Those which are made of metal were bottle caps (ME02), aluminum drink cans (ME03), metal fragments (ME08), wire (ME09), and other metals (ME10). Rubber materials include tires (RB04), inner-tubes (RB05), and other rubbers (RB08). Matches (WD05) and other woods (WD06) were classified into wood materials. From cloth material is other cloth (CL06); and those include in other materials were sanitary (tampon) (OT02), electronics equipment (OT03), and other (OT05).

3.2. Composition of marine debris
The highest composition of macro-size debris found in dry season was the plastic materials; it covers 33%, while glass and ceramic material (50%) dominated the wet season (figure 2). Glass and ceramic
dominated the meso-size debris in dry and wet seasons with the composition of 56% and 72%, respectively (figure 3).

The average of total weight of macro-size marine debris in Manado Bay in dry and wet season during the study was 8,217.93 g and 9,551.32 g, respectively. One of the materials that was different in composition was glass and ceramic; this material was only 17% of all materials during dry season but increased to 50% in wet season. Several materials decreased in composition; plastic was, among others. This type of material had a composition of 33% in dry season and decreased to 23% in wet season. One other material, rubber, was 7% in dry season, decreased to 0%. This showed a variation of macro-size marine debris, but the variation was found to be non-significant ($p > 0.05$).

The composition of meso-size marine debris in Manado in dry and wet seasons was also different. The average of total weight of this size was 338.65 g in dry season and 344.10 g in wet season. One of the materials that increased from dry to wet season was glass and ceramic, the composition in dry season was 56% and increased to 72% in wet season. It was differed from plastic materials which decreased from 34% in dry season to 21% in wet season. But then the difference in composition was found to be non-significant ($p > 0.05$).

![Figure 2](image)

**Figure 2.** Percent composition of marine debris for macro-size debris (>2.5 cm) in Manado Bay, North Sulawesi, Indonesia (A: dry season; B: wet season).

![Figure 3](image)

**Figure 3.** Percent composition (%) of marine debris for meso-size debris (0.5–2.5 cm) in Manado Bay, North Sulawesi, Indonesia (A: dry season; B: wet season).
The same condition was reported by Djaguna et al. [26] and Bangun et al. [27] that marine debris of the plastic material was the most dominant type of materials in beaches around Manado Bay. They found that more than 50% of the marine debris found in Tongkaina Beach, Talawaan Bajo Beach, Tasik Ria Beach and Tumpaan Beach was categorized as plastic materials. This is in line with Jambeck et al. [12] who reported that Indonesia is one of the largest contributors of plastic waste to the marine environment in the world.

3.3. Density of marine debris

Density of marine debris both macro and meso-sizes in Manado Bay in dry and wet season was also determined (figure 4 and figure 5). For macro-size debris, it was found that plastic material was the dominant one in both on dry and wet seasons. The density of this material was found to be 6.25 fragment/m² and 9.18 fragment/m², respectively. It was then followed by glass and ceramic which has the density of 1.64 fragment/m² and 1.95 fragment/m²). Foamed plastic has a higher density in wet season (0.53 fragment/m²) than dry season (0.10 fragment/m²). For meso-size (figure 5), the highest density in dry season was plastic materials (11.04 fragment/m²), and it was followed by glass and ceramic (7.7 fragment/m²), metal (0.98 fragment/m²). The same highest density for plastic material was also found in wet season (12.86 fragment/m²) and followed by glass and ceramic (10.04 fragment/m²). Foamed plastic was a little bit higher in wet season (0.80 fragment/m²) than in dry season (0.16 fragment/m²).

![Figure 4](image)

**Figure 4.** Density (fragment/m²) of marine debris for macro-size debris (>2.5 cm) in Manado Bay, North Sulawesi, Indonesia (A: dry season; B: wet season).

When comparing the study in dry and wet season of marine debris in Manado Bay, the wet season has a slightly higher density of marine debris than the dry season, both in macro and meso-size. In dry
season, the average of total density of macro size marine debris was 9.34 fragment/m² and it increased to 12.92 fragment/m² in wet season. The same goes to meso-size, the average of total density in dry season was 20.34 fragment/m² and it increased to 24.78 fragment/m² in wet season; the was a 4.44 fragment/m² differences. However, this was not significantly difference ($p > 0.05$). The similar finding was reported by Bangun et al. [27] in Tasik Ria Beach. This area is approximately 12 km to the south of Malalayang Beach and is also part of Manado Bay.

The abundance of marine debris is influenced by season [21], rainfall, winds and tides [4, 17, 19, 28, 29, 30], input from rivers to the sea also plays a significant role in contributing the increase of the debris materials [19, 30–32], and high population of coastal communities, for instance in Indonesia [33]. During wet season, as the river water discharge increases, more waste from the land would accumulate in coastal area around the river mouth. This probably the case in Manado Bay, especially in Bailang Beach where the plastic materials dominated the wet season because of the increasing of water discharge from the river. However, tourism activities in the beach during dry season can also increase the abundance of marine debris [29].

![Figure 5](image)

**Figure 5.** Density (fragment/m²) of marine debris for meso debris (0.5–2.5 cm) in Manado Bay, North Sulawesi, Indonesia (A: dry season; B: wet season).

According to Thiel et al. [29], the accumulation of marine debris in beach varies in different types of beach. For the rocky type beach, the debris that arrives on the beach can be crushed by the waves and currents in the shore area. This is probably the case in Malalayang Beach which has the rocky type beach, in which the meso-size materials were dominated by glass and ceramic. The accumulation of marine debris was also influenced by the river input [19–20]; this could be the case in Bailang Beach where the debris arrive from the land through Bailang River.
4. Conclusions
Based on study on marine debris in Manado Bay it was concluded that there was no variation of the marine debris found in the area. However, further study is needed to find out the factors that can affect the presence of marine debris in the area and how they behave during dry and wet season.

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