Daily accumulation rates of marine litter in Pulau Rambut Wildlife Sanctuary, Jakarta Bay, Indonesia

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Abstract. Studies showed that the amount of marine litter is linked with unmanaged litter entering the ocean. Some marine litter could be stranded on small uninhabited islands, including on Pulau Rambut (25 ha), a wildlife sanctuary for waterbirds that consists of mangroves, beaches, and forests located near Jakarta Bay, where 13 rivers from Jakarta ended in the bay. The aim of this study was to identify the daily accumulation of marine litter (classified into non-organic and organic) that is stranded and trapped on this island. Shoreline surveys for the sandy beach (25 m x 7 m plot) and beach forest (25 cm x 6 cm), as well as visual surveys for mangroves (20 m x 4 m; 2 plots), were employed, repeated for 9 times within 17 days. Of 14,610 litter items collected, 14,585 items were non-organic, dominated by foam and plastic. The accumulation rates were 433.5 items/day for non-organic litter and 0.5 items/day for organic litter. The sandy beach and beach forest accumulated higher marine litters compared to mangroves.

1. Introduction
Indonesia has been recorded as one of the five countries that are responsible for over half of land-based plastic leakage to the world’s ocean [1]. Based on the same study, the other four countries including China, the Philippines, Thailand, and Vietnam which are at a stage of economic growth yet with an inadequate local waste-management infrastructure. It is also reported that about 75% of the leakage from the land originated from uncollected waste and the other 25% are the leaks of the existing waste management system [2]. That being said, the current waste management system is not yet a reliable way to prevent land-based plastic or waste leakage. This leaked waste then entered the ocean via the river, thus this waste is now commonly known as marine litter. Nowadays, marine litter is widely present and distributed in the densely populated to remote points of all marine habitats.

The distribution of marine litter is affected by wind streamlines as well as ocean currents [3]. Marine litter then floating in the oceans. Some of this floating marine litter were stranded in the shoreline or buried in the beach or even trapped in the mangrove prop roots. Not only it is unpleasant to see, but it is also could disturb the ecosystem as well as harming wildlife and its habitat. For example, prolonged suffocation on mangroves by plastic caused immediate pneumatophore growth and potential leaf loss thus mangroves are likely to deteriorate eventually [4]. The presence of marine litter is becoming more abundant that marine litter could change the physical properties of the environment [5].

The occurrence of marine litter is present in Pulau Rambut Wildlife Sanctuary. Marine litters were also found on the shoreline, primary mangrove forest, beach forest, even in the secondary mangrove forest. These litters were either trapped in the prop roots or buried in the beach [6]. This could disturb and harm the ecosystem since Pulau Rambut is an essential habitat of various waterbird species.

The study about the quantity of marine litter in Pulau Rambut Wildlife Sanctuary has never been done before. Studying the number of marine litters stranded in Pulau Rambut is a must for further management
action. Therefore, the aim of this study was to identify the daily accumulation of marine litter that is stranded and trapped on this island.

2. Methods
Pulau Rambut has five types of land cover consisting of a normal beach, beach forest, secondary forest, secondary mangrove forest, and primary mangrove forest. Four plots were employed for this study that represents each type of land covers in Pulau Rambut Wildlife Sanctuary as shown in figure 1.

![Figure 1. Location of plots of this study [5].](image)

Data of this study were collected using a modified version of the shoreline survey method by the National Oceanic and Atmospheric Administration (NOAA) [7] for beach and beach forest and a modified version of a visual survey for mangroves [8]. The sampling for beach and beach forest was collected by making a plot consisting of 100 m in length which was then divided in half (50 m x 50 m) with the width depends on the distance from the land to the end of the beach. For the mangrove, the plot consisting of 20 m in length with 4 m in the width.

Any marine litters with a size over 2.5 cm (macro litter) were collected and then was sorted by type and location and then we analyzed the amount, types, and weights of the marine litter that were found. The sample was conducted when the tide was at the lowest and repeated nine times within 17 days. Since this is an accumulative study, we removed the plot from all litter two days before.

3. Results and discussion
3.1. General condition
Pulau Rambut Wildlife Sanctuary is a small uninhabited island that only consists of 25 ha which is located in Jakarta Bay, Indonesia where 13 rivers from Jakarta ended up in the bay. It is a home and an important habitat for various species of waterbirds. Around 48 species of birds live in Pulau Rambut which makes it an essential habitat of these species of birds. Marine litter has been a major problem on this island and could endanger the habitat of these birds. About 15 species of waterbirds in Pulau Rambut depended on the mangrove ecosystem yet marine litter could be easily found in the prop roots. It is also reported that one species of waterbirds called little black cormorant (Phalacrocorax sulcirostris) in Pulau Rambut Wildlife Sanctuary, used synthetic ropes as a material of their nest [9]. This case could be risky for birds, especially for chicks. They could be easily entangled in synthetic ropes.

It is unlikely these litters came from within the island, yet it is most likely these litter came from the nearest mainland area. The nearest mainland of Pulau Rambut is Java Island specifically Jakarta Province and Banten Province area. Studies showed that litter from the city of Jakarta was polluting the shores of islands up to 20 km away in the Pulau Seribu archipelago in the Java Sea [10]. The wind
direction also influenced the direction of floating litter. According to the wind data in 2020, the ocean current around Pulau Rambut was around 2.71 to 4.54 m/s with the wind direction towards the southeast of the island.

3.2. Marine litter collection

Marine litters that were found in Pulau Rambut Wildlife Sanctuary were classified into two categories, organic and non-organic litter. This classification is based on the ability of the litter to degradable [6]. Organic litter consists of logs and bamboos. Whereas non-organic litter consists of plastic, foam, metal, glass, rubber, fabric, and others.

About 14,610 items of litter were collected during 19 days of research. Around 99.8% of it were non-organic litters and 0.2% of it were organic litters. Non-organic litters that were found were dominated by plastic and foam as shown in figure 2. The number of organic litters that were found was not significant. Since the organic litters that were found only consisted in small woods like woods for heels and small bamboo for fishing.

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|      | Plastic | Foam  | Metal | Glass | Rubber | Fabrics | Other |
|------|---------|-------|-------|-------|--------|---------|-------|
| Count| 5235    | 8072  | 110   | 11    | 831    | 321     | 5     |
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Figure 2. The accumulation of marine litter.

Based on the observed plot, plot 2 had a higher number among other plots whereas plot 4 had the lowest number as shown in table 1. This is because plot 2 was located in the shoreline and south part of the island. On the other hand, plot 4 was located in the middle of the island. It was possible that the litters were already buried or trapped in the outer part of Pulau Rambut before it infiltrates the middle part of the island.

|      | Non-Organic | Organic |
|------|-------------|---------|
| Plot 1| 3,783       | 6       |
| Plot 2| 8,237       | 3       |
| Plot 3| 1,645       | 1       |
| Plot 4| 920         | 15      |
| Total | 14,585      | 25      |
Table 2. Total weight (gr) per plot.

|       | Non-Organic | Organic |
|-------|-------------|---------|
| Plot 1| 99,049      | 307     |
| Plot 2| 80,190      | 399     |
| Plot 3| 17,109      | 33      |
| Plot 4| 5,751       | 1,220   |
| Total | 202,099     | 1,959   |

However, for the weight, plot 1 was heavier compared to the other plots. The second heaviest was plot 2 (table 2). This is because a truck tire weighing around 55,000 gr or 55 kg along with a single sofa weighing around 9,000 gr or 9 kg were found in plot 1 (figure 3). Meanwhile, a car tire weighing around 7,000 gr or 7 kg was also found in plot 2 hence it became the second heaviest plot. These items were big and heavy enough to be half-buried in the shoreline before it had a chance to infiltrate Pulau Rambut further.

Figure 3. A truck tire and a single sofa that was found in plot 1.

3.3. Daily accumulation of marine litter

Data for daily accumulation rates were gathered for 17 days with 2 days interval. Two days before the survey began, the litters were removed from the plot. The data from that day were not included in this accumulation rates calculation. This is because the marine litters that were stranded or trapped already were from an indefinite time. If it was included in the data, the result would be biased.

As shown in figure 4, the daily accumulation of all the marine litters that were fluctuated each day. From day 1 to day 2, it was significantly decreasing from 3,066 items to 670 items and it continued to decrease until day 3. But from day 3 to 5 it was slightly increasing. The lowest point was on day 6 but it fluctuated again from day 7 to day 9.

Figure 4. Daily accumulation of marine litter.
Based on the data per plot, organic litters were not found in plot 3 and plot 4 (figure 5). But there was a small number of organic litters that were found in plot and plot 2 although the amounts were not significant. From this data, the accumulation rate of organic litter was estimated at around 0.5 items/day.

**Figure 5.** Daily accumulation of organic litter.

As for the non-organic litters, the daily accumulation fluctuated significantly. Plot 1 has the most fluctuated graph compared to other plots (figure 6). But the common ground of these plots was on day 6. About 3 out of 4 plots, the number were decreasing on day 6 and increasing on the next day. This decrease was because of the weather and the ocean current on that day. The day before the survey was sunny but the next day was raining and a local storm basically happened. Which affected the increasing number of litters that were found. From this data, the accumulation rates of non-organic litter were estimated at around 433.5 items/day.

**Figure 6.** Daily accumulation of non-organic litter.
Based on the observation in the field, marine litters were coming from the south and the southwest area of the island despite the wind data result. The south area of Pulau Rambut is Jakarta and the southwest area is Tangerang (Banten).

According to a report by World Bank in 2018, around 165 tons of waste were extracted daily from Jakarta. The composition of the waste including plastic bags (16%), plastic packaging (5%), plastic bottles (1%), other plastics (9%), glass and metal (4%), diapers (21%), and organic waste (44%) [11]. Based on the data by World Bank, around 44% of organic waste was disposed of in the waterways, however, from the finding of this study, organic litters were not a lot. There are many possibilities. Either it reached other islands first or it has already deteriorated in the ocean. Moreover, the data did not mention what kind of waste was disposed of.

Based on the same report, the main hotspots of waste leakage in Jakarta are in Muara Kamal in the west and Cilincing in the east. It is still unclear the sources of marine litters that were stranded in Pulau Rambut Wildlife Sanctuary. Therefore, it cannot be concluded that the litter came from a particular area. Further research about marine and plastic litter sources needs to be done in order to know for sure the litter sources.

4. Conclusions
During 19 days of research, there are 14,610 items of marine litter that was stranded in Pulau Rambut Wildlife Sanctuary with 99.8% (14,585 items) of non-organic litter. The accumulation rates of non-organic litter were 433,5 items/day and for organic litter were 0.5 items/day. Based on the field observation, the beach forest (plot 2) and sandy beach (plot 1) accumulated higher marine litters compared to mangroves (plot 3 and 4).

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