Assessment of marine debris in seagrass beds of Pramuka Island, Kepulauan Seribu

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Abstract. Indonesia is referred as the second largest contributor of marine debris in the world after China, with an estimated 0.48-1.29 million metric tons per year. High anthropogenic activities from locals and tourists can produce large marine debris and impact the seagrass ecosystem. This research aimed to identify marine debris in the habitat of seagrass beds on Pramuka Island. Extensive surveys include observing seagrass community structures, the measurement of chemical and physical parameters of the water, and marine debris inventory at three stations in Pramuka Island. Observation results found six seagrass species, with coverage ranged from 1.67 - 47.32% while the density 28 - 112.76 stand/m². Marine debris can be classified into six types: plastic, metal, rubber, glass, organic matter, and others. The weight of marine debris for each type ranges from 0.03 – 2.38 kg. In addition, microplastic found consisted of fiber, film, and fragment with a unit weight of 20 – 440 particles/kg. In conclusion, the seagrass conditions of each station are classified as damaged. The marine debris that has the most impact on the seagrass beds is plastic. Fiber type microplastic has the most abundance. this can interfere with respiration and the photosynthesis process of seagrass.

Keywords: marine debris; microplastics; Pramuka Island; seagrass; seagrass beds

1. Introduction
Indonesia is referred as the second largest contributor of marine debris in the world after China, with an estimated 0.48-1.29 million metric tons per year [1]. Estimates that an increase in marine debris will occur globally by 2025, if it is not taken seriously. Marine debris is a solid waste or material discarded directly or indirectly into the marine environment [3]. Marine debris is categorized into several classes, including plastic metal, rubber, glass, organic matter, and others [4]. Marine debris includes all forms of manufactured or processed materials that are then disposed of or left in the marine environment. This marine debris consists of goods, food/snacks that have been used by people and then brought into the sea, either intentionally or unintentionally, such as marine transportation, drainage, and waste or garbage disposal systems by the wind [5]. Disposal of garbage into the sea causes damage to coastal ecosystems, especially seagrass.

Seagrass is a flowering aquatic plant (Anthophyta) that lives and grows immersed in the marine environment. Seagrass has vascular, rhizome, rooted and reproduces generatively by seeds and vegetatively [6]. Seagrass ecosystems provide an essential role in marine ecology; as primary producers, bottom stabilizers of waters, nutrient recyclers, food sources, and nursery ground for numerous vertebrate and invertebrate species [7]. Seagrass beds as a result of their thick tall canopy, are known to increase sedimentation of particles as well as reduce the chances of particle re-suspension. A study highlighting seagrasses to buffer sediment re-suspension by three times as much when compared to a non-vegetated sea floor [8]. The hydrodynamic influences of seagrasses are shown to increase...
sedimentation of finer particles. A number of studies indicating the presence of microplastics in seagrass sediments, especially in subtidal environments [9]. Other studies have examined how seagrass leaves provide a means of collecting microplastic particles, offering an additional mechanism for their potential concentration.

Anthropogenic could be one of the activities that cause damage to seagrass, such as tourism. The increase in visitors who travel in coastal areas is one of the factors for the increase in marine debris. This condition coincides with many irresponsible visitors who intentionally dispose of food packaging, plastic bottles, cigarette butts, etc. Garbage disposed of will gradually be carried away by ocean currents and further increase the amount and volume of waste in the waters [10].

Pramuka Island, the administrative centre of the Thousand Islands Regency, is a residential island with a reasonably high population density and is a tourist destination visited by many tourists. Activities from local communities and tourists can produce large amounts of marine debris that impact coastal ecosystems, specifically seagrass ecosystems that live in shallow sea waters close to settlement [11].

The development of human activities in coastal areas, especially in the shallow sea of Pramuka Island, such as fishing, tourism, settlements, and reclamation activities, has led to changes in the seagrass ecosystem, such as community structure, high sedimentation processes and closure of water surfaces in

**Figure 1.** Observation stations on Pramuka Islands, based on the presence of seagrass beds.

**Figure 2.** Seagrass observation transects based on seagrass watch.
seagrass habitat by stagnant litter [12]. Apart from human activities on Pramuka Island, the large amount of debris is also influenced by a considerable amount of waste from Jakarta Bay. According to [13], 8.32 tons of waste enters Jakarta Bay every day.

The amount of marine debris in Pramuka Island that enters the sea causes a direct or indirect impact on the seagrass ecosystem. The direct impact is the decreasing light intensity as the main supply for seagrass growth due to a large amount of marine debris [14]. The indirect impact is that it can affect the ecology, especially the habitat of associated biota in seagrass. Research on marine debris in marine coastal vegetated ecosystems is still in its infancy. Within seagrass meadows specifically, although documented to be present, we still know little about the variability of microplastics in the beds. The study's objective about waste is to determine the characteristics of marine debris found in the seagrass habitat of Pramuka Island, Kepulauan Seribu.

2. Material and methods

2.1. Date and study area

Seagrass and marine debris observation were conducted at three stations in Pramuka Island (figure 1) from February to March 2020. The stations were selected based on the presence of seagrass habitat, located on the east and north side of the Islands. All stations covered three sub-stations for observing marine debris and seagrass communities and three sub-stations for microplastics inside each station. Sediment fraction analyses were taken at the Marine Biomaterial and Bioprospecting Laboratory, Department of Marine Sciences & Technology, Faculty of Fisheries and Marine Sciences, IPB University.

2.2. Materials

The tools and materials used for seagrass and marine debris observation were 0.5 m x 0.5 m square transect, roll meter, datasheet, camera, newtop paper, GPS, office stationery. Refractometer, thermometer, pH meter and DO meter were used for observation of water quality. To carry sediment samples, tools are needed in the form of: plastic strap, distilled water, cores, scales, cool box. oven, saturated NaCl solution, graded sieve, extract paper, vacuum pump, and stereomicroscope are needed for microplastic observation.

2.3. Field sampling seagrass.

The Seagrass Watch method was carried out to determine species composition, density, and seagrass cover. At each station, three-line transects were laid along 50 m perpendicular to the shoreline, with a distance of each transect being 25 m. A 0.5 m x 0.5 m square plot was used in each line transects to estimate the species density and seagrass cover (figure 2) [15].

2.4. Marine inventory

Marine debris can be categorized into 5 types based on their size (table 1). Macro marine debris is grouped by accumulation survey on a 50-meter long transect, vertically or horizontally from the beach to the sea. All marine debris was collected and removed along the shoreline transects path were (figures 3a and b) [14].

Micro-sized marine debris obtained from sediment samples. Sediment is taken using a core with a depth of 10 cm and stored in a plastic strap. Microplastic content on sediment was identified by drying the sediment samples at a temperature of 105°C. For ± 12 hours (depends on sediment conditions). The dried sediment was filtered using a graded sieve at 5 mm, 60 mm. Sediment is separated between fine sediment and coarse sediment and weighed at 50 grams (each of sediment) using an analytical scale. The density separation in the sediment is carried out by adding 150 ml saturated NaCl solution into the
sediment (50 g). The sample was stirred for 2 minutes [16]. Dissolving NaCl with distilled water using a stirrer took approximately 5 minutes [17]. The light-sized plastic will be lifted to the top (for density separation) after the stirring process. The separation was carried out with the help of Whatman filters (1.2 m) and a stereomicroscope [18]. The data on microplastic content based on the microplastic were collected through these processes.

2.5. Characteristic of aquatic environment
Aquatic environment characteristics were obtained by measuring five parameters (table 2). Measurements were repeated twice on each station during the low tide. The purpose of collecting water quality data is to determine the health condition of the waters in the seagrass beds, because the health of the waters in an area affects the health of its organisms.

2.6. Data analysis
2.6.1. Seagrass bed. To determine the health condition of a seagrass bed, it can be seen from the density value and percentage of cover. Seagrass density is the number of stands of a particular species per unit area. The density at each station is calculated using the formula [19]. The percentage of seagrass cover is the area covered by seagrass plants. Seagrass cover was determined based on the formula [20].

2.6.2. Marine debris. The macro-sized debris at each station is collected and classified by type; metal, glass, rubber, organic matter, etc [4]. After that, the litter form was weighed at each observation station. Marine debris data are described and presented with a bar chart, while micro-sized debris is gathered from sediment extraction using saturated NaCl. The microplastics in each sub-station were identified to their type, and the abundance was calculated.
2.6.3. Microplastics with seagrass vegetation correlation analysis. The correlation of microplastics with seagrass vegetation was analyzed using Correspondence Analysis (CA) using XLStat2016. The CA method is a factorial analysis that groups statistical units into homogeneous groups from several variables or characters. The CA method is descriptive, which means no variable has a more important role than other variables. The variables analyzed included the type of microplastic and the type of seagrass vegetation at all observation stations.

The purposes of using CA are discover a close relationship between the modalities of two characters or variables in a table or a contingency data matrix and observe a close relationship between all character modalities and similarities between individuals based on the configuration of answers in the complete contingency data table or matrix [21]. The CA analysis was based on a data matrix of i rows (type and abundance of microplastics, species and seagrass density) and j columns (observation stations).

3. Results and discussion

3.1. Characteristic of aquatic environment

The temperature at each station ranged from 28.4 to 30.2 °C, with the average temperature occurring at 29.4 °C (table 3). Each station was categorized as good and compliant with Indonesian government standards between 28-30 °C [22]. Water temperature is one of the crucial factors in a living organism, especially marine organisms [23]. Temperature conditions will increase photosynthesis and respiration production salinity at each observation station ranged from 30 to 33 ppm, with an average of 31.3 ppm. The salinity in Stations 1 and 3 is not reached a standard range. While Station 2 has a relatively better salinity value [22]. The optimum salinity value for seagrass growth is 35 ppm [24]. The salinity values at Stations 1 and 3 are not classified as bad even though the salinity score did not comply with quality standards. Most of the seagrasses have a wide tolerance range for salinity, 10-40 ppm. Therefore the water quality in Pramuka Island is still classified as suitable for seagrass growth.

Dissolved Oxygen (DO) in each station ranged from 6.9 to 7.7 mg/L. (average 7.4 mg/L). DO value of each station achieved the quality standard of more than 5.0 mg/L according to [22]. Dissolved oxygen is essential for respiration, metabolic processes or exchange of substances, providing energy for growth and reproduction [25].

### Table 2. Characteristic of aquatic environment.

| Parameter                     | Unit | Instrument and technique | Description |
|-------------------------------|------|--------------------------|-------------|
| Temperature                   | °C   | Thermometry              | In-situ     |
| Salinity                      | Ppt  | Refractometer            | In-situ     |
| Acidity (pH)                  |      | pH meter                 | In-situ     |
| Dissolved Oxygen (DO)         | mg/L | DO meter                 | In-situ     |
| Sediment fraction             | %    | Multi-tiered sieve       | Ex-situ     |

### Table 3. Characteristic of Aquatic Environment.

| Station | Temperature (°C) | Salinity (ppm) | DO (mg/L) | pH       |
|---------|------------------|----------------|-----------|----------|
| 1       | 29.5 ± 0.70      | 31 ± 1.08      | 6.9 ± 0.29| 7.5 ± 0.40|
| 2       | 28.4 ± 0.78      | 33 ± 1.63      | 7.7 ± 0.21| 7.4 ± 0.20|
| 3       | 30.2 ± 0.49      | 30 ± 0.81      | 7.5 ± 0.35| 8.2 ± 0.29|
The degree of acidity (pH) in all observation stations ranged from 7.4 to 8.2, with an average pH of 7.7, achieving the quality standard ranging from 7.0 to 8.5 according to [22]. Water with a pH range of 7 to 8.5 is a potential area for cultivation and recreation [26]. The pH of the seawater in all stations was suitable for marine organisms.

3.2. Percentage coverage seagrass species

During the observations and identification of seagrass vegetation at three stations on Pramuka Island, six species are recorded with different species and locations. The composition of seagrass species at the observation station is shown in figure 5. The six species are Enhalus acoroides, Thalassia hemprichii, Cymodocea serrulata, Cymodocea rotundata, Halophila ovalis, and Syringodium isoetifolium. Three different species are found in station 1: Enhalus acoroides, Cymodocea serrulata, and Cymodocea rotundata. Additional species are discovered in station 2, Thalassia hemprichii and Halophila ovalis, while at Station 3, Syringodium isoetifolium and four other species are recorded. Enhalus acoroides was found on the study site. The presence of this species indicates that Enhalus acoroides had high adaptability to turbid waters due to the high rate of siltation (turbidity) from the mainland if sunlight and the necessary nutritional elements are still sufficient [27].

The percentage of seagrass cover at each station has various values figure 5. Station 1 has a total cover value of 34.24%, consisting of Enhalus acoroides 20.96%, Cymodocea serrulata 24.73% and Cymodocea rotundata 10%. Cymodocea serrulata is observed to have the highest cover percentage of 24.73% in station 1. Station 2 covers 28.93%, with the most significant percentage, 16.52% of Thalassia hemprichii. Station 3, with a total cover of 36.06%, was significantly by Thalassia hemprichii with a percentage cover of 47.32%.
Cymodocea serrulata has the highest value at Station 1 due to the advantage of fast regeneration ability and better ability to neutralize ocean waves by having wide and long leaves and vigorous rhizomes [28]. Meanwhile, Thalassia hemprichii has the highest value at Stations 2 and 3. *Thalassia hemprichii* is a cosmopolitan seagrass (found in almost all habitats) with high adaptability to various aquatic environmental conditions; therefore, this species has an extensive tolerance to salinity. While other species optimally grow in the salinity range of 24-35 ppm, *T. hemprichii* have reported life in the salinity of 3.5-60 ppm [29].

Based on these results, the seagrass beds' condition is damaged due to the low seagrass coverage in each observation station (less than 60%) according to [30]. The research suggests that one factor that led to the destruction of seagrass beds on Pramuka Island is the development of tourism facilities. Arguably, the rising of tourism development facilities will escalate the number of visitors to the island and increase waste production every day.

### 3.3. The density of seagrass species

The density of seagrass species differed between sampling stations (figure 4). In station 1, *Cymodocea serrulata* has the highest density of species (74.94 ind/m²). In comparison, in stations 2 and 3, the highest density is found on *Thalassia hemprichii* (96.96 ind/m²) and (112.76 ind/m²) *Cymodocea serrulata* has the highest density at station 1 due to its quick regeneration, so that number of populations grow faster and dominate the station 1. *Thalassia hemprichii* has the highest density in stations 2 and 3 because the species has a wide tolerance to salinity. It can survive and appears in significant numbers even though the waters are exposed to pollution from waste, both solid and liquid.

In stations 1 to 3, the seagrass population was composed of 3, 4, and 5 species. The different number of species is due to different environmental characteristics throughout all stations. The density of seagrass species will be higher if the environmental conditions, especially the waters, are in good condition. According to [31], the density of seagrass species is influenced by environmental factors. Several factors that affect the density of seagrass species include depth, brightness, water currents and substrate type.

### 3.4. Marine debris composition on seagrass bed

Marine debris from each station has a composition of various types. According to [4], marine debris is classified into six types: plastic, metal, rubber, glass, organic matter, etc. The composition of marine debris based on its constituent materials can be seen in figure 7. In Station 1, there were 123 types of plastic, one type of metal, four types of rubber, one organic matter, and ten other debris types. In Station 2, there are 43 types of plastic, two types of metal, 1 type of glass, two types of rubber and one other types.
In Station 3, there were 55 types of plastic, one metal, two types of glass, one rubber, one organic material and seven others. Station 2 has the least waste compared to Stations 1 and 3 due to the further distance from resorts and settlements, rarely visited by residents or visitors.

Among all types of marine debris, plastic was the most common waste found in each station. Much of plastic-type waste on Pramuka Island is due to intentionally disposal of waste in the area and input from other places such as Jakarta Bay. [13] Stated that 8.32 tons of waste enter Jakarta Bay every day, dominated by 59% plastic waste. According to [32], plastic waste is the most common and typical type and the most at risk of impacting marine organisms.

3.5. Marine debris weight

The weight of marine debris in a wet state has a total value of 10.83. The weight of marine debris can be seen in figure 8. Station 1 has a total waste weight of 2.99 kg consisting of 1.85 kg of plastic, 0.06 kg of metal, 0.35 kg of rubber, 0.97 kg organic matter, and 0.62 others. Station 2 has a total waste weight of 1.83 kg, consisting of 1.24 kg of plastic, 0.08 kg of metal, 0.05 kg of glass, 0.37 kg of rubber, and 0.8 kg of others. Station 3 has a total waste weight of 6 kg consisting of 2.38 kg of plastic, 0.03 metals, 0.5 kg of rubber, 0.8 kg of glass, 1.4 kg of organic matter, and 1.5 kg of others. The weight of marine debris at Stations 1 and 3 has a greater value than Station 2. Station 1 is close to the pier, and Station 3 is affected by tourism and local community activities. Plastic-type waste has a dominating weight at each station. This condition is because the amount of plastic-type waste dominates in the coastal area of Pramuka Island.
3.6. Microplastic composition and abundances

The composition of microplastics from each sub-station consisted of microplastics, fiber, fragments, and films. Types of fiber originated from a settlement near coastal areas, with most people working as fishers. The fragments come from waste disposal or garbage from shops and food stalls in the surrounding environment. This type of film is a secondary plastic polymer derived from plastic bags or plastic packaging fragmentation and low density [33]. The low density makes film-type microplastics easier to be lifted into the waters and carried away by the currents, making them difficult to find in sediments.

The abundance of microplastics was found different in each sub-station. The abundance of microplastics is presented in figure 9. The abundance of microplastics ranged from 20-440 particles/kg. The highest microplastic abundance occurred in the fiber of 440 particles/kg at sub-stations 2.1, and 2.3 and a minimum of the lowest microplastic abundance are located in sub-station 2.2.

Microplastics at each sub-station are dominated by fiber and have the highest abundance in all sub-station. The dominance of fiber types was also recorded in several studies, along the coast of Europe [34] and in the Bohai Sea and the Yellow Sea, China [35]. Many fiber types can be attributed to the high level of human activity [35] because the fiber generally comes from cloth or rope [16]. Meanwhile, the sub-station 2.2 was recorded has a lower value. This condition is presumably caused by shipwrecks located before the initial seagrass vegetation. When the high tide occurred the shipwrecks are submerged, and the particles dissolve in the ocean or settle on sediment.

3.7. Correlation between microplastics with seagrass vegetation

The data used in the CA are the abundance of microplastics and the density of seagrass species (figure 9). The results of the CA analysis showed that the abundance of microplastics with seagrass vegetation was centred on two axes; F1 of 39.99% and F2 of 32.31%, with a total variance of 72% on both axes.
These results make the majority of the microplastics lie in certain types of seagrass dominant at certain stations. The abundance of microplastics with seagrass vegetation can be seen in figure 9.

CA analysis was divided into two groups. The first group showed that the microplastic fragments and films were grouped with seagrass species *Enhalus acoroides* (Ea) and *Cymodocea rotundata* (Cr) in sub-stations 1.1, 1.2, and 1.3 as non-dominant groups. The presence of microplastic fragments and films in seagrass species Ea and Cr was caused by the large canopy of the Ea species and the density between the stands of the Cr species, which made plastic trapped. Plastic that is stuck for a long time will gradually settle and will decompose into microplastics. So that in seagrass species Ea and Cr, there are types of microplastics sourced from plastic. This result is also recorded in a study by that showed that the fragments come from waste disposal or garbage from shops and food stalls in the surrounding environment. This type of film is a secondary plastic polymer derived from plastic bags or plastic packaging fragmentation and low density.

The second group showed that fiber type microplastics were grouped with seagrass species *Thalassia hemprichii* (Th) in sub-stations 2.1, 2.2, 2.3, 3.1 and 3.2 as the dominant group. The presence of fibre-type microplastics in seagrass species at station two and partly station three is caused by station two, where there are shipwrecks. The ship is made of fiber, and station 3 is close to settlements, lodging, and ship repair places. The type of fiber is carried out from residential areas in coastal areas, with most people working as fishers [33].

4. Conclusion

The conclusion of this study is that the seagrass conditions of each station are classified as damaged. The marine debris that has the most impact on the seagrass beds is plastic because apart from being the largest in number, this type is more difficult to decompose. Fiber type microplastic has the most abundance. This can interfere with respiration and the photosynthesis process of seagrass. If the amount of waste cannot be reduced in the coming year, it can be predicted that the seagrass beds on Pramuka Island will be increasingly damaged and the species will not vary.

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