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Analysis of the Types and Abundance of Beach Debris in Mata Ikan Bay, Batam, Riau Islands

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ABSTRACT

The study was conducted in May 2025 at Teluk Mata Ikan Beach, Batam, Riau Islands, to determine the types and differences in waste abundance. This study used a survey method with sampling locations divided into 3 stations consisting of 2 plots, consisting of the upper intertidal zone and the lower intertidal zone. Station 1 is located in a coastal tourist area that is frequently visited by local tourists. Station 2 is located at the ship port. Station 3 is in a residential area. The results showed that plastic waste dominated, with the highest abundance reaching 1.39 units/m² (59%) at Station 3. The lowest abundance was textile waste, with an abundance of 0.06 units/m² with a percentage of 3% at station 3. Overall, the upper intertidal zone had a higher average waste abundance than the lower zone. The results of the one-way Anova indicated a significant difference in waste abundance between stations ($p = 0.011 < 0.05$). Further LSD tests revealed significant differences among Stations 1, 2, and 3, except between Stations 2 and 3, which showed no significant difference. Meanwhile, the independent t-test produced a sig value (2-tailed) of 0.214 (0.214> 0.05), indicating no significant difference between the upper and lower zones. Differences in waste abundance are influenced by different activities at each station, resulting in different amounts of waste at each location.

Keywords: Abundance, Mata Ikan Bay, Trash, Intertidal Zone

1. INTRODUCTION

Coastal areas, rich in natural resources, offer diverse development potential to boost the local economy, including fisheries, industry, tourism, and transportation. However, the waters in these areas are vulnerable to pollution from land-based waste. Pollutants from industrial, agricultural, and domestic activities can contaminate the aquatic environment and cause negative impacts (Manengkey et al., 2022).

Marine waste has become a global and national problem. Indonesia is the second-largest waste producer in the world (Faizal et al., 2021). Waste is defined as solid waste generated from human and animal activities, which is then discarded because it is deemed useless or undesirable (Santosa, 2013). According to Law Number 18 of 2008 concerning Waste Management, waste is the residue of daily human activities or natural processes in solid or semi-solid form, whether organic or inorganic, which can be decomposed or not, and is considered useless and therefore discarded into the environment (Novianto et al., 2018).

Land-based waste has three main sources: industrial waste, poorly organized community waste management systems, and the habit of littering. This is in line with previous research that states that littering can have a direct impact on the cleanliness and health of the surrounding environment (Ardan et al., 2022). Furthermore, the spread of waste in coastal areas is also influenced by current movements that can carry waste far from its source, as well as anthropogenic factors such as population density (Hasibuan et al., 2020; Ningsih et al., 2020). Waste causes various problems, such as the decline in the beauty of coastal areas and tourist areas due to scattered and smelly waste piles, the emergence of various diseases, and the disruption of the food chain and fish productivity. Furthermore, the metabolism of marine plants such as seagrass and mangroves can also be affected (Citasari et al., 2012).

To mitigate this problem, a series of integrated waste management and handling measures is needed. These efforts include reducing waste at the source, increasing public awareness of waste sorting and not littering, providing adequate management facilities, and implementing environmentally friendly collection, transportation, and final processing systems. Furthermore, supervision in tourist and coastal areas needs to be strengthened to prevent waste from entering the sea, along with regular cleaning and the implementation of the reduce, reuse, and recycle (3R) principles, which can support a circular economy in coastal communities (Cordova & Nurhati, 2019; Wati et al., 2021).

Teluk Mata Ikan Beach is located in Sambau Village, Nongsa, Batam City, Riau Islands. This beach boasts a stretch of white sand and rows of coconut trees, adding to its beauty. Besides being a tourist destination, the area also serves as a fishing ground for local fishermen. Tourist activities, fishing activities, and a lack of environmental awareness among the community contribute to the increasing amount of waste at Teluk Mata Ikan Beach. Batam City, as a tourist destination, both domestic and international, also contributes to the increase in the volume of macro-waste in this coastal area. To understand the problem, an exploratory study is needed to determine the types and abundance of waste at Teluk Mata Ikan Beach, Batam City, Riau Islands.

2. RESEARCH METHOD

Time and Place

This research was conducted in May 2025. Beach debris sampling was conducted at Teluk Mata Ikan Beach, Batam City, Riau Islands Province (Figure 1). The debris samples obtained from the field were then transported to the Chemical Oceanography Laboratory, Department of Marine Sciences, Faculty of Fisheries and Marine Sciences, Universitas Riau, for identification of the type and abundance of debris.

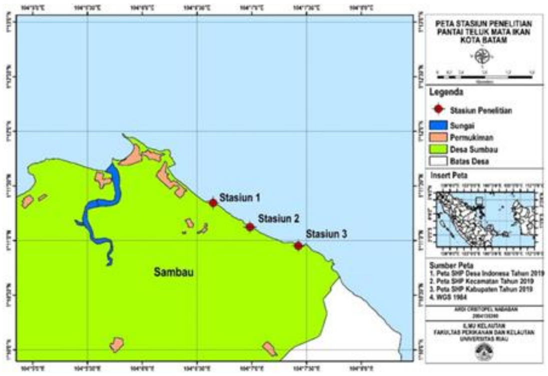

Figure 1. Research location map

Method

Study: This is a use method survey, data collected through documentation and observation directly in the field. The samples obtained were analyzed to identify the type, size, and mass of trash, then the results were tabulated. Determination Location taking sample done with purposive sampling method.

Procedures

Determining the Research Location

This study uses a survey method, data collected through documentation and direct observation in the field. The samples obtained were analyzed by identifying the type, size, and mass of waste, and then the results were tabulated. Determination of sampling locations was carried out using a purposive sampling method. Sampling was carried out at three stations with different anthropogenic activities. Station 1 is located in a coastal tourist area, with local tourists. Station 2 is located where the ship port is. Station 3 is located in the settlement of Sambau Village, Nongsa, Batam City. Each station is represented by 2 plots, where plot 1 is located in the upper intertidal zone and plot 2 in the lower intertidal zone, each measuring 10 m x 10 m.

Beach Trash Collection at Mata Ikan Bay

Sampling was conducted before the weekend (Friday), on Sunday, and after the weekend (Tuesday). Sampling was conducted by following each predetermined point following the potential survey walking patterns scheme established by the NOAA Marine Debris Shoreline Survey Field Guide (Opfer et al., 2012) (Figure 2). The debris within the plot was then collected and placed in plastic bags. Only the debris found in the walking pattern was recorded. The weight of the debris found in the walking pattern was then measured using a scale, and the amount was calculated after characterizing the type of debris.

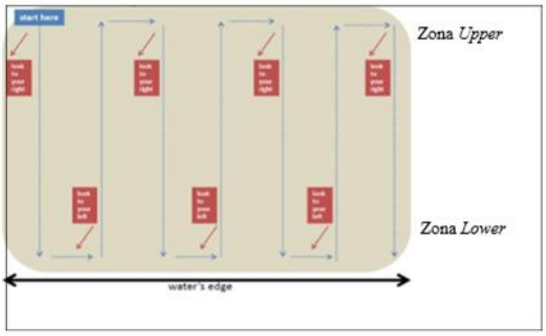

Figure 2. Walking pattern (Opfer et al., 2012)

Waste Collection Based on Type in Mata Ikan Bay

The waste collection method based on type is carried out to identify the composition and characteristics of waste found in coastal areas. This process is carried out through systematic waste collection along predetermined coastal transects, taking into account topographic conditions and human activities around the location. According to the Marine Debris Monitoring and Assessment Project (MDMAP) guidelines from NOAA (2013), waste collection is carried out on 100-meter transects along the coastline and covers the area from the high tide line to the vegetation boundary. All types of visually visible waste are collected and recorded on observation sheets, so that data is representative of actual conditions in the field (NOAA, 2013). Each collected waste is then grouped by material type according to classifications commonly used by marine research institutions, such as plastic, metal, glass, rubber, wood, textiles, and other materials.

This classification is important to determine the dominance of certain types of waste in a location. According to research by Muhdhar et al. (2019), waste type grouping is carried out using a material category approach because differences in physical properties and origin of waste sources affect the rate of degradation and its impact on the coastal environment. Furthermore, each collected waste item is recorded in quantity and category using a standard identification sheet as recommended by the OSPAR Commission (2010), the identified and classified waste is then weighed to determine the total weight of each category according to Putra et al. (2020), the combination of counting the number of items and measuring weight provides a more comprehensive picture of the pollution load in a coastal area. Thus, the method of collecting waste based on type/group not only functions to identify composition, but also provides a scientific basis for waste management efforts and policies for reducing waste in coastal environments.

Measuring the Abundance of Beach Debris in Mata Ikan Bay

The waste abundance measurement method is used to determine the level of pollution in coastal areas using standardized units, namely the number of items per unit area (items/m²) or weight per unit area (g/m²). According to NOAA (2013), abundance measurements are performed by calculating the total amount of waste in a specific transect area, then dividing the result by the area of the observation area. The formula used is:

$$C = \frac{N}{A}$$

Information:

C	:	Abundance of waste
N	:	Number of trash items found
A	:	Area of observation

Differences in Species and Abundance Between Stations and Between Zones on Teluk Mata Ikan Beach

Analysis of differences in waste types and abundance between stations and zones was conducted to determine spatial variations in the distribution and dominance of waste types in coastal areas. According to Putra et al. (2020), a commonly used statistical test for analyzing differences in abundance is one-way Analysis of Variance (ANOVA), which can test differences in average abundance between groups of stations.

In addition to quantitative differences, a descriptive analysis of waste type composition was also conducted to identify the dominant types at each station and zone. The percentage of each waste type was calculated using the formula used by Ardan et al. (2022) as follows.

$$Pi = \frac{ni}{N}$$

Information:

Pi	:	percentage of type i of waste
Ni	:	number of items of the i-th type of waste
N	:	Total amount of waste at the observation location

Data Analysis

Results collected so far, which were and further to, to be continued with data processing, which was obtained and further analyzed using statistics, including One-Way ANOVA to see differences in abundance between stations, and a T-test to see whether there is a difference in the abundance of waste in the upper and lower zones.

3. RESULT AND DISCUSSION

Types of Beach Trash in Mata Ikan Bay

This study found eight main types of waste at Teluk Mata Ikan Beach: plastic, metal, glass, wood, rubber, paper, textiles, and others.

The most dominant type of waste was plastic, with the highest abundance reaching 1.39 units/m² or around 59% at station 3 (residential area). The plastic waste found included plastic bags, mineral water bottles, straws, food packaging, and detergent wrappers. Meanwhile, the type of waste with the lowest abundance was textiles, with a value of 0.06 units/m² or around 3%. These findings indicate that household activities and public consumption are the main contributors to plastic pollution in coastal areas.

These results are in line with research by Kahar et al. (2020); Johan et al. (2019), which reported that plastic is the most dominant type of waste on Indonesian beaches due to its widespread use and difficulty in decomposing in nature. This is consistent with the research findings of Amri et al. (2023) at Pasir Putih Losari Beach, which found that, in addition to plastic, wood and rubber were found in large quantities from port activities and boat waste disposal. Meanwhile, metal and glass waste were found in relatively small quantities because their use is not as extensive as plastic and rubber in coastal areas. In general, the composition of waste types at Teluk Mata Ikan Beach indicates that the main source of waste comes from poorly managed anthropogenic (community) activities.

Abundance of Beach Trash in Mata Ikan Bay

A waste monitoring survey conducted by NOAA (2015) categorized waste into several broad categories: plastic, metal, glass, wood, rubber, and textiles. The results of the overall waste abundance calculations can be seen in Table 1.

Table 1. Abundance of waste

Types of Waste	Average waste abundance (units/m2) ± St. Dev		
	Station 1	Station 2	Station 3
Plastic	1.05 ± 0.24	0.67 ± 0.09	1.39 ± 0.27
Metal	0.11 ± 0.03	0.07 ± 0.03	0.10 ± 0.03
Glass	0.12 ± 0.04	0.16 ± 0.03	0.10 ± 0.02
Wood	0.23 ± 0.12	0.18 ± 0.05	0.27 ± 0.09
Rubber	0.13 ± 0.03	0.14 ± 0.03	0.10 ± 0.02
Paper	0.15 ± 0.08	0.12 ± 0.01	0.19 ± 0.05
Textiles	0.07 ± 0.04	0.07 ± 0.03	0.06 ± 0.01
Etc	0.25 ± 0.05	0.20 ± 0.01	0.16 ± 0.04
Amount	2.11 ± 0.29	1.61 ± 0.12	2.37 ± 0.30

Based on Table 1, the type of waste with the highest abundance is plastic, with abundance values of 1.05 units/m² at station 1, 0.67 units/m² at station 2, and 1.39 units/m² at station 3, respectively. Meanwhile, the type of waste with the lowest abundance is textile, namely 0.07 units/m² at stations 1 and 2, 0.06 units/m² at station 3. For metal waste, the abundance at station 1, station 2, and station 3 was recorded at 0.11, 0.07, and 0.10 units/m². Glass waste has an abundance at each station 1, station 2, and station 3 of 0.12, 0.16, and 0.10 units/m².

The type of wood waste shows an abundance of 0.23 units/m² at station 1, 0.18 units/m² at station 2, and 0.27 units/m² at station 3. Rubber waste has an abundance value at station 1, station 2, and station 3 of 0.13, 0.14, and 0.10 units/m². Meanwhile, paper waste has an abundance at station 1, station 2, and station 3 of 0.15, 0.12, and 0.19 units/m². As for other types of waste, there is an abundance of 0.25 units/m² at station 1, 0.20 units/m² at station 2, and 0.16 units/m² at station 3.

The highest waste abundance was found at station 3 with an average value of 2.37 units/m². Meanwhile, station 1 had an abundance value of 2.11 units/m² and station 2 had an abundance value of 1.61 units/m². The high waste abundance at station 3 is due to the different intensity of human activity, where tourist and residential areas tend to produce more plastic, paper, and disposable waste from visitor and household activities. These results are consistent with research by Arifin (2021) at Losari Beach, Makassar and Amri et al. (2023) at Pasir Putih Losari Beach, Brebes, which reported that areas with high community activity have higher levels of beach waste accumulation, especially plastic and metal types.

At station 2, the abundance of waste was lower because fishing activity decreased due to high rainfall during the sampling period. Weather conditions also influence waste distribution through marine hydrodynamic mechanisms. According to Subekti (2017) and Cordova & Puspitasari (2023), high rainfall can increase surface runoff that carries waste from land to sea, but at the same time, currents and waves can move waste to other locations, thus reducing accumulation in the harbor. Differences in coastal morphology also play a significant role, where closed beaches (such as in residential areas) tend to accumulate waste, while open beaches (such as harbors) experience material distribution due to the influence of wind and ocean currents (Wardhana et al., 2023).

The results of the one-way ANOVA test showed that the amount of waste showed a significant value of p (0.011) < 0.05, meaning that the abundance of waste between stations was significantly different. The results of the LSD further test obtained a significant difference between stations 1 and 2 and 3, while there was no significant difference between stations 2 and 3. This is due to different anthropogenic activities. At stations 1 (tourist area) and 3 (community settlements), there are always residents or tourists, which allows for increased waste generation. Meanwhile, at station 2 (ship port), fishermen do not go to sea due to high rainfall in March.

In addition, the weather also affects the presence of waste on the beach because it is carried into the water. This is in accordance with the statement of NOAA (2015), Waste and land can end up in the sea because the waste will be carried by rainwater, which then enters the river and will be carried to the sea, increasing the amount and volume of waste in the water. Then, the movement of water masses can carry waste from the coast into the sea. This is supported by research by Subekti (2017); Johan et al. (2020), which states that during the rainy season, waste enters water bodies, increasing river water discharge, which results in the waste being washed away. This aligns with Simatupang et al.'s (2016) statement that currents are the movement of water masses influenced by surface tension, wind, and several other factors, or the horizontal and vertical displacement of water masses. The abundance of beach waste before the weekend, during the weekend and after the weekend can be presented in Table 2.

Table 2. Abundance before weekend, weekend, and after weekend

Types of Waste	Average waste abundance (units/m²) ± St. Dev		
	Before the weekend	Weekend	After the weekend
Plastic	1.15 ± 0.44	1.10 ± 0.44	0.85 ± 0.25
Metal	0.11 ± 0.04	0.09 ± 0.04	0.08 ± 0.03
Glass	0.15 ± 0.04	0.10 ± 0.03	0.13 ± 0.02
Wood	0.29 ± 0.07	0.16 ± 0.02	0.22 ± 0.10
Rubber	0.11 ± 0.05	0.12 ± 0.03	0.14 ± 0.02
Paper	0.13 ± 0.02	0.21 ± 0.07	0.12 ± 0.04
Textiles	0.06 ± 0.03	0.07 ± 0.01	0.08 ± 0.04
Etc	0.18 ± 0.02	0.20 ± 0.08	0.22 ± 0.05
Amount	2.18 ± 0.45	2.05 ± 0.46	1.82 ± 0.28

Based on Table 2, the most common type of waste found before the weekend was plastic, with an average abundance value of 1.15 units/m², while textile waste was the least abundant waste, with 0.06 units/m². During the weekend, plastic remained the dominant type of waste with an average of 1.10 units/m², and textiles again became the lowest with a value of 0.07 units/m². The highest waste found after the weekend was plastic, still recording an abundance of 0.85 units/m², while textiles showed the lowest abundance value of 0.08 units/m².

The highest average abundance of waste occurred before the weekend, which was 2.18 units/m², followed by the weekend at 2.05 units/m², and after the weekend at 1.82 units/m². The average value of waste abundance during Weekdays was higher than on weekends. This contrasts with Aditya's (2019) research, which found that weekend waste production was higher than on weekdays. This was due to the presence of beach cleaners at Pandan District Beach who cleaned the area during the weekend. This could be due to higher waste production during the weekdays. The abundance of waste in the lower and upper zones can be seen in Table 3.

Table 3. Abundance in the Lower and Upper Zones

Types of Waste	Average waste abundance (units/m^2) ± St. Dev	
	Lower	Upper
Plastic	1.33 ± 0.48	1.78 ± 0.60
Metal	0.13 ± 0.04	0.15 ± 0.08
Glass	0.17 ± 0.04	0.21 ± 0.06
Wood	0.27 ± 0.09	0.40 ± 0.04
Rubber	0.19 ± 0.04	0.18 ± 0.06
Paper	0.19 ± 0.07	0.27 ± 0.04
Textiles	0.07 ± 0.03	0.13 ± 0.02
Etc	0.27 ± 0.05	0.33 ± 0.11
Amount	2.62 ± 0.50	3.45 ± 0.62

Based on Table 3, the type of waste with the highest abundance in the Lower zone is plastic, with an average abundance value of 1.33 units/m², while textiles are the lowest, with an average abundance value of 0.07 units/m². In the Upper zone, the highest abundance value was recorded at 1.78 units/m², while textiles remain the type of waste with the lowest abundance, with an average of 0.13 units/m².

The main factors causing this similarity are the almost similar physical characteristics of the beach and the influence of tides, which cause most of the waste in the lower zone to move to the upper due to wave push. This phenomenon is in accordance with the findings of Ardan et al. (2022), who reported that waste material in the tidal zone can move dynamically depending on the current speed and wave direction. The study of Siregar et al. (2024) at Parangtritis Beach also supports these results by showing that the vertical difference between the high tide (upper intertidal) and low tide (lower intertidal) zones is not significant to the total waste generation, especially for light plastic types.

4. CONCLUSION

Plastic waste is the most common type found, and the least found is textiles. The highest abundance of waste is found in residential areas (station 3) at 2.37 units/m², while the lowest abundance of waste is found in the estuary (station 2) at 1.61 units/m². Based on time, before the weekend has the highest average of 2.18 units/m² and after the weekend has the lowest average of 1.82 units/m². The average abundance of the upper zone is 3.45 units/m² while the lower zone is 2.62 units/m². The abundance of waste between stations with different anthropogenic activities has a significant difference ($p < 0.05$), although the abundance of waste before the weekend, weekend, and weekend does not show a significant difference. There is no significant difference between the abundance of waste in the lower and upper zones

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