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Optimizing The Waste Management Of Coastal And Marine Litters To Support Environmental Cleanliness In Reducing Plastic Debris And Saving Penyengat Island

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Abstract

The beach on Penyengat Island is a rapidly growing tourist destination and has a quite potential strategy. The rapid development of tourism on Penyengat Island has caused various problems, including environmental degradation, environmental pollution, and waste problems. Plastic debris is the most commonly found waste and it is hard to decompose by soil. The purpose of this research is to optimize the waste management of coastal and marine litters to support environmental cleanliness in reducing plastic debris and saving Penyengat Island. The survey method was used in this study. Sampling was carried out three times (once / twice a week) at 3 observation stations. There are 3 stations, namely S1 (residential area), S2 (ecotourism area), and S3 (port area). Marine litter was collected from 3 plots placed along the line transect. Observation of marine litter was carried out by modifying the shoreline survey methodology based on NOAA and MSFD. The result calculation shows that station 1 (one) has the highest amount of floating litter, which is 50 items/m (41 items/m inorganic waste and 9 items/m organics). Plastic debris dominates inorganic waste, especially types of plastic bags or food wrappers. The average value of floating litters is 24 items/m^2.

Keywords: impact, waste management, Penyengat island, marine, and coastal litters

Introduction

The coastal area is a transitional area between land and sea, where the characteristics of land and sea still influence each other. This area has abundant potential resources and beautiful environmental services (Tratalos & Austin, 2001; Wabnitz *et al.,* 2018; Johan *et al.,* 2018, Perbawasari et al., 2019 and Sembiring et al., 2019,). In addition, the potential for pollution of the coastal and marine environment also has considerable opportunities. This opportunity can be caused by Indonesia's dense population, high tourism activities including transportation, and large developments.

Penyengat Island as a small island with a limited carrying capacity and environmental carrying capacity. The volume of waste continues to grow, and the various types have more impact on the environment. The island of stinging with all its limitations on land, landfill, waste management facilities and human resources. Lack of understanding and awareness of the community to carry out waste management. The culture of throwing garbage directly into the sea, and the absence of local government efforts to manage waste that is safe enough for the environment.

Pollution reduces the environmental quality to be damaged and interferes with the natural resources, one of the pollution is marine debris. Marine debris is the result of production or processing in the form of solid goods that are disposed of intentionally or unintentionally, transported through rivers, drainage, or waste disposal systems carried by water and wind currents from land and then end up in the sea (UNEP, 2005, 2016). Marine debris will increase and have a wider impact every year, but research on the management and impact of marine debris is very limited, especially in Indonesia. Marine debris has a direct impact on the life of marine biota as well as damage to the wider ecosystem, health problems for coastal communities, aesthetic impacts in the coastal environment, and economic impacts on various industries that depend on the coastal and marine environment (McGranahan *et al.,* 2007; Neumann *et al.*, 2015).

Plastic is the most dominant marine litter because plastic is a pollutant that has been globally distribued in all waters due to its durable and easy-to-float nature (Zhukov, 2017). The amount of plastic waste in the sea originates and is influenced by activities and human populations, such as in areas with a high population, namely China, Indonesia (Jambeck *et al.*, 2015). The difference in the number of litter on the beach

with coral reefs is affected by the seasons, currents, and winds. The amount of garbage on the beach is affected by the previous season and after the rain seasons (Lippiatt *et al.,* 2013).

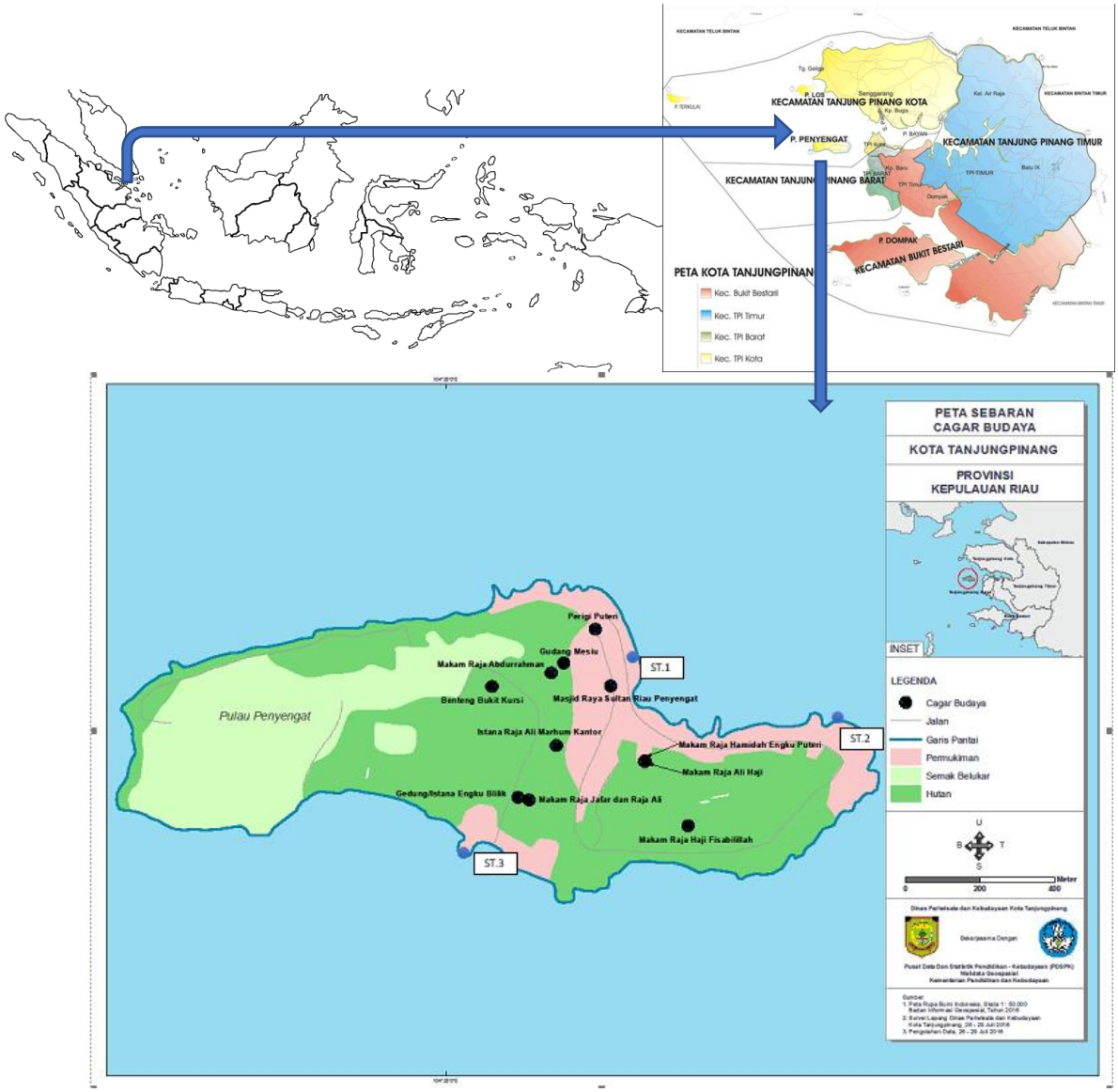


Figure 1. Study area on Penyengat Islnad, Tanjungpinang, Kepuluan Riau Indonesia

Research Methods

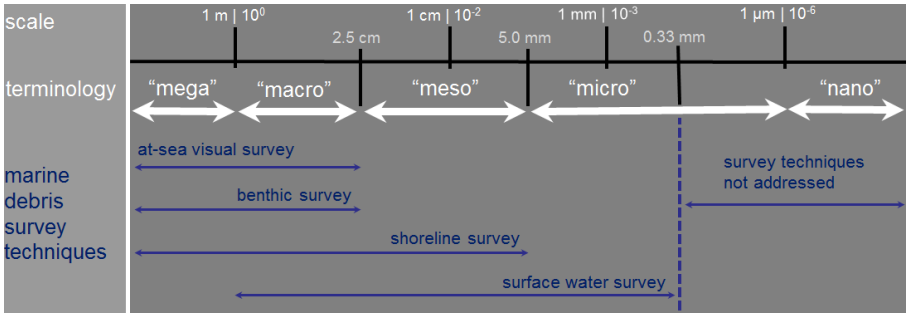
Mechanism of Data Collection for Coastal and Marine Litters

Waste data was taken by using the line transect method to determine the type, weight, amount, and area of the waste. The size of the waste observed has a cross-sectional area of >2.5 cm or it is included in the size of macro waste (Figure 1). Marine debris data is then sorted by type, weight, and size.

Table 1 The Method of Data Collection for Marine Litter

No	Parameter	Unit	Tool/Method	Description
1	Litter on the seashore			
	Types of litter organic, inorganic	item/m^2	line transect	Primary in-situ
	Litter Size (volume)	m^3/m^2	line transect	Primary in-situ
	Weight	kg/m^2	line transect	Primary in-situ
2	Floating Litter	item/m^2	line transect	Primary in-situ
3	Increasing Litter	item/m^2	line transect	Primary in-situ

The sampling of marine litter using the transect sampling method. Sampling (Figure 2) in a transect with a width of 5 m and a length trails the width of the beach.

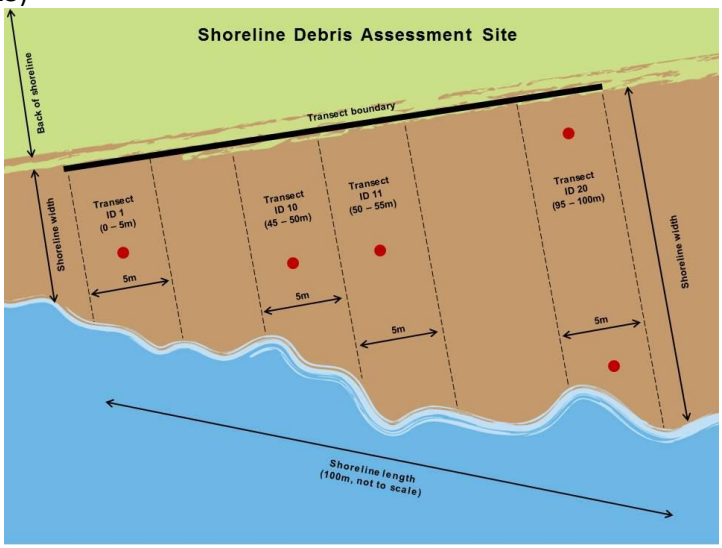


Sourcce : (Lippiatt *et al.,* 2013)

Figure 2. Marine litter size - Marine litter survey technique

a. litters on the seashore

Observations were made at the lowest low tide in the intertidal area, the observed beach length was 50 m (Lippiatt *et al.,* 2013)



Source : (Lippiatt *et al.,* 2013) dan (NOAA, 2013)

Figure 3. Litter Sampling Technique

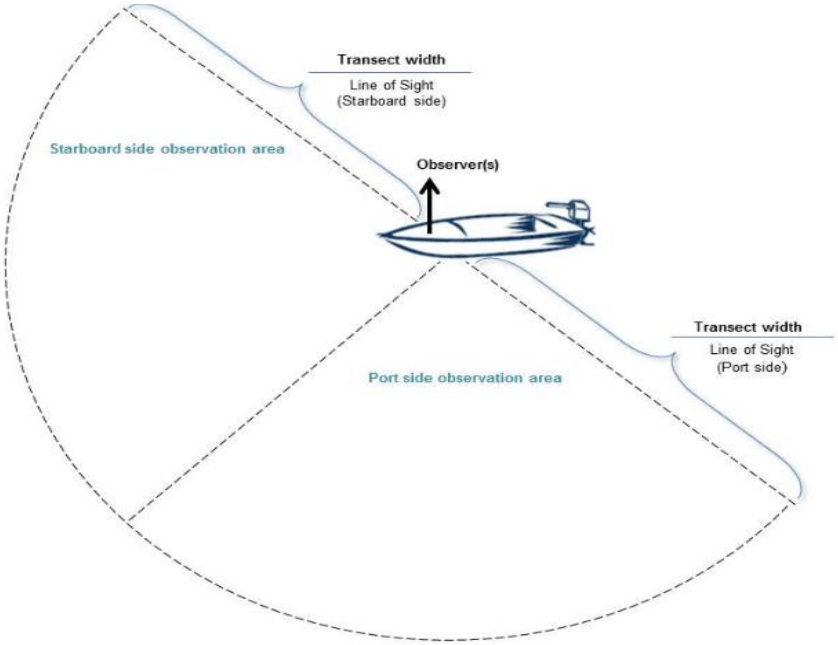
b. Floating Litters

Sampling starts from the highest tidal limit or land or building boundary. All solid marine litter is taken, cleaned of mud, soil, and sand, and then collected in large plastic bags. Furthermore, the waste is sorted according to the type and according to the location that has been determined. The location has 3 (three) points by considering the direction of ocean currents and wind and the source of Bintan Island waste. Then analyzed the amount, type, and weight of the solid marine litter. According to UNEP (2009), observations of floating litter samples can be carried out by visual surveys with direct observations. MSFD recommends that visual surveys not be carried out when environmental conditions are such that minimum debris cannot be detected, and provides a recommended transect width (from 3 to 15 meters) based on the speed of the vessel and the height of the observer above the water (MSFD, 2013) (Table 2).

Table 2 Recommended Visual Survey Transect Width Based on Speed and Height of The observer from the Ship

Observer height on the water	Speed		
	2 knots	6 knots	10 knots
0,5 meter	4 meters	2 meters	1,5 meters
1 meter	6 meters	4 meters	3 meters
3 meters	8 meters	6 meters	4 meters
6 meters	10 meters	8 meters	6 meters
10 meters	15 meters	10 meters	5 meters

Source: Adapted from MSFD (2013), with adjustments to ship conditions, wind speed, currents, and sea wave height. Knot is a unit of speed equal to ome nautical mile (1.852 km) per hour, approximately 1.151 miles per hour



Where possible, a minimum of two surveyors should survey the bow of the ship, and data from the port and starboard may be collected from two separate datasheets. If only one surveyor is available, the surveyor may wish to survey from the free side of the vessel (Ribic, *et al.,* 1993). Each surveyor is responsible for visually scanning the sea level and recording all litters >2.5 cm that passes over the starboard or starboard side of the ship and records it. Debris is picked up and counted on land.

Visual survey data should be reported in # items/km, based on transect width and length (determined from the latitude and longitude of the transect start and endpoint). During the visual survey, the observer is responsible for visually observing the sea level within the specified transect width. Sampling was repeated 2 times while leaving and returning to the beach. Furthermore, the litter is sorted by type and the volume, weight, and composition of the solid marine litters are calculated (Vlachogianni, 2014; Galgani *et al*, 2019). Debris is taken when the water is calm, because if the ocean currents are strong, the position and density of the debris may change.

c. Increasing Litters

The sampling technique of increasing litters with the same observation points (3 station points) is the same as the technique of collecting litters on the beach with line transects. Observation time was carried out at 7-day intervals, sampling was carried out every 2 days with 4 days of measurement time (2 weekend days; 2 weekdays). The deposited marine litter is taken and sorted, then analyzed for the amount, type, weight, and size of the solid marine debris (Eriksson *et al.,* 2013; Galgani *et al*., 2019; Hermawan *et al.,* 2017).

The litter data consisting of the number of pieces (items), size (m^3), and weight (kg) is made a comparison with the area (m^2) with the equation:

$$C = \frac{n}{(w \times l)}$$

Note:

C = Concentration of debris (items/m^2)

w = Width of transect area (m)

l = Length of transect area (m) modification from (Lippiatt *et al.,* 2013)

The density and relative density of the solid litter was analyzed by the following equation (Coe and Rogers 1997):

1. Density (number of debris)
   = Number of debris in each category (item) / Area (m^2)

2. Density (weight of litter)
   = Weight of litters in each category (gr) / Area (m^2)

3. Relative density (number of debris)
   = Number of debris in each category (item) / Total number of debris for all categories (items) X 100%

4. Relative density (weight of litters)
   = Weight of debris in each category (gr) / Total weight of debris of all categories (gr) X 100%

Data analysis of the marine litters increasing rates

The average increasing rate of marine litter is calculated per day with an interval of 4 days of observation, under normal conditions and west and east wind conditions (modification from Eriksson *et al.,* 2013; EU, 2016; Smith and Markic, 2013) as follows:

$$P = \frac{\sum x}{\sum n}$$

Note:
P = Litter Addition Rate (g/day)
x = The increasing weight of litter (g)
n = The number of observation days (day)

Result and Discussion

Amount and Composition of Coastal Waste

The waste that must be managed is not only domestic waste but also coastal waste (coastal waste that is not the result of the island and or residents of penyengat islands) which is shipping waste, litter on the coast of Penyengat beach, and marine litter around penyengat island. The following figure is a display of coastal litter data on Penyengat Island which is presented in Figures 5 to 10:

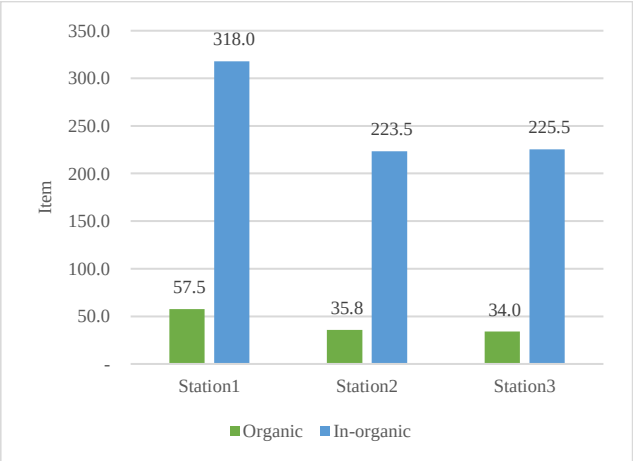


Figure 5. The average number of organic and inorganic coastal debris at each observation station

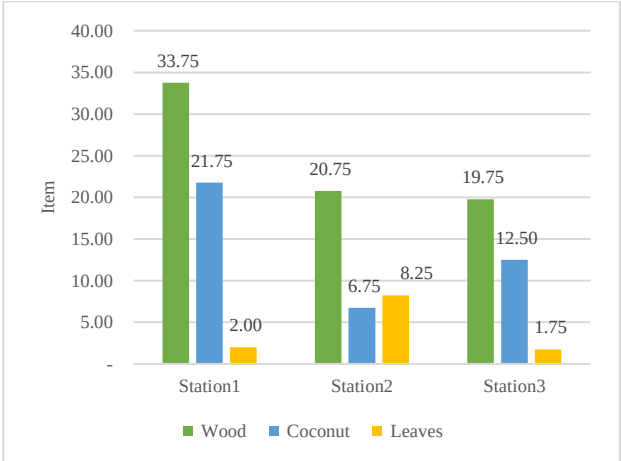
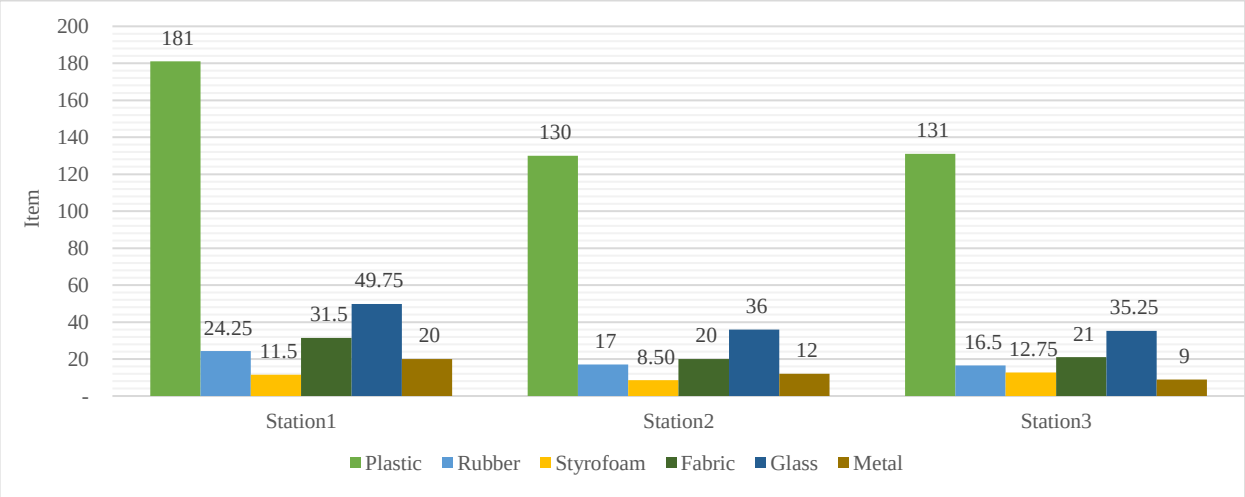


Figure 6. The average number of organic coastal debris at each observation station



verage number of inorganic coastal debris
at each observation station

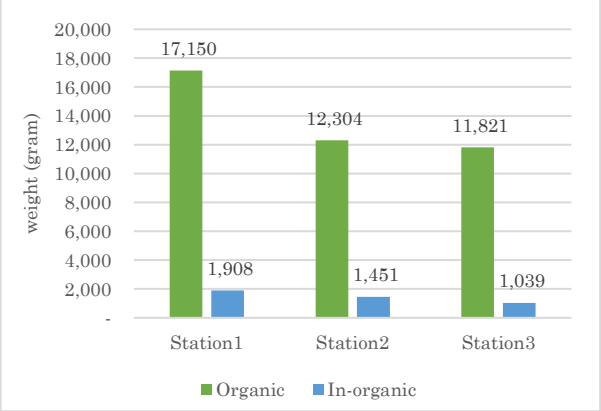


Figure 7 The average weight (grams) of organic and inorganic coastal debris at each observation station

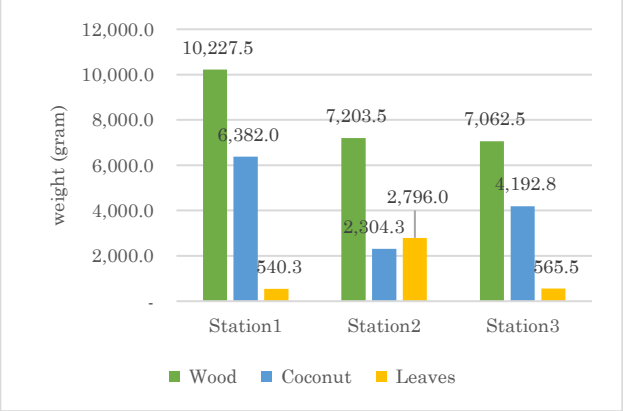


Figure 8 The average number of organic coastal debris at each observation station

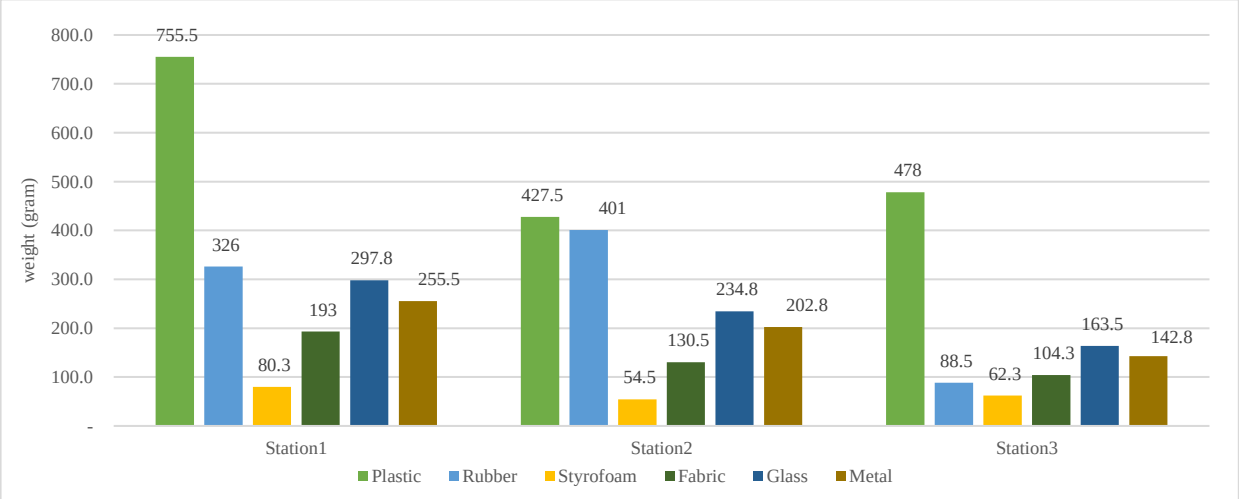


Figure 9 The average number of inorganic coastal debris by type at each observation station

One of the coastal litters on Penyengat Island comes from floating litter carried by ocean currents. The marine litter is carried from islands that are passed by ocean currents during the west season. The current and wind patterns carry floating litter material to Penyengat Island. The type of litter that is deposited is not

only from the domestic litter for several locations, it can be seen from the type of organic waste that is dense and light. Although some people on Penyengat Island dumped their garbage out to the sea. If there is domestic waste disposal, there will be accumulation at several points, while the marine litter is evenly distributed along the west coast of Penyengat Island.

The Amount and Composition of Marine Garbage

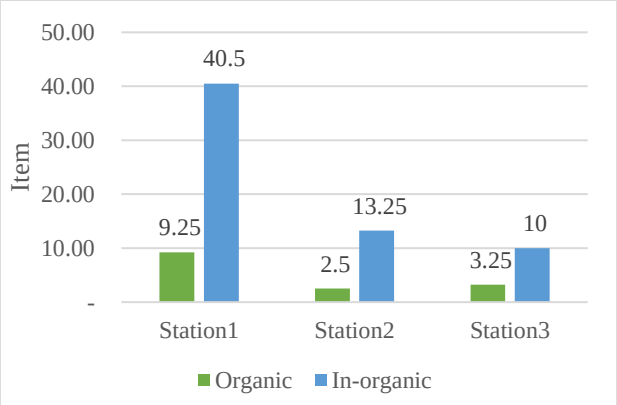


Figure 10 The average number of organic and inorganic marine debris floating in the ocean

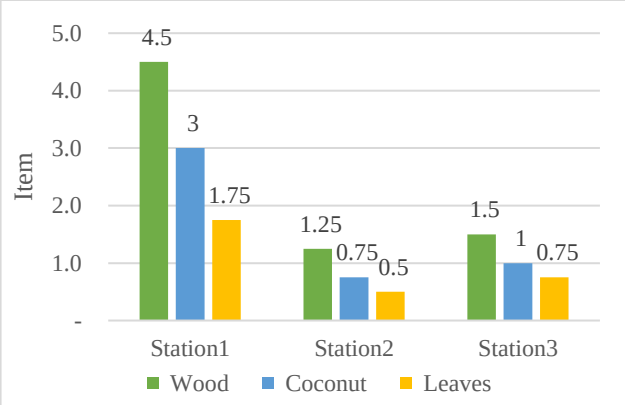


Figure 11 The average number of organic marine debris floating in the ocean

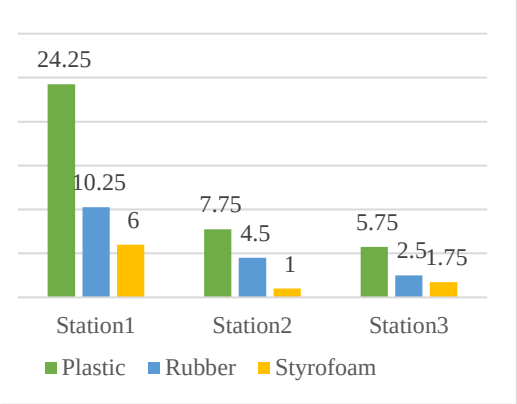


Figure 12 The average number of inorganic marine debris floating in the ocean

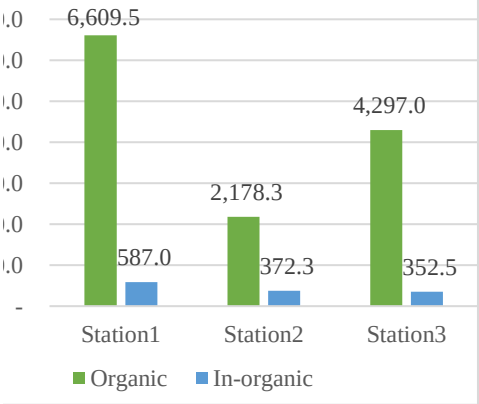


Figure 13 The average weight (grams) of organic and inorganic marine debris floating in the sea

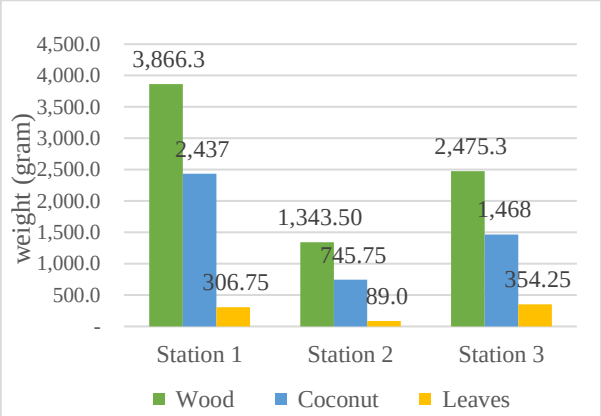


Figure 14 The average weight of organic debris floating in the sea

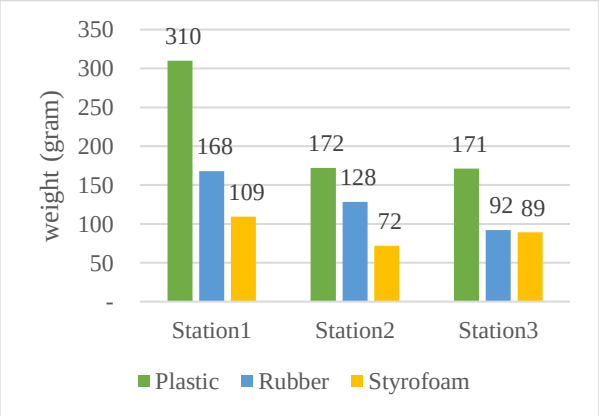


Figure 15 The average weight of inorganic debris floating in the sea

Marine litter consists of solid waste that has a density less than seawater, so it floats along with the ocean currents. Marine litter consists of various types of waste, to facilitate observation and analysis, it is sorted according to its composition, namely organic and inorganic litter. Organic litter consists of wood, leaves, and coconut. The number of seagrass leaves was not observed because it was difficult to calculate, so only weight measurements were carried out.

The marine debris is litter that floats, is carried by currents, and is deposited on the shore or intertidal area. The result of the calculation is that station 1 (one) has the highest amount of floating litter, which is 50 items/m (41 items/m organics and 9 items/m inorganics). Station 1 (one) is directly opposite the northwest side of Bintan Island where there is market activity there so that more litter floats at this station. Plastic debris dominates inorganic litter, especially types of plastic bags or used plastic food wrappers, the average value of floating litter is 24 items/m2. Plastic debris is not only light in weight, but it is also hard to break down, especially those used as food wrappers because the quality of food is very dependent on the packaging so that manufacturers improve the quality of the plastic wrappers.

Marine debris has a density less than seawater so it floats on the surface of the water. Based on observations, the amount of floating litter at the time of observation, namely the end of February, was quite a lot. February is the middle of the west monsoon, so the currents and winds are a bit strong, so a lot of litter material floats. The composition of floating litter is dominated by plastic, coconut, and wood waste, the calculation of floating litter is more detailed (Appendix).

Trends in the Numbers of Coastal Litter

Litter trend observations were carried out on the beach by counting and weighing coastal and marine litters for 7 days with 4 days of data collection. Data collection lasts one day, where the time of data collection is done when the water recedes. Marine litter, data collection is carried out in the morning, from February 21 to 27, 2020. Based on observations, the waste consists of wood, coconut, and leaves. Inorganic debris in the form of plastic (plastic cups, plastic wrap, plastic bottles), rubber sandals, and styrofoam.

Based on the calculation results of the weight and number of coastal and marine debris analyzed in graphic images.

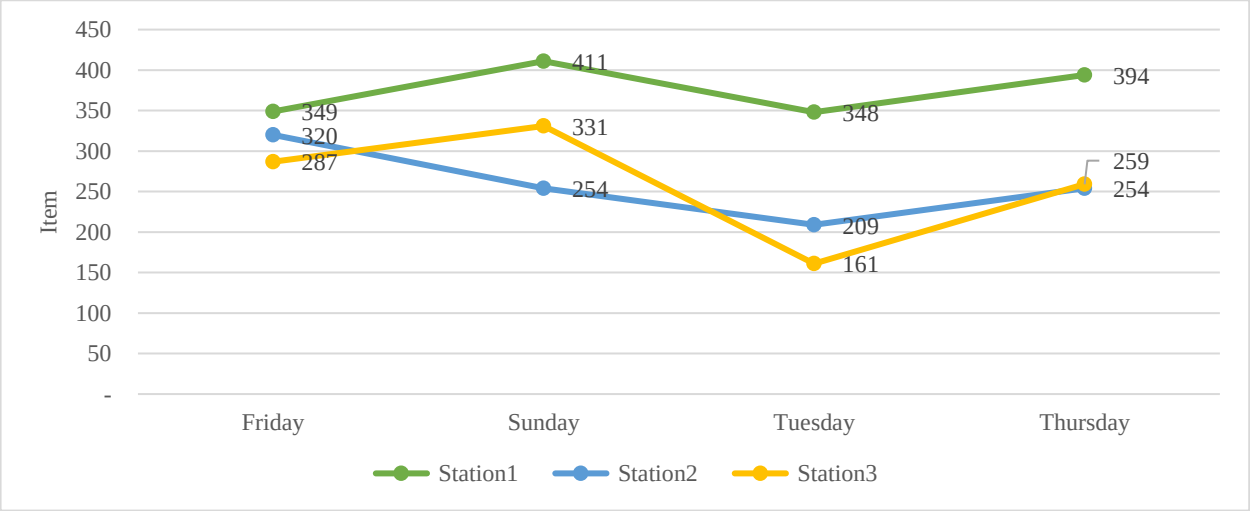


Figure 16 Trends in the numbers of coastal litter (Items) at each station and observation day

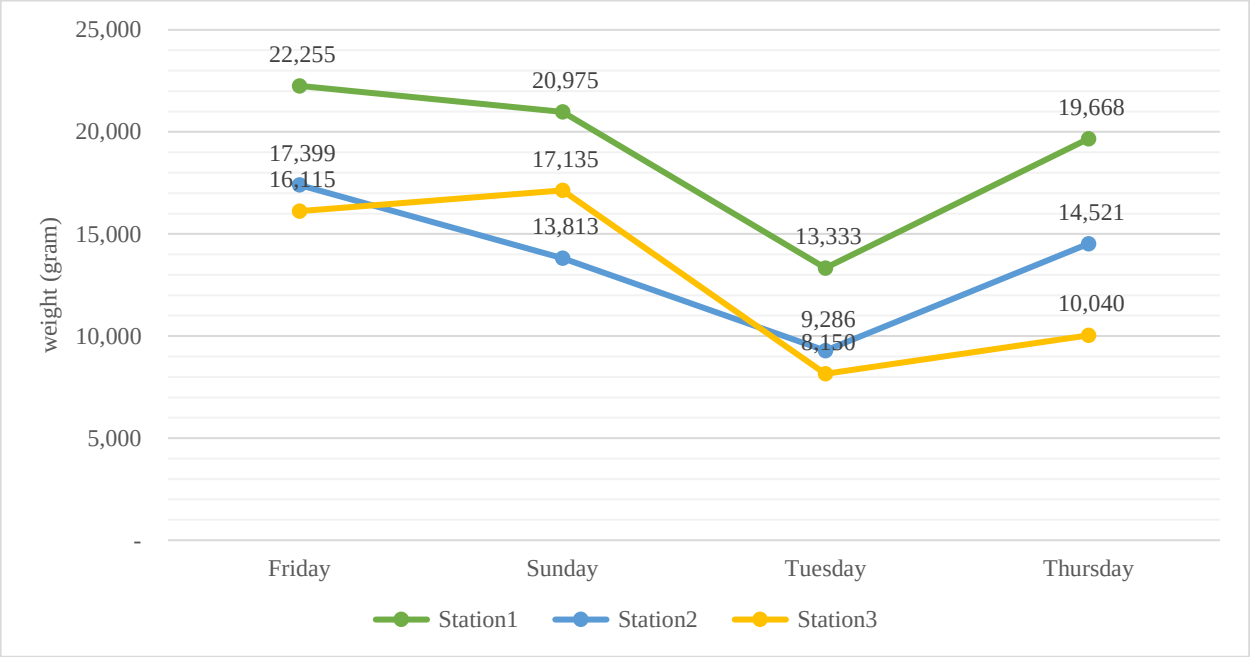


Figure 17 Trends in the numbers of coastal litter (grams) at each station on the day of observation

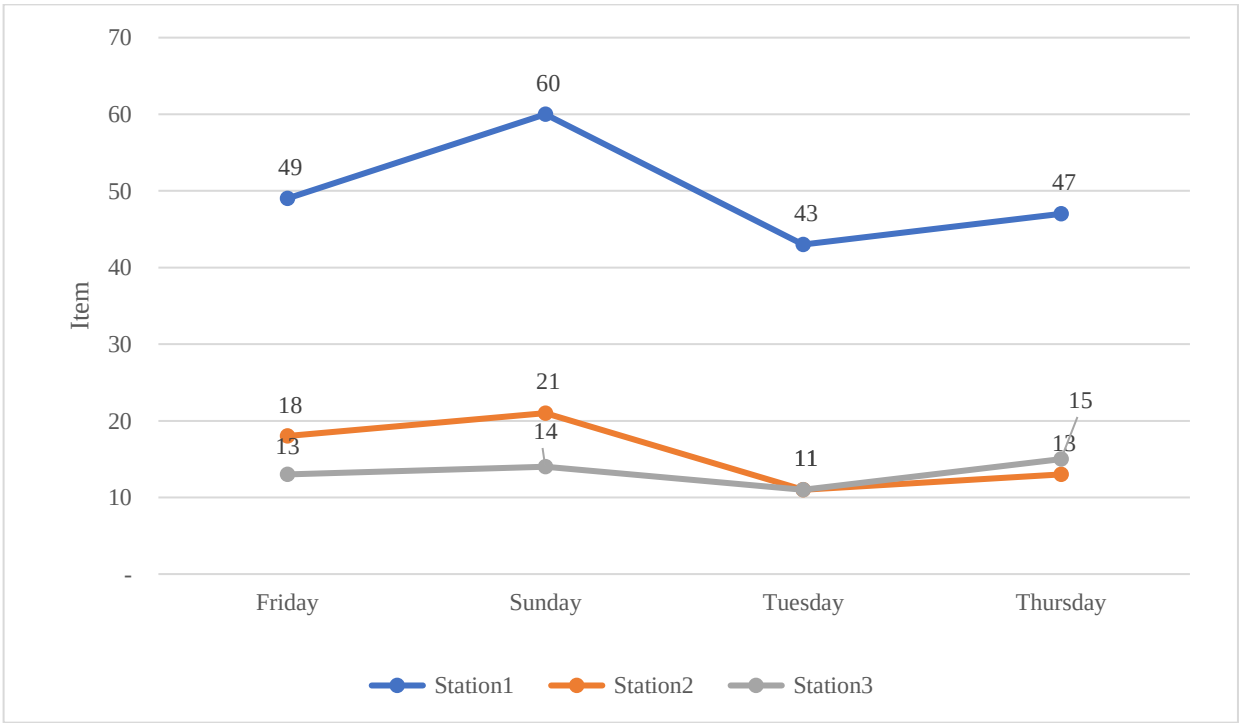


Figure 18 Trends in the number of marine litter (items) at each station on the day of observation

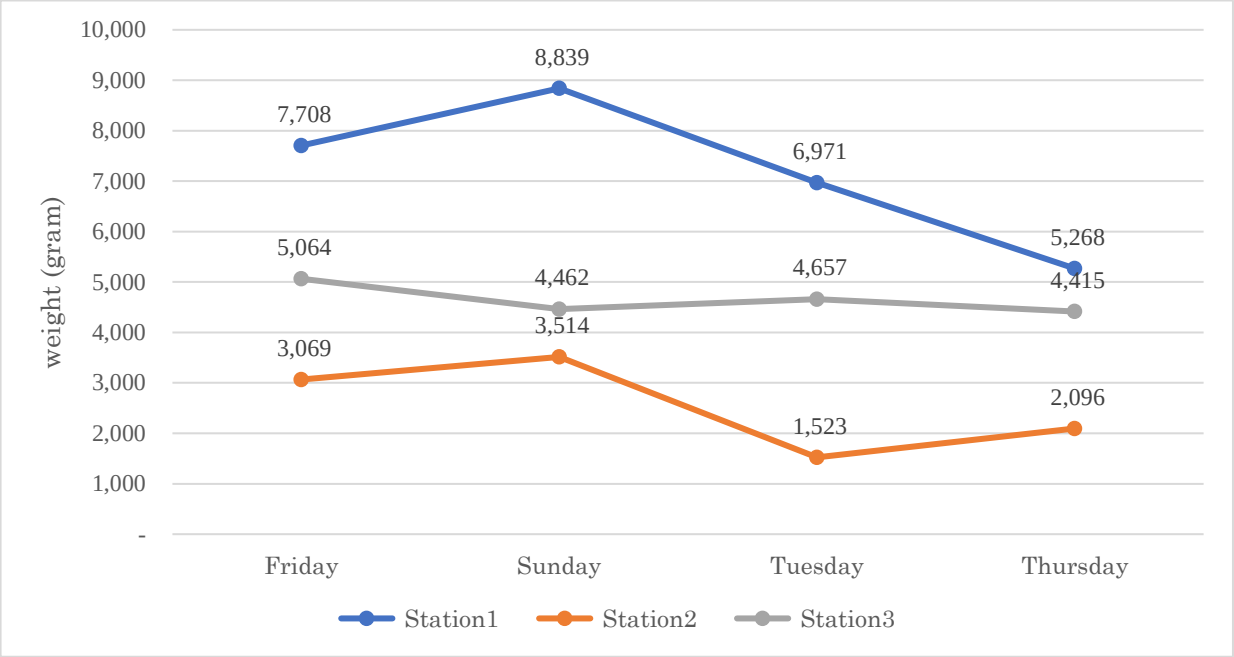


Figure 19 Trends in the number of marine litter (grams) at each station and day of observation

The increasing litter has elevated on weekends. On Friday, many local and foreign tourists visit Penyengat Island for pilgrimages, Friday prayers. While on Sundays apart from tourists, it is also influenced by shopping activities at the Bintan Island market in the Pelantar area where on the northwest side it is directly opposite the Penyengat Island. Litter will be carried by currents and winds. The sea currents and wind speed at the end of February are getting faster and faster. Garbage carried by the current increases in number along with the flow of seawater.

Marine litter was dominated by inorganic waste consisting of plastic and rubber, plastic debris such as plastic bottles, and plastic cups. The shape of the plastic bottle that has a large air space makes it float for a very long time. Plastic cups are very light and strong so they can float for a very long time and be carried away by ocean currents. Ropes and fishing nets are the remains of fishermen's gear that are intentionally discarded or damaged so that they are carried away by ocean currents and deposited on Penyengat Island. The main material of the ropes and nets is plastic with the quality and design to be able to survive in the water as long as possible.

As a result of improperly disposed of fishing gear will make the inadvertent capture or entanglement of certain species, such as turtles, seabirds, and marine mammals, covering and disrupting ecosystems, increasing synthetic materials into the food chain, increasing migrating invasive species, increasing costs for repairs and cleaning of marine debris and impact on socio-economic activities (Macfadyen *et al.,* 2009; Hardesty *et al.,* 2015)

Marine debris found in the coastal area of Peyengat Island is influenced by oceanographic factors. Oceanographic factors, namely currents and waves carrying marine debris at the time of high tide, so that a lot of litter are trapped and accumulated in the Pengagat Island area. This is the same as stated by NOAA (2016), that currents are one of the factors that support the movement of marine litter in waters over long distances. The movement of currents that occur at high tide gives a very different amount of waste accumulation at the study site. During high tides or storms, the seawater overtakes the low shore and carries marine litter to the island area. At low tide the marine debris is left behind because it is blocked by the beach, resulting in a buildup of marine debris in the beach area or under the house.

Wind affects the surface current patterns that carry floating litter material along with the surface current patterns (Choy and Drazen, 2013; Arulrajah *et al.,* 2017). The westerly monsoons push surface currents and carry floating waste material to the east coast of Penyengat Island. The north wind season lasts from December to February in Tanjungpinang with a speed of 30 km/hour. Wind patterns and current patterns greatly affect the distribution of marine litter (Critchell & Lambrechts, 2016 ; Critchell *et al.,* 2015). The surface current patterns are influenced by the direction and strength of the wind (Paduan and Washburn, 2013; Ren

et al., 2015). Based on data obtained from (CLS, 2015) Wind and current patterns were taken from December 2019 to February 2020 to describe wind and current patterns during the west monsoon.

The pile of garbage is highest in areas that face directly to the sea, while the beach area and under houses that are slightly inward is reduced because they are blocked by dense vegetation. Marine litter in that area consists of plastic waste, Styrofoam, and so on. If the marine litter left on the surface of the mangrove substrate will cover the mangrove seedlings, as well as the mangrove seeds on the ground, are blocked by marine litter and eventually dry up and fail to germinate. The accumulation of garbage on mangrove vegetation will have an impact such as limiting growth, it will also clearly affect the benthic organisms that live around the vegetation. Mangroves have an important role in coastal ecosystems, such as the natural protection of coastlines against erosion. Seeing that the substrate at the research site is generally sandy, the benefits of this vegetation as a buffer in the coastal area to prevent abrasion are very significant. Plastic debris (macro) is destroyed into microplastics, it can be a source of food and enter the mesenteric network of coral reefs (Andrady, 2011; Hall *et al.*, 2015). Microplastics derived from macro plastics become toxic materials when they enter the body of marine biota (Alimba and Faggio, 2019) and interfere with health (Cole *et al.*, 2011; Lindeque *et al.*, 2020) such as liver in fish (Browne, Galloway and Thompson, 2010; Rochman *et al.*, 2015). Pieces of plastic can move between consumers (Wright, Thompson and Galloway, 2013) and humans through food chain processes (Farrell and Nelson, 2013; Santana *et al.,* 2017). If plastic material enters the human body through the food chain process by eating fish, it will disrupt health, especially pregnant women and children (Halden, 2010; Campanale *et al.*, 2020).

Conclusion

Coastal and marine litter in Penyengat Island consists of organic waste: wood, leaves, seagrass, and coconut; inorganic waste: sandals or rubber shoes, styrofoam, metal cans, glass bottles, and light bulbs; plastic bottles and cups, plastic ropes and nets. The highest total amount (item) of waste is inorganic waste and the highest total weight of waste is organic waste. Coastal and marine litter spread along 70.78 km or 65.14% of the length of the west coast of Penyengat Island. Coastal and marine litter harm the social community, there are economic losses on boats and fixed fishing gear on Penyengat Island. Marine litter has an impact on the disruption of the growth of mangrove seedlings, the destruction of seagrass, and the spread of foreign species. Coastal and marine litter can be reduced by using marine waste management strategies by recycling, reusing, energy conversion, and supporting community participation in the TPS3R program. The need to increase public awareness, knowledge, and skills in managing waste. The role of local governments, the private sector, and the community in marine waste management needs to be encouraged so that awareness arises in managing marine waste. Products from marine waste processing need to be strived to be able to have a high selling or usage value so that they are easily accepted by the market. Waste management needs to be strived to involve the community from all circles so that the benefits can be felt equally.

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