



Distribution of marine debris in mangrove ecotourism area in Kupang, East Nusa Tenggara, Indonesia

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Abstract. Marine debris is a large, complex and urgent problem in coastal management. The emergence of marine debris into this coastal area will then disrupt the ecological, economic and health conditions of the people who live around the area. The purpose of this study was to determine the distribution of marine debris based on the type composition and density in the mangrove ecotourism area in the coastal area of West Oesapa, Kupang city. The data were collected using the observation method by determining the point of observation to place the line transect. The data were analyzed using qualitative and quantitative descriptive analysis methods. The observations found 9 types of marine debris consisting of (1) plastic bags, (2) foamed plastics, (3) fabric, (4) glass and ceramics, (5) metal, (6) paper and cardboard, (7) rubber, (8) wood, and (9) other types of marine debris. The highest average value of the type composition and total density was plastic bags with an average composition value of 92.32% and a total density value of 9.622 items m^{-2} . The composition and the total density for other types of waste were filled with foamed plastics of 0.829% with a total density value of 0.092 item m^{-2} , fabric is 2.407% with a total density value of 0.230 item m^{-2} , glass and ceramics is 0.605% with a total density value of 0.060 item m^{-2} , metal is 0.411% with a total density value of 0.042 item m^{-2} , paper and cardboard of 0.367% with a total density value of 0.040 item m^{-2} , rubber of 1.390%, with a total density value of 0.148 item m^{-2} , wood of 1.240% with a total density value of 0.130 item m^{-2} , and other marine debris of 0.429% with a total density value of 0.034 item m^{-2} . The largest contributor to marine debris in the mangrove ecotourism area in Kupang, East Nusa Tenggara, Indonesia comes from plastic bag waste.

Key Words: coastal management, plastic waste, marine debris distribution, mangrove ecosystem.

Introduction. In general, marine debris impacts the economic and tourism sectors, disrupting marine life and coastal ecosystems and human health. Marine debris is a persistent solid material, which is intentionally or unintentionally disposed of and left in the marine environment or also originates from residential activities in coastal areas which are carried by floods leading to coastal and marine areas, but in the end the waste will be exposed to coastal areas and carried away by the flow (CSIRO 2014). Engler (2012) also states that marine debris is any human waste in solid form (a state of matter with a fixed volume and shape) or material that enters the seawater environment, either directly or indirectly. Marine debris includes all forms of materials that are produced or processed and then discarded or left in the marine environment which consists of certain items, food/snacks or packaging etc. which are used by humans and then put into the sea, either intentionally or accidentally, such as marine transportation, drainage, and sewage or garbage disposal systems by wind (Galgani et al 2010). The high amount of marine plastic waste due to transportation and accumulation is a complex problem in Indonesia due to the high population of coastal communities and marine activities (Purba et al 2019). This is also in line with Plastics Europe (2017) and Kim et al (2017) that the use of plastics in human life in recent years has increased and led to an increase in the disposal of plastic waste in both terrestrial and aquatic ecosystems.

The emergence of marine debris into this coastal area will have an impact on the disruption of the ecological, economic and health conditions of the people living around the area (Citrasari et al 2012). The potential effects or effects caused by chemical marine

debris tend to increase with decreasing waste particle size, while the physical effects increase with increasing waste size (UNEP 2011). The smaller the particle size of marine debris, the easier it is pushed into the substrate which will then be mixed with organic water or sediment particles which are used as food for suspended particle-eating biota or detritus and will cause digestive disturbances for the biota that consume them, in the end will lead to the death of these biota. Meanwhile, the larger the size of the waste will have a physical impact such as covering the surface of the sediment, thus inhibiting the growth of mangrove seeds which will later become the habitat for certain biota that utilize the mangrove ecosystem as their habitat. Other consequences caused by the presence of marine debris in coastal areas are high levels of water turbidity, low dissolved oxygen content, imbalance in the pH content of the waters (high acidity) resulting in low food content for various marine biota and inhibiting the photosynthesis process for aquatic plants and affecting other biological activities for various biota and also aquatic plants that exist in the aquatic environment (Smith & Markic 2013). This is in line with the statement that plastic waste accumulating in aquatic ecosystems can reduce the physical quality of habitats, transport chemical pollutants, threaten aquatic life, and interfere with human health (Possatto et al 2011; Klein et al 2015; Auta et al 2017; Horton et al 2018).

Marine debris has been found in almost all coastal areas in eastern Indonesia. Marine debris has also been found in Kupang Bay, precisely in the mangrove ecotourism area on the coast of West Oesapa, Kupang City. Based on preliminary observations, it was found that there was a large amount of trash exposed or stuck in the mangrove roots in this ecotourism area. This marine debris is thought to come from people who throw garbage directly into the coastal and marine areas, it could also come from the sea which is carried by currents to the ecotourism area. According to van Sebille et al (2012) and Li et al (2016), currents can affect how much and how little marine material, including garbage that leads to coastal areas. Exposure to marine debris in the coastal areas of the mangrove ecotourism area in West Oesapa will reduce the aesthetic value as a tourism area. Another impact is an imbalance in the condition of the aquatic environment, both physical, chemical and biological, so that the survival and growth of aquatic biota in the mangrove ecotourism area will be disrupted. Therefore, by referring to various marine debris issues and problems, it is important to conduct a study on the distribution of marine debris types in the mangrove ecotourism area in West Oesapa, in order to obtain data and information on the distribution of marine debris in an effort to support the management of mangrove ecotourism areas.

Material and Method

Description of the study sites. This study was conducted from June to July 2020 which took place in the mangrove ecotourism area, West Oesapa, Kelapa Lima district, Kupang city (Figure 1). This mangrove ecotourism area is an area managed by the CCDP - IFAD division, the Department of Marine Affairs and Fisheries, Kupang city. In this mangrove area, there are various types of mangroves including *Rhizophora mucronata*, *Rhizophora stylosa*, *Avicennia marina*, *Avicennia alba*, *Osbornia octodonta* and *Ceriops tagal* (Sine et al 2019). Throughout this ecotourism area, a bridge or wooden pathway with a length of ± 230 meters and a height of about 4 meters was built, which is provided for visitors to more freely observe various types of mangroves and provide opportunities for visitors who want to explore further inside to enjoy the beauty of the mangrove location and ocean views.

The monsoonal climate in Indonesia is greatly influenced by seasonal winds which change every certain period. The West Monsoon winds blow around October to April which is wet so that it brings the rainy season, while in the East Monsoon winds blow from around May to September which is dry which causes the Indonesian region to experience the dry season (BMKG 2020). Based on the Schmidt-Ferguson climate classification, the location of this study includes a tropical climate with an average amount of rainfall of 1,284.9 mm year⁻¹ with the highest rainfall occurring from December to March, while the smallest rainfall occurs in April to November, in this period

there is a long dry season. During the rainy season the weather is cloudy to moderate/heavy rain sometimes accompanied by strong winds and lightning.

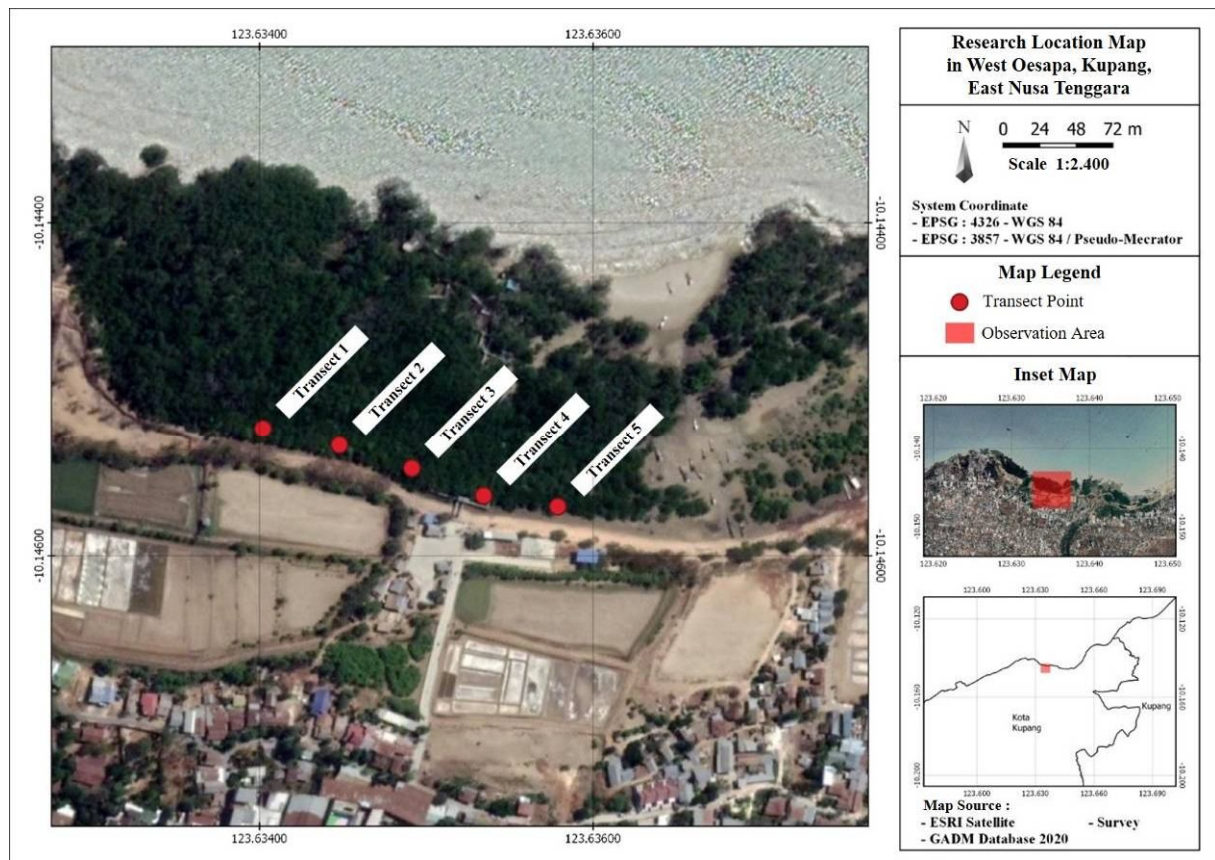


Figure 1. Research location map in West Oesapa, Kupang.

Experimental design. The process of collecting data using observation techniques with the main parameter observed in this study is the distribution of types of waste as seen from the value of composition and density of marine debris. In order to observe the type of marine debris at the research location, observation points must be determined for placing the line transect. The number of observation points is 5 points, from each point 1 line transect is determined, so the total number of line transects for all observation points is 5 transects. The distance between 1 transect and the other transect is 50 meters, with the coordinates of the line transect placement at each point, namely transect I at coordinates 10°8'42.54" S, 123°38'2.20" E, transect II is at coordinates 10°8'43.17" S, 123°38'4.78" E, transect III is at coordinates 10°8'43.91" S, 123°38'6.86" E, transect IV is at coordinates 10°8'44.14" S, 123°38'8.95" E, transect V is at coordinates 10°8'44.52" S, 123°38'11.07" E. In 1 line transect 5 observation plots are set, so that the total observation plots in 5 transects are 25 plots (Figure 2). The distance between 1 observation plot and another is 10 meters with the size of the observation plot is 10x10 m². Furthermore, marine debris samples that have been taken are then identified following instructions from UNEP (2009).

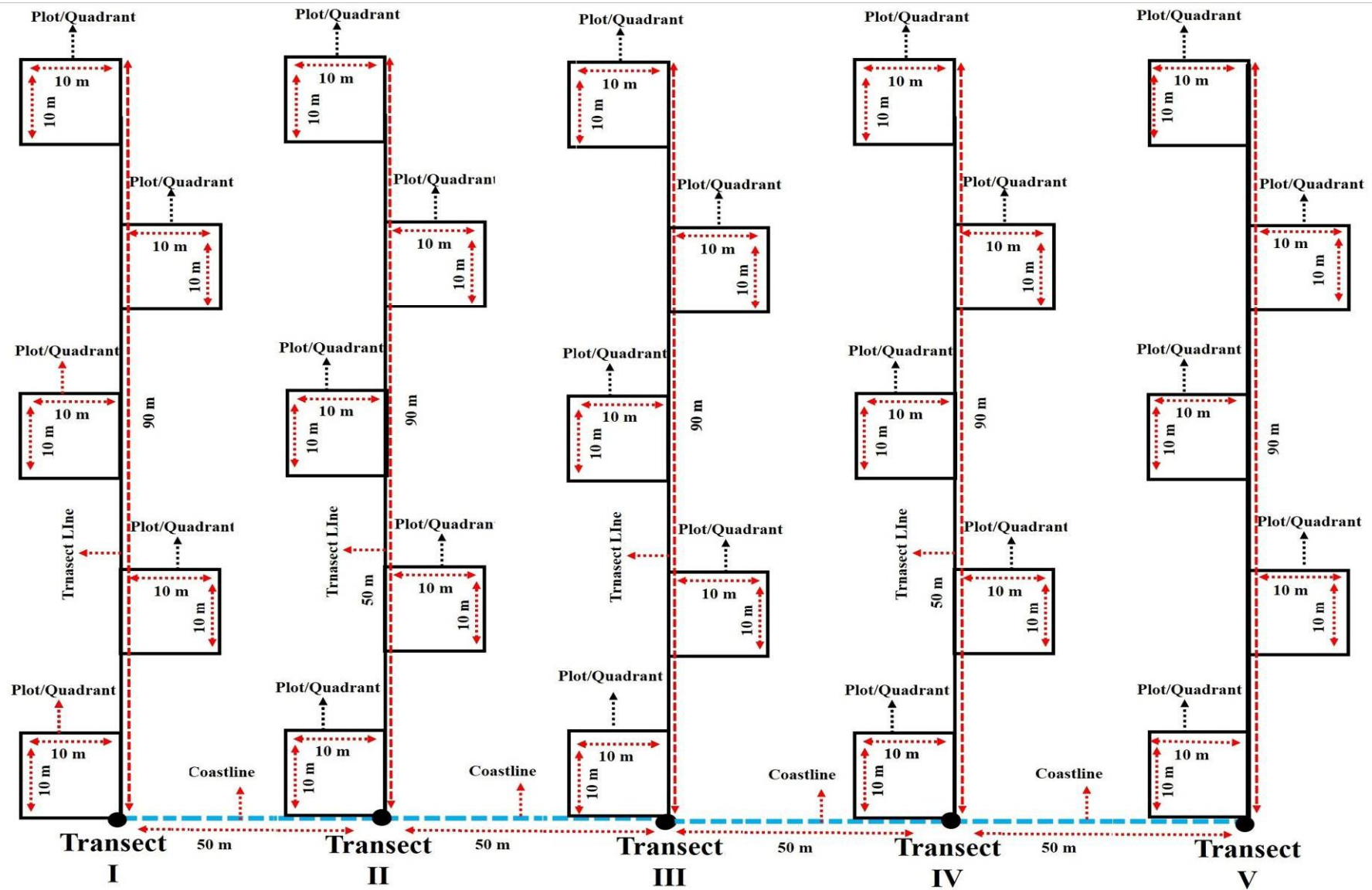


Figure 2. Schematic of transect position of marine debris sampling station.

Data analysis. The data on the distribution of types of waste observed in this study are the composition of types and densities, these two variables can be calculated by following the instructions or formulas set by UNEP (2009):

$$\text{Composition type (P)} = \frac{si}{N} \times 100$$

$$\text{Density type (KSi)} = \frac{si}{A}$$

where, P is the composition of marine debris types, KSi is the density of marine debris types, si is the number of marine debris types i, N is the total amount of all types of marine debris and A is the area where samples of marine debris are exposed.

Furthermore, the calculated data from both the composition and the density of marine debris will be analyzed using qualitative and quantitative descriptive analyzes.

Results. The distribution of marine debris based on identification results with reference to UNEP (2009) guidelines found 9 types of marine debris, namely plastic, foamed plastics, fabric, glass and ceramics, metal, paper and cardboard, rubber, wood and other types. Based on 9 types of marine debris, it was found that each marine debris has a variety of waste specimens. For types of plastic waste, there are 24 specimens, namely (a) plastic bags, (b) plastic bottles < 2 liters, (c) plastic bottle covers, (d) raffia ropes, (e) fiber shards, (f) plastic straws, (g) CD cassette pieces, (h) medicine packages, (i) banners, paralon pipes, (j) plastic mica/rice boxes, (k) plastic sacks, (l) jars, (m) plastic rugs, (n) plastic plates, (o) nylon rope/netting rope, (p) plastic cups (pocari, aqua and ale-ale brands) and others, (q) fragments of plastic kettles, (r) plastic jerry cans, (s) children's toys (balls and others), (t) toothpaste packaging (pepsodent brand), (u) broken motorcycle fenders, (v) detergent packaging, (w) snack food packaging and (x) styrofoam. An overview of the 24 plastic specimens is presented in Figure 3. For the type of foamed plastic waste, 2 categories were found, namely sponge foam and roller foam for wall paint (Figure 4), while for the type of fabric waste there were 4 categories, namely fabric bags, pieces of fabric, fabric wallets and other pieces of fabric (Figure 5). Glass and ceramic waste consist of 3 categories, namely glass bottles, glass shards and other glass bottle shards (Figure 6), while metal waste consists of 2 categories, namely beverage cans and other aluminum scraps (Figure 7). Paper and cardboard waste specimens were found from cigarette and cardboard packages (Figure 8), while 6 categories of the type of rubber waste consisted of rubber sandals, motorcycle bin, motorcycle tires, car tires, rubber hoses and rubber shoes (Figure 9). In Figure 10, there are 4 categories of wood waste types, namely pieces of wood planks, pieces of lumber, and other pieces of wood, while the other types of waste consist of 2 categories, namely diapers and fractional fan (Figure 11).

The types of waste that have been previously described, including plastics, foamed plastics, fabric, glass and ceramics, metals, paper and cardboard, rubber, wood and other types, if grouped by composition, can be detailed and presented in Table 1.

Table 1
Composition of Marine Debris Types in Mangrove Ecotourism Area in West Oesapa

No	Marine debris types	Composition value between transects (%)				
		I	II	III	IV	V
1	Plastic	93.426	92.009	91.525	92.153	92.500
2	Foamed plastic	1.083	1.294	0.636	0.670	0.463
3	Fabric	2.398	2.664	4.237	1.531	1.204
4	Glass and Ceramics	0.232	0.685	0.789	0.670	0.648
5	Metal	0.387	0.304	0.424	0.383	0.556
6	Paper and Cardboard	0.232	0.533	0.212	0.766	0.093
7	Rubber	1.237	1.446	1.059	1.818	1.389
8	Wood	0.733	0.685	0.847	1.340	2.593
9	Other	0.272	0.380	0.271	0.669	0.554

Source: Primary Data 2020.



Figure 3. Specimens/samples of plastic marine debris in mangrove ecotourism area in west Oesapa: (a) plastic bags, (b) plastic bottles < 2 liter, (c) plastic bottle covers, (d) raffia ropes, (e) fiber fragments, (f) plastic straws, (g) CD cassette pieces, (h) medicine packages, (i) banners, (j) plastic pipes, (k) mica/plastic rice boxes, (l) plastic sacks, (m) plastic jars, (n) plastic carpets, (o) plastic plates, (p) nylon rope/netting rope, (q) plastic cups, (r) fragments from plastic kettles, (s) plastic jerry cans, (t) children's toys (balls and others), (u) toothpaste packaging, (v) broken motorcycle fenders, (w) detergent packaging and snack packaging, (x) styrofoam.



Figure 4. Specimens/samples of foamed plastic marine debris in mangrove ecotourism area in West Oesapa: (a) sponge foam, and (b) foam roller for wall paint.

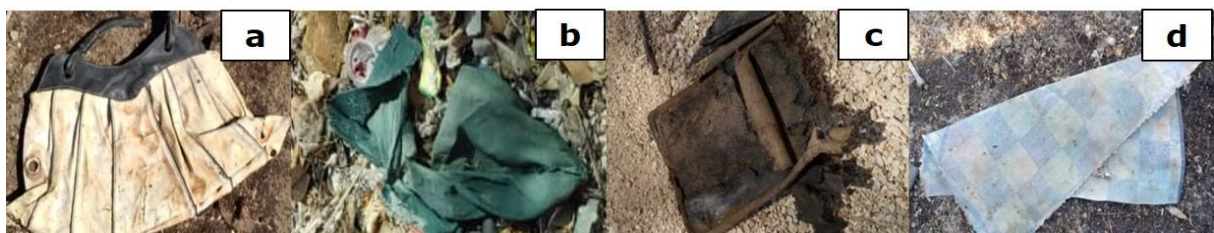


Figure 5. Specimens/samples of fabric marine debris in mangrove ecotourism area in West Oesapa: (a) fabric bags, (b) pieces of fabric, (c) fabric wallets, and (d) other pieces of fabric.



Figure 6. Specimens/samples of glass and ceramic marine debris in mangrove ecotourism area in West Oesapa: (a) glass bottles, (b) glass shards, (c) other glass bottle shards.



Figure 7. Specimens/samples of metal marine debris in mangrove ecotourism area in West Oesapa: (a) beverage cans, (b) other aluminum scraps.



Figure 8. Specimens/samples of paper and cardboard marine debris in mangrove ecotourism area in West Oesapa: (a) packs of cigarettes, (b) cardboard.

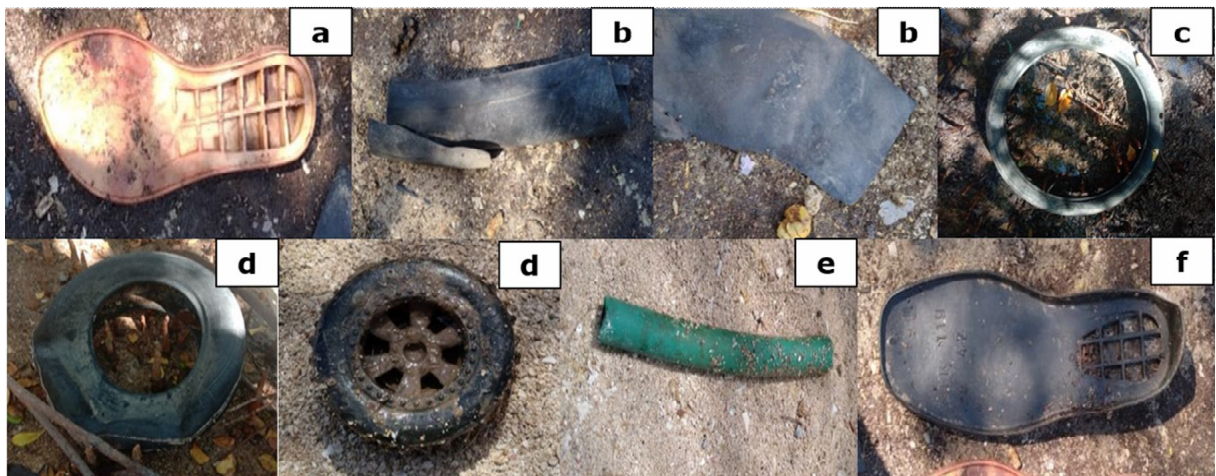


Figure 9. Specimens/samples of rubber marine debris in mangrove ecotourism area in West Oesapa: (a) rubber sandals, (b) motorcycle inner tube, (c) motorcycle tires, (d) car tires, (e) rubber hoses, and (f) rubber shoes.



Figure 10. Specimens/samples of wood marine debris in mangrove ecotourism area in West Oesapa: (a) pieces of wood planks, (b) pieces of lumber, and (c) other pieces of wood.



Figure 11. Specimens/samples of other marine debris in mangrove ecotourism area in West Oesapa: (a) diapers and (b) fractional fan.

Data on the distribution of marine debris based on the type of density in the mangrove ecotourism area on the coast of West Oesapa based on the analysis results are presented in Table 2.

Table 2
Density of marine debris types in mangrove ecotourism area in West Oesapa

No	Marine debris types	Density value between transects ($item\ m^{-2}$)				
		I	II	III	IV	V
1	Plastic	2.416	2.418	0.864	1.926	1.998
2	Foamed plastic	0.028	0.034	0.006	0.014	0.010
3	Fabric	0.062	0.070	0.040	0.032	0.026
4	Glass and ceramics	0.006	0.018	0.008	0.014	0.014
5	Metal	0.010	0.008	0.004	0.008	0.012
6	Paper and cardboard	0.006	0.014	0.002	0.016	0.002
7	Rubber	0.032	0.038	0.010	0.038	0.030
8	Wood	0.020	0.018	0.008	0.028	0.056
9	Other	0.004	0.008	0.002	0.010	0.010

Source: Primary Data 2020.

Discussion. The value composition of marine debris types and density based on the previous explanation appears to have high and low values between transects, but overall the average value of the composition of these types of waste and also the total density value of marine debris types show that there are certain types of marine debris which has the highest composition and density values compared to other types of marine debris, for details, see Figure 12 and Figure 13 as well as the following explanation.

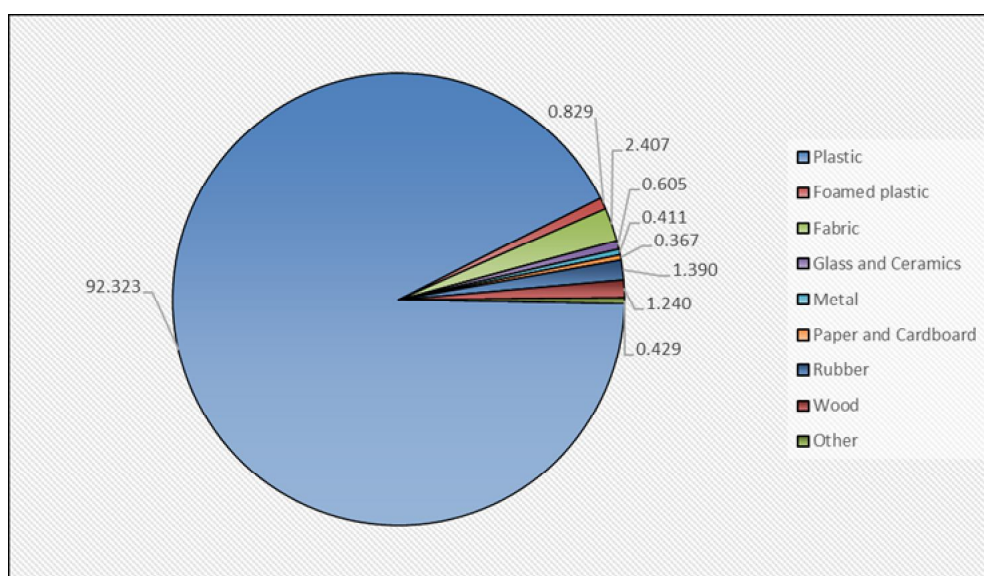


Figure 12. The average value of marine debris composition in mangrove ecotourism area in West Oesapa, Kupang city, East Nusa Tenggara, Indonesia.

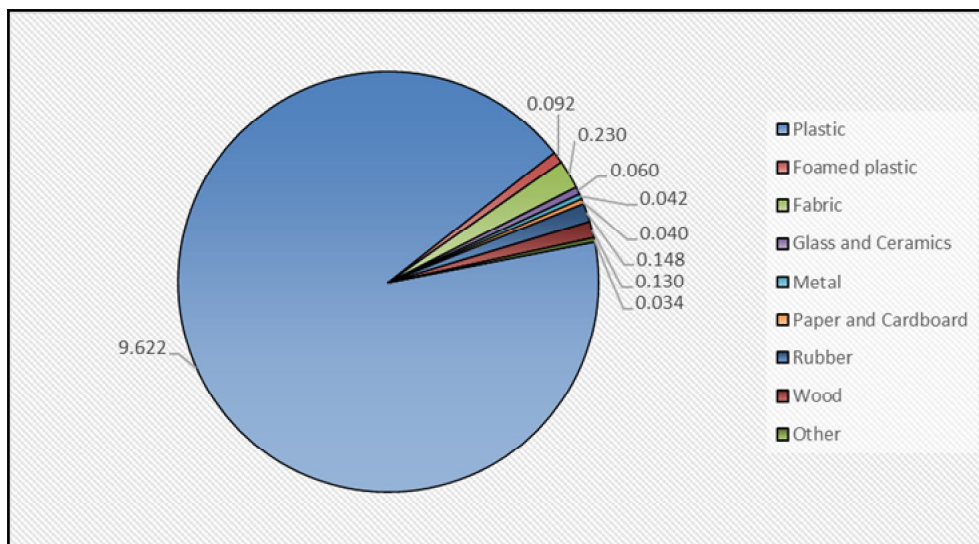


Figure 13. The total density value of marine debris in mangrove ecotourism area in West Oesapa, Kupang City, East Nusa Tenggara, Indonesia.

The average value of the type composition and the total density of each type of marine debris based on Figures 12 and 13 shows that the type of marine debris from plastics has an average composition value of 92.323% with a total density value of 9.622 item m⁻², foamed plastic is 0.829% with a total density value of 0.092 item m⁻², fabric is 2.407% with a total density value of 0.230 item m⁻², glass and ceramics is 0.605% with a total density value of 0.060 item m⁻², metal is 0.411% with a total density value of 0.042 item m⁻², paper and cardboard of 0.367% with a total density value of 0.040 item m⁻², rubber of 1.390%, with a total density value of 0.148 item m⁻², wood of 1.240% with a total density value of 0.130 item m⁻², and other marine debris of 0.429% with a total density value of 0.034 item m⁻². From the average value of the type composition and the total density value of marine debris, it can be seen that marine debris from plastic types has the highest composition and density value compared to marine debris from other types with composition value is below 5% and the density value is below 1 item m⁻² such as foamed plastics, fabric, glass and ceramics, metal, paper and cardboard, rubber, wood and other marine debris. This indicates that the type of marine debris that dominates the mangrove ecotourism area on the coast of West Oesapa, Kupang city comes from plastic waste.

The dominance of marine debris from plastic types compared to other types in this region is caused by certain factors; according to Jambeck et al (2015) in Zhukov (2017) that plastic is the dominant marine waste because plastic is a polluting material that is already global distributed throughout the waters due to its durable and buoyant nature.

In addition, the large amount of plastic waste in the sea is a result of the high activity and number of human populations. From its geographical location, the sea and coastal areas of Southeast Asian countries are estimated to be one of the world's most productive regions and play an important role for the economic development of every country in the region (Paulus et al 2019). Based on geographical clustering data of mismanaged plastic waste, a high share of the world's ocean plastics pollution has its origin in Asia. Highly populated areas such as China and Indonesia are the largest contributors to mismanaged plastic waste in Asia (Ritchie & Roser 2018). In 2012, the Scientific and Technical Advisory Panel (CBD-STAP) in Gall & Thompson (2015) stated that plastic is the dominant type of marine debris, because plastic is a type of waste that is commonly found in various places, both on land and water. In addition, the composition of plastic waste is more dominant because its density is lower than the density of other types of marine debris, so that it is easily transported to any area, including mangrove ecotourism areas (Ryan et al 2009). Furthermore, Derraik (2002) also states that plastic is a synthetic organic polymer and has material characteristics suitable for use in everyday life and types of plastic commonly used in everyday life

include plastic bags, beverage bottles, food wrappers, soap wrappers, sacks, raffia, straws, styrofoam, cutlery and other solid plastics.

Regarding the description of the explanation above, if it is related to the findings in this study, it can be clearly seen that marine waste is more dominant in the type of plastic compared to other types that enter the mangrove ecotourism area in West Oesapa, because plastic waste is water pollutants with durable properties that are easy to float and have been globally distributed in all marine areas in the world, including in eastern Indonesia, to be precise in the area that is the location of this study. In addition, the dominance of plastic waste exposed to this area is also a result of the activities of people living in coastal areas around the area and also other activities in coastal areas which often contribute to the disposal of waste including plastic waste into the marine area. So that with the sea currents the waste can be distributed in this research area. The results of this study are also the same as previous findings that the high population and downstream activities of residents have a major impact on the abundance of microplastics in the estuary, coastal and marine areas (Desforges et al 2014; Baldwin et al 2016; Hitchcock & Mitrovic 2019; Kataoka et al 2019; Yin et al 2019; Lodo et al 2020). Another contributing factor is the impact of the activities of visitors who come to the mangrove ecotourism area, which is provided with snacks and drinks that are brought for consumption during recreation and then the packaging of these snacks or drinks is disposed of in the mangrove ecotourism area and becomes marine waste. Furthermore, the factors causing the amount of marine debris including plastic are also due to the mangrove ecotourism area which is located between two river estuaries on the left and right of the area, so that activities from the mainland such as garbage disposal including plastic waste from household waste, of course at certain times will be carried away by flooding and entering the river body towards the estuary, then entering the marine area to become marine debris and with the help of the current, the plastic waste will be distributed to the mangrove ecotourism area at the location of this study. This finding is also supported by statements from several previous studies that the abundance of plastic in river bodies is a complex problem, especially regarding the presence of waste input in coastal areas (Hastuti et al 2014; Lee et al 2015; Stolte et al 2015; Zhang 2017; Lodo et al 2020).

Plastic waste from household waste can be proven from the results of this study which found that the dominant plastic waste found in the mangrove ecotourism area in West Oesapa is mostly from household waste such as plastic bags, plastic bottles with size < 2 L, plastic bottle covers, raffia ropes, fiber shards, plastic straws, CD cassette pieces, medicine packaging, banners, paralon pipes, mica/rice boxes, sacks, jars, plastic rugs, plastic plates, nylon ropes, bottled drinking water (aqua, ale-ale and other brands), fragments of plastic kettles, jerry cans, plastic children's toys (balls and others), toothpaste packaging (pepsodent brand), broken motorcycle fenders and detergent and snack packs and etc. Another important finding is that although marine debris from the dominant type of plastic is found at this location, other types of marine debris such as foamed plastics, fabric, glass and ceramics, metal, paper and cardboard, rubber, wood and other types of waste were also found. In this ecotourism area, it can be said that human activities of local residents or local tourism objects have a high impact on the amount of marine debris in this area and with the presence of marine debris, it is certain that it will have an impact on mangrove plants and biota in the ecosystem.

Conclusions. The distribution of marine debris consists of plastic bags, foamed plastics, fabric, glass and ceramics, metal, paper and cardboard, rubber, wood and other types of marine debris. The highest average value of type composition and total density is plastic waste with an average composition value of 92.32% and a total density value of 9.622 item m⁻². Compared to marine debris from other types, such as foamed plastics, fabric, glass and ceramics, metal, paper and cardboard, rubber, wood, and other marine debris its composition value is below 5% and the density value is below 1 item m⁻². This indicates that the type of marine debris that dominates the mangrove ecotourism area on the coast of West Oesapa, Kupang city comes from plastic waste.

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