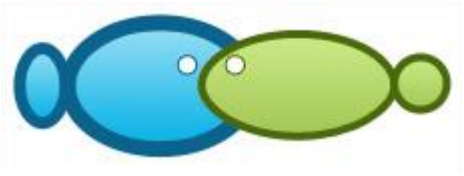

Density and composition of macro- and meso-plastic in Teluk Penyu coast, Cilacap

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Abstract. The density of tourists in Cilacap Teluk Penyu (or Cilacap Turtle Bay) can be one of the causes of pollution to the environment, especially from the disposal of plastic waste. If pollution due to plastic waste continues to occur, it will have an impact on the environment and humans in the area. This research will examine the type, density, and composition of plastic waste. Sampling was carried out on eight repetitions using the line transect method. The samples taken were then grouped to be identified based on their size and type. The grouping was carried out with reference to the 2020 KLHK guidelines, and the data obtained were analyzed to calculate the abundance based on the weight, type, and composition of plastic waste. Of the 17 types of plastic waste found, the density of the waste was dominated by 95% macroplastics and 5% mesoplastics. Macroplastic waste is generally used more by people in their daily activities compared to mesoplastic because it is strong, lightweight, flexible, and easy to carry everywhere. Based on the composition of the types of plastic waste, on tourist beaches you can find PL04 (spoon, fork, and straw) and PL07 (plastic bags) in macro waste and PL01 (bottle caps), PL08 (toy flakes), and PL11 (cigarette butts) in meso waste which is a type of disposable waste that is discarded by users. Awareness from the public needs to be increased again regarding environmental awareness, especially plastic pollution. Promotion of environmental awareness through several programs carried out by institutions or the community needs to be carried out to deal with plastic waste pollution. Environmentally responsible behavior is also promoted among coastal tourists.
Key Words: coastal management, marine pollution, plastic debris, Teluk Penyu, tourism.

Introduction. Teluk Penyu, located on the south coast of Cilacap, is one of the beach tourism objects with a high activity level in Cilacap City. In 2017-2021 it had the highest tourist growth after Salatiga City at 141.4% (Kepemudaan et al 2021). The beach, located only about ±2 km from the city center and one of the main tourist attractions, is the second tourist destination with an attraction of 143,209 tourists in 2021 (Kepemudaan et al 2021). The panoramic view of Nusakambangan Island and oil tankers become the distinctive characteristic of Teluk Penyu. However, the density of tourists can cause several problems, one of which being the increase in marine waste due to the use of various food packaging by tourists (Syakti et al 2017). The number of tourists on tourist beaches also affects the amount of marine debris generated, including plastics (Garcés-Ordóñez et al 2020; Hayati et al 2020). Waste on the beach can be caused by several factors, such as tourism activities, stores, and waste disposal from hotels or restaurants along the beach (Retama et al 2016; Dowarah & Devipriya 2019; Maione 2021). Such waste generation can eventually have various negative effects on the aquatic environment and human health.

SCBD & STAP-GEF (2012) reported that plastic is the most dominant type of marine debris. The same thing was reported by da Silva et al (2018) at Arraial do Cabo tourist beach RJ, Brazil, Rakib et al (2022) on the Cox's Bazar beach of the Bay of Bengal, Bangladesh, and Abelouah et al (2021) on the central Atlantic coast of Morocco. The oceans are estimated to contain 1 tonne of plastic for every 3 tonnes of fish in 2025, and in 2050 there will be more plastic than fish in the oceans by weight (Ellen MacArthur Foundation 2017). It is estimated that 10% of all plastics produced will be discharged into rivers and end up on beaches and the ocean (Van Cauwenberghe et al 2013). Since plastic is a common disposable material that humans often use because it is elastic, lightweight, transparent, and cheap, it is usually considered unimportant after use and is simply discarded.

Coastal issues due to interactions between humans who use coastal resources for tourism activities are essential to study, one of which is Teluk Penyu Beach, Cilacap, which is one of the areas that have the potential to contribute plastic waste that can cause pollution problems in the area (Kusumawati et al 2018). In that case, it will impact the environment and habitat in the area (Syakti et al 2017; Ningsih et al 2020; Sahami et al 2020). Hence, this study aims to assess the type, density, and composition of plastic waste. The results are expected to be used as a basis for monitoring for plastic waste pollution in Teluk Penyu coastal, Cilacap.

Material and Method

Study sites. The research was conducted in Teluk Penyu, Cilacap coast, in September 2021. Sampling was carried out using the survey method, which was carried out by observing a research object directly and conducting eight repetitions to obtain objective data (Figure 1). The sampling location was determined based on the researcher's judgment that the sampling point was suitable. Syakti et al (2017) have also used this sampling location for three consecutive years to monitor activities each year. The sampling point was determined by dividing the length of the coast line obtained with an interval of 100 m for the placement of each quadrant transect measuring 5 meters × 5 meters referring to Syakti et al (2017). The sample identification and analysis process was carried out at the Water Quality and Productivity Laboratory, Faculty of Fisheries and Marine Science, Universitas Jenderal Soedirman.

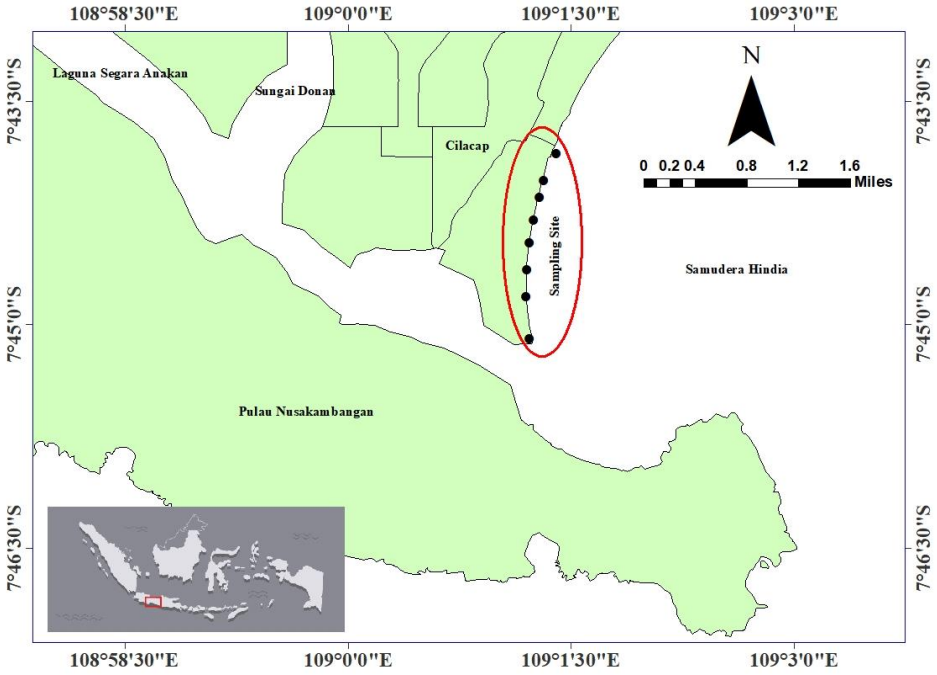

Figure 1. Sampling location in Teluk Penyu, Cilacap.

Sample collection. Sampling was conducted using the line transect method to determine the type, amount, and density of plastic waste. Sampling in the field refers to

KLHK (2020) where the steps taken are determining one point, and then a line is drawn along 100 m parallel to the shoreline, then a 5 meter × 5-meter quadrant transect is placed at each sampling point for a transect length of 20 m which is used to collect macro waste samples (Figure 2). Surface sediments 1-3 cm deep were collected using a shovel and sieved using a 25 mm sieve. Any debris left above the sieve was categorized as macro debris and collected for further identification.

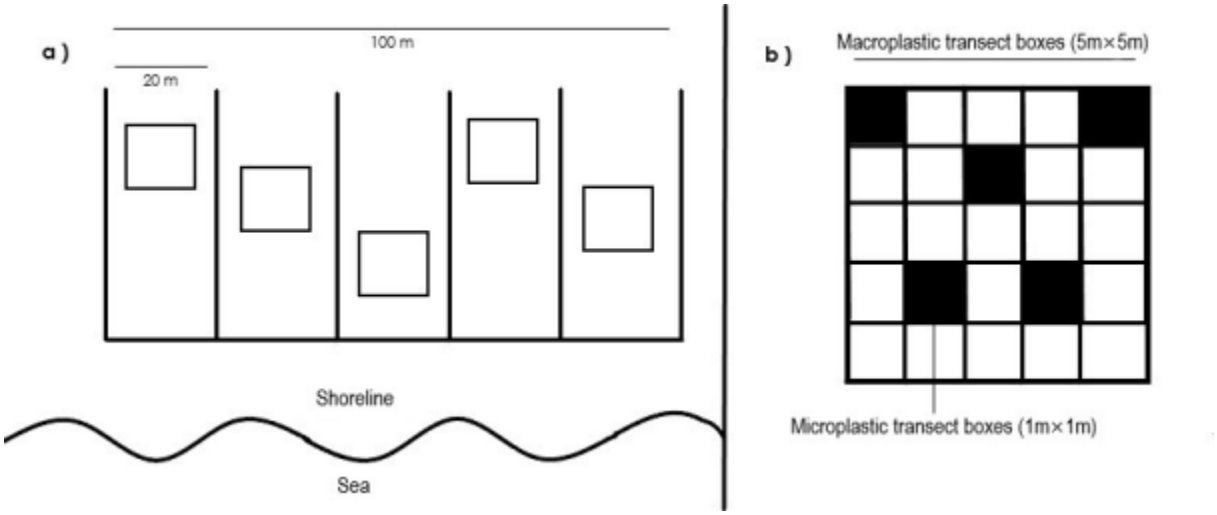

Figure 2. Illustration of sample plotting (a) and size of each transect (b) in Teluk Penyu, Cilacap.

Meso samples were taken from 1 meter × 1-meter transects laid out within 5 meters × 5-meter transects. In this transect, sediment 1-3 cm deep was taken using a shovel and sieved using a 5 mm sieve. Retained debris was separated as meso-debris and further identified. Samples were cleaned of adhering sediment, then placed in separate containers of trash bags for each sampling point. The sampling process, in this case was carried out in stages starting from the first 20 m to the fifth lane at eact point. After that, the samples obtained were visually identified. The steps of plastic waste sampling are presented in Figure 3.

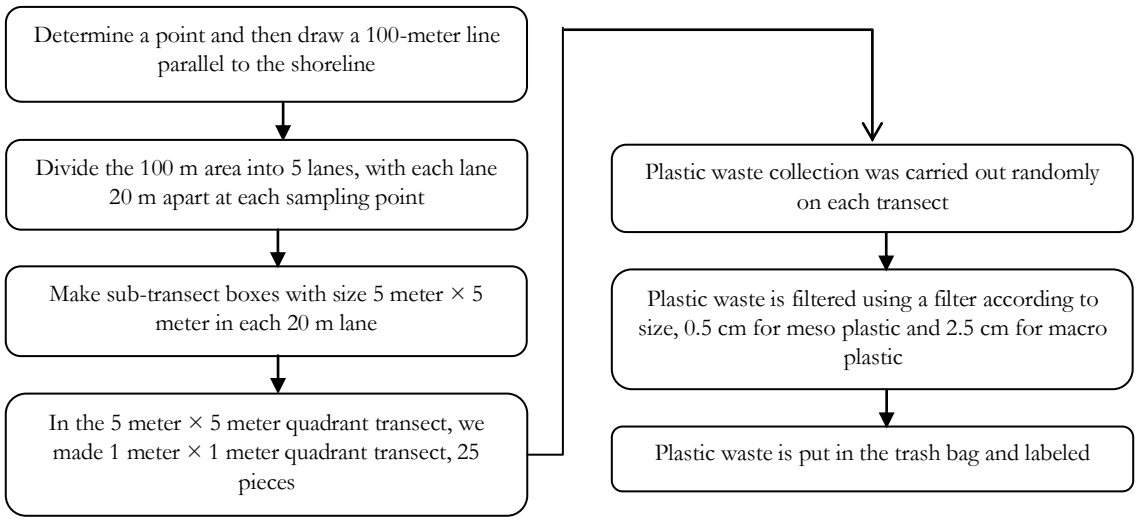

Figure 3. Steps of plastic waste sampling.

Data analysis. The data used is in the form of primary data on waste on the Teluk Penyu coast. The obtained plastic samples were cleaned to remove sediment and residue that was still attached, then separated based on the macro and meso waste size categories, after which they were classified based on the waste code according to the KLHK (2020). The plastic waste code for each group is presented in Table 1.

Table 1

Classification of plastic waste by code (KLHK 2020)

No	*Waste code*	*Waste classification*	*No*	*Waste code*	*Waste classification*
1	PL01	Bottle cap	13	PL13	Baskets, crates and trays
2	PL02	Botttle < 2L	14	PL14	Plastic mooring buoy (buoy)
3	PL03	Bottle, drums, jerry cans and buckets > 2L	15	PL15	Mesh bags (vegetable, oyster nets and clam bags)
4	PL04	Knives, forks, spoons, straws, stirrers, and cookware	16	PL16	Tarpaulin (tarpaulin or other woven plastic bags, pallet wrap)
5	PL05	Food container beverage equipment package (fast food, cups, lunch boxes, etc.)	17	PL17	Fishing equipment (bait, traps and pots)
			18	PL18	Monofilament string
6	PL06	Food containers (fast food, cups, lunch boxes, etc.)			
7	PL07	Plastic bag (opaque or clear)	19	PL19	Rope
8	PL08	Toys and party supplies	20	PL20	Fishing net
9	PL09	Gloves	21	PL21	Plastic ribbon strap
10	PL10	Cigarette lighter	22	PL22	Fibreglass flakes
11	PL11	Cigarettes, butts and filters	23	PL23	Plastic ore
12	PL12	Syringe	24	PL24	Other plastic materials

After classification, the weight, percentage, and density of each type and size of plastic waste (both macro and meso waste) obtained are calculated, then the calculation results were analyzed descriptively and visualized in the form of tables and graphs. The formulae used in the calculation is as follows:

a. Weight of plastic waste. Litter collected per square meter (M) is the total weight of litter per transect box area. The weight of waste per square meter is reported in grams per square meter (g m^{-2}) (KLHK 2020):

$$M = \frac{\text{Total weight of litter (g)}}{\text{Length (m) x Width (m)}}$$

b. Density of plastic waste. Litter density (K) was calculated from the amount of litter per type per transect box area. Waste density data is reported in units of number of waste per type m^{-2} (KLHK 2020):

$$\text{Density (K)} = \frac{\text{Total amount of litter per type}}{\text{Length (m) x Width (m)}}$$

c. Composition of plastic waste. Waste composition was calculated as a percentage (%), which is the weight of waste per type per total waste in the transect box (KLHK 2020):

$$\text{Percentage (\%)} = \frac{X}{\sum_{i=1}^{n} xi} \times 100$$

where: X = weight of waste per type.

Results

Type and density of plastic waste. The plastic waste that is the object of this study is divided into two sizes, macroplastics which are the most common of waste that can found

and can be seen clearly because the size is more than 2.5 cm and mesoplastics with sizez between 5 mm and 2.5 cm (Chubarenko et al 2020; Jeyasanta et al 2020; KLHK 2020). Specifically, the plastic debris found consisted of PL01, PL02, PL04, PL05, PL06, PL07, PL08, PL10, PL11, PL12, PL13, PL16, PL17, PL19, PL20, PL21, PL22, and PL24 for macro debris and PL01, PL04, PL05, PL06, PL07, PL08, PL11, PL13, PL16, PL19, PL20, PL21, PL22, and PL24 for mesoplastics (Table 2). Litter density (K) was calculated from the amount of litter per type per transect box area, litter density data is reported in units of number of litter per item m^{-2}. Based on the results found in the field, macroplastic types (PL04) such as plastic forks or spoons and (PL07) such as plastic bags had the highest density of 12.24 types m^{-2} each, then types (PL06) such as fast food containers had the second highest value of 8.68 types m^{-2}. The highest total mesoplastics density was in type (PL01) worth 0.68 types m^{-2} with the plastic classification being bottle caps.

Table 2

Density of macro- and meso-plastics by weight and item

Code	*Waste classification*	*Weight (g m^{-2})*		*Density (item m^{-2})*	
		Macro	*Meso*	*Macro*	*Meso*
PL01	Bottle cap	3.456	0.46	2.12	0.68
PL02	Bottle < 2L	10.364	-	0.36	-
PL03	Bottles, drums, jerry cans, and buckets > 2L	-	-	-	-
PL04	Knives, forks, spoons, straws, stirrers, and cookware	7.164	0.056	12.24	0.16
PL05	Food container beverage equipment package (fast food, cups, lunch boxes and the like)	3.228	0.008	2.44	0.04
PL06	Food containers (fast food, cups, lunch boxes and the like)	10.144	0.012	8.68	0.04
PL07	Plastic bag (opaque or clear)	24.348	0.056	12.24	0.16
PL08	Toys and party supplies	1.868	0.252	1.24	0.44
PL09	Gloves	-	-	-	-
PL10	Cigarette lighter	1.752	-	0.12	-
PL11	Cigarettes, butts and filters	0.248	0.296	1	0.32
PL12	Syringe	0.108	-	0.08	-
PL13	Baskets, crates and trays	0.304	0.1	0.28	0.12
PL14	Plastic mooring buoy (buoy)	-	-	-	-
PL15	Mesh bags (vegetable, oyster net and clam bags)	-	-	-	-
PL16	Tarpaulin (tarpaulin or other woven plastic bags, pallet wrap)	3.936	0.068	0.24	0.08
PL17	Fishing equipment (bait, traps, pots)	1.02	-	0.32	-
PL18	Monofilament string	-	-	-	-
PL19	Rope	30.472	0.04	2.48	0.08
PL20	Fishing net	1.004	0.016	0.72	0.04
PL21	Plastic ribbon strap	0.548	0.04	1.88	0.12
PL22	Fibreglass flakes	0.196	0.072	0.2	0.08
PL23	Plastic ore	-	-	-	-
PL24	Other plastic materials	11.496	0.072	4.68	0.08

Composition of plastic waste. Based on the results, the waste density is dominated by macroplastics, with a percentage of 95% and 5% for mesoplastics. The weight percentage was also dominated by 99% macroplastics and 1% mesoplastics (Figure 4).

Figure 4. Percentage composition comparison based on density (%) (a) and weight (%) (b) of macro and meso-plastics in Teluk Penyu, Cilacap.

Composition of macroplastic. The types of macroplastics found during field sampling are displayed in Figure 5. The results showed that the composition of macro litter was dominated by PL07 (plastic bags) both in terms of weight and quantity with the same value, namely 25%. This is expected because plastic bags are a waste that tourists quite often use in this area.

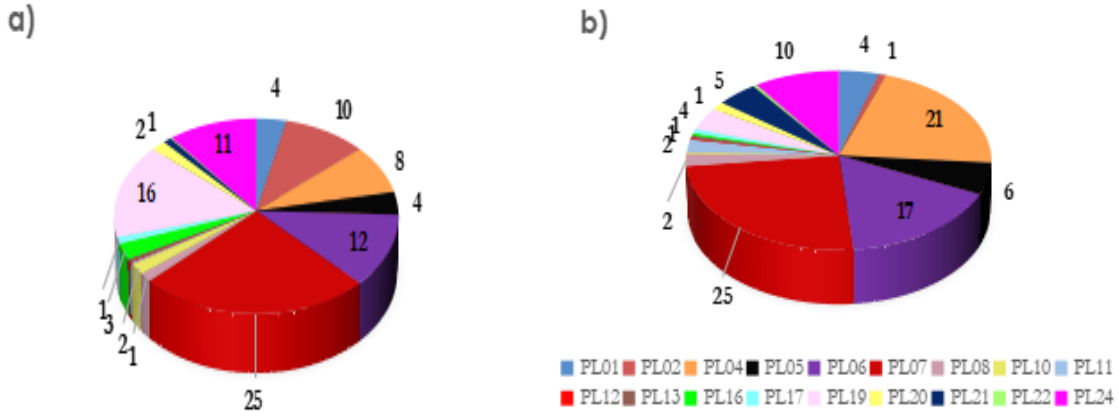

Figure 5. Percentage composition by weight (%) (a) and amount (%) (b) of macroplastics in Teluk Penyu, Cilacap.

Composition of mesoplastic. Based on the results of the weight and amount percentage diagrams on mesoplastics (Figure 6), in the mesoplastic category, bottle caps or PL01 become plastic waste with the highest abundance of 28% compared to PL08, which is toy waste with the lowest abundance of 14% and PL11 is cigarette waste totaling 19% between the of PL01 and PL08. Meanwhile, other plastic waste tends to have a small percentage amount. In other types of plastic waste, the results are not comparable to the third type of plastic that is very dominant in abundance on the tourist beach.

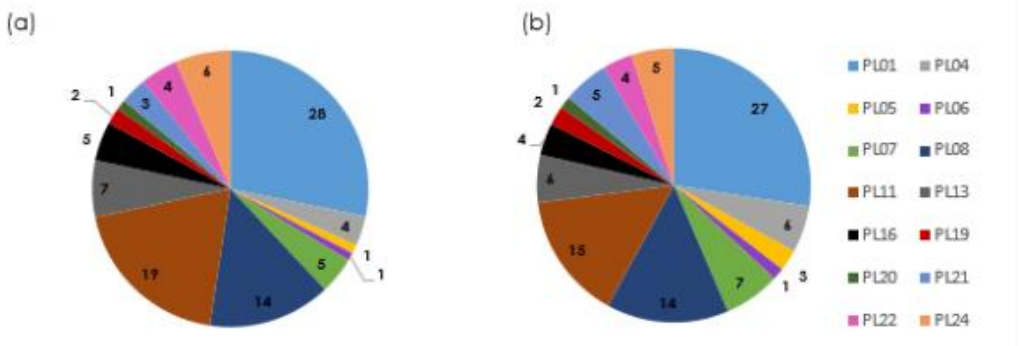

Figure 6. Percentage composition by weight(%) (a) and amount(%) (b) of mesoplastics in Teluk Penyu, Cilacap.

Discussion. Macroplastic types PL04 (i.e. spoons) and PL07 such as plastic bags had the highest density of 12.24 item m^{-2}, then types (PL06) such as fast food containers had the second highest value of 8.68 item m^{-2}. Tourists generally walk on the beach enjoying nature's beauty while eating food they buy or bring themselves. However, the plastic they use to carry or wrap food is often thrown on the beach after its use (Williams et al 2016). The same results were also reported by Syakti et al (2017), da Silva et al (2018), Frigione et al (2021) and Rakib et al (2022); that single-use plastics are the most dominating waste on tourist beaches, the level of visitor intensity in traveling can also cause the accumulation of plastic waste due to tourist waste. If single-use plastic waste continues accumulating, the effect on the environment will also adversely affect the habitat by changing species distribution, entangling organisms, and causing damage or even increasing mortality due to plastic waste (Welden 2020).

Based on the size, the marine debris is dominated by macroplastics (95%) for the item density, as well as for the weight (99%) as shown in Figure 4. Plastic waste in Teluk Penyu beach comes from floating debris carried by ocean currents and domestic waste from community, especially from tourists who throw it directly on the beach area. The community generally uses macroplastic waste in daily activities, such as plastic bags, bottles, straws, and cups (Atmanti & Purwanti 2021). Macroplastic waste is more common than mesoplastic waste, such as cigarette punting. It causes the density and weight of macroplastic to be higher than mesoplastics. The same results were also obtained by Damayanti et al (2022) that the type of waste in the plastic category is the most dominating marine debris in the west coast tourist area of Mataram City. This is due to the light mass of waste so that it easily floats, is carried by waves, and then accumulates in the waters. In addition, research conducted by Schaduw et al (2021) found that plastic waste has the highest composition than other types of waste at Malayang Beach.

Beach users, including tourists and people conducting economic activites in the beach area, have been identified as major sources of waste (Williams et al 2016). This is expected from the high input of plastic packaging waste from human activites that are not managed properly. Human activities are essential in contributing plastic pollutans to the environment (Olivatto et al 2019). The same applies to tourism activites. In addition, Teluk Penyu Beach is also a famous and crowded area visited by tourists. Significantly during the holiday season, the number of tourist who come to the location also increases. It shows that waste in coastal areas can increase by about twice the usual amount during the holidays (Lasaliesanti 2019). The types of beach waste found in the research location include bottle caps, bottles, jerry cans, and plastic bags (Figure 5). Teluk Penyu is one of the largest industrial areas with various industrial activities in it such as the petroleum industry that is still operating. In addition, the Teluk Penyu beach tourism area is the most popular tourist attraction in Cilacap and in the tourist attraction that contributes the most regional original revenue in Cilacap (Pamungkas 2019). This causes the types of macro marine debris on this beach also to vary and have specific characteristics, as evidenced by the discovery of macro marine debris in the form of used equipment commonly used in industrial activities and macro marine debris from tourist attraction visitors (Kusumawati et al 2018).

Based on Figure 5, it is evident that PL07 (plastic bags) dominates the composition of macro-sized waste. The amount of plastic waste far exceeds that of other types of waste. According to Zhukov (2017), plastic is the most commonly found marine debris. This is due to its durability, ability to float and its resistance to decomposition, which makes it a significant pollutant that has spread globally throughout the waters. The amount of plastic waste in the ocean originates and is influenced by human activity and population, such as in highly populated areas of China and Indonesia (Jambeck et al 2015). It is undeniable that plastic bags are still favored and difficult to replace due to their strong, lightweight, flexible, resistant, unbreakable, and malleable properties (Surono & Ismanto 2016). In addition, people still often use plastic bags as necessities, such as shopping, storing goods, and carrying things. Therefore, it takes awareness from ourselves to reduce the use of plastic waste, especially plastic bags, which are the main problem of the macroplastic category.

The amount of marine waste that accumulates, especially from the type of plastic waste, can have an impact on the aesthetic value of coastal areas and does not rule out the possibility of having an impact on marine pollution and the health of marine animals and even have an impact on human health. Plastic waste has an impact on marine pollution because plastic will not disappear but only decompose in an ecosystem from size of macroplastics to microplastics (Teuten et al 2009). Macroplastics can also injure marine animals when entangled by plastic waste and can also cause death in marine animals if macroplastic waste is swallowed so that marine animals experience irritation in the digestive system (Cordova 2017). In research coducted by Djaguna et al (2019) the same results were obtained that the types of marine debris generally found at the research site were plastic, rubber, metal, glass, and wood. However, the most common type of waste is plastic waste. The results showed that plastic debris was found in the largest amount, followed by rubber, glass, and metal. The main factor causing the abundance of marine litter at the study site was the population's activities, indicating that land-based (industrial) sources provide the primary input for plastic pollution at the beach.

Figure 6 displays a diagram depicting the weight percentage and amount of mesoplastic. Of the several varieties of mesoplastic, bottle caps (PL01) have the most plastic waste (28%), toy trash (PL08) has the least waste (14%), and cigarette waste (PL11) is among these sorts (19%). The percentage of other types of plastic trash is comparatively low.

The primary reason for the dominance of plastic bottle caps in the mesoplastic waste category is that they are made of polypropylene, which is highly resistant to high temperatures and concentrated acidic liquids. Polypropylene is also recognised for its exceptional resistance to halogenated and oxidising substances, as well as hydrocarbons, aldehydes, esters, and ketones (Maddah 2016). Polyvinyl chloride (PVC) is the thermoplastic material that is most frequently employed in the production of toys on a global scale, with an annual demand of 35 million tonnes. PVC is a durable and cost-effective material that can be utilised for an extended period (Sadat-Shojai et al 2011). Cigarette waste is a semi-synthetic polymer that is frequently referred to as cellulose acetate. Cellulose acetate polymers are employed in a variety of products, such as cigarette filters, plastic films, and textiles (Puls et al 2011).

Tourist beach areas have a high amount of mesoplastics, which may be due to the crowds of visitors. Additionally, it has been found that around 40% of the waste found on beaches is actually associated with residential garbage (Jangga et al 2021). In addition, currents directly affect the abundance of mesoplastics on the beach surface because the smaller the particle size of the debris, the easier it is carried by currents (Bagaskara et al 2020). Jangga et al (2021) found that in the Malacca Regency, Indonesia, 76% of the total amount of marine litter was plastic waste. The various types of plastic waste found in the research location are types that are usually used in everyday life, such as bags, beverage bottles, food wrappers, raffia ropes, nylon ropes, straws, and other hard plastics. Kusumawati et al (2018) said that plastic waste is a type of waste that easily floats and is carried away by currents. Therefore this is also conveyed by NOAA (2015) that in research on marine debris in all waters of the world, plastic waste is the most common type and harmful to marine organisms.

Conclusions. Based on the study's results, it shows that the density and composition of plastic waste in Teluk Penyu, Cilacap is dominated by general disposable plastic waste due to waste from tourists or other beach activities. More specifically, of the 17 types of plastic waste found, at the macroplastic size, the PL04 and PL07 types dominate with similar density values of 12.24 items m^{-2}. When viewed from the percentage of weight and amount, the PL07 type has a directly proportional value of 25%. At the mesoplastic size dominated by PL01 and PL08 with density values of 0.68 and 0.44 items m^{-2}, when viewed from the percentage of weight, PL01 has a value of 19% and PL08 has a value of 14%, and the percentage of the amount in PL01 and PL08 is 15% and 14%.

There is also a need for awareness from the community around the beach or tourists to pay more attention to the plastic waste generated by them. Promoting

environmental awareness through several programs carried out by the government or the community is also essential to deal with plastic waste pollution like this. There needs to be an institutional role to strengthen regulations and public awareness of environmental pollution so that waste solutions can be prevented and handled together. Enviromentally responsible behavior also need to be promoted among coastal tourists.

Acknowledgements. The authors would like to thank the Pusat Studi Biosains Maritim (PSBM), Lembaga Penelitian dan Pengabdian Masyarakat Universitas Jenderal Soedirman and Stasiun Pengawasan Sumber Daya Kelautan dan Perikanan (PSDKP), Cilacap for their support of this research.

Conflict of interest. The authors declare that there is no conflict of interest.

References

Abelouah M. R., Ben-Haddad M., Alla A. A., Rangel-Buitrago N., 2021 Marine litter in the central Atlantic coast of Morocco. Ocean and Coastal Management 214:105940.

Atmanti H. D., Purwanti E. Y., 2021 The impact of waste on domestic tourist visits to Pengaradan beach, Banten Province. International Journal of Economics, Business and Accounting Research (IJEBAR) Peer Reviewed 5(2):399-406.

Bagaskara I. G. D., Suteja Y., Hendrawan I. G., 2020 [Modeling the movement of microplastics in the Bal Strait]. Journal of Marine and Aquatic Sciences 6(2):205-215. [in Indonesian]

Chubarenko I., Esiukova E., Khatmullina L., Lobchuk O., Grave A., Kileso A., Haseler M., 2020 From macro to micro, from patchy to uniform: analyzing plastic contamination along and across a sandy tide-less coast. Marine Pollution Bulletin 156:111198.

Cordova M. R., 2017 Pencemaran plastic di laut. Oseana 42(3):21-30. [in Indonesian]

da Silva M. L., Castro R. O., Sales A. S., de Araújo F. V., 2018 Marine debris on beaches of Arraial do Cabo, RJ, Brazil: an important coastal tourist destination. Marine Pollution Bulletin 130:153-158.

Damayanti A. A., Larasati C. E., Amir S., Setyono B. D. H., Lestari D. P., 2022 [Characteristics of meso-sized marine debris in tourist destinations on the west coast of Mataram city]. Jurnal Sains Teknologi dan Lingkungan 8(1):38-47. [in Indonesian]

Djaguna A., Pelle W. E., Schaduw J. N., Manengkey H. W., Rumampuk N. D., Ngangi E. L. A., 2019 [Identification of marine debris on Tongkaina and Talawaan Bajo Beach]. Jurnal Pesisir dan Laut Tropis 7(3):174-183. [in Indonesian]

Dowarah K., Devipriya S. P., 2019 Microplastic prevalence in the beaches of Puducherry, India and its correlation with fishing and tourism/recreational activities. Marine Pollution Bulletin 148:123-133.

Ellen MacArthur Foundation, 2017 The new plastics economy: rethinking the future of plastics and catalysing action. Ellen MacArthur Foundation, 68 pp.

Frigione M., Marini G., Pinna M., 2021 A thermal analysis-based approach to identify different waste macroplastics in beach litter: the case study of Aquatina di Frigole NATURA 2000 site (IT9150003, Italy). Sustainability 13(6):3186.

Garcés-Ordóñez O., Espinosa Díaz L. F., Pereira Cardoso R., Costa Muniz M., 2020 The impact of tourism on marine litter pollution on Santa Marta beaches, Colombian Caribbean. Marine Pollution Bulletin 160:111558.

Hayati Y., Adrianto L., Krisanti M., Pranowo W. S., Kurniawan F., 2020 Magnitudes and tourist perception of marine debris on small tourism island: assessment of Tidung Island, Jakarta, Indonesia. Marine Pollution Bulletin 158:111393.

Jambeck J. R., Geyer R., Wilcox C., Siegler T. R., Perryman M., Andrady A., Narayan R., Law K. L., 2015 Plastic waste inputs from land into the ocean. Science 347(6223): 768-771.

Jangga R. A. Q., Tallo I., Toruan L. N. L., 2021 [Composition of marine debris on the coast of Malaka district, East Nusa Tenggara Province]. Jurnal Ilmiah Bahari Papadak 2(2):22-30. [in Indonesian]

Jeyasanta K. I., Sathish N., Patterson J., Edward J. K. P., 2020 Macro-, meso- and microplastic debris in the beaches of Tuticorin district, Southeast coast of India. Marine Pollution Bulletin 154:111055.
Kepemudaan D., Olahraga, Pariwisata, 2021 [Central Java tourism statistics book in 2021]. 74 pp. [in Indonesian]
KLHK, 2020 [Guidelines for monitoring marine debris]. Direktorat Pengendalian Pencemaran dan Kerusakan Pesisir dan Laut, Direktorat Jenderal Pengendalian Pencemaran dan Kerusan Lingkungan, Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia, 86 pp. [in Indonesian]
Kusumawati I., Setyowati M., Salena I. Y., 2018 [Composition identification of the marine debris in the coastal of West Aceh]. Jurnal Perikanan Tropis 5(1):59-69. [in Indonesian]
Lasaliesanti P., 2019 [Implementation of the Bali Beach Clean Up program as Corporate Social Responsibility (CSR) by the Coca-Cola Amatil Indonesia Company at Kuta Bal Beach]. Jurnal Ilmiah Administrasi Negara 4(1):5-8. [in Indonesian]
Maddah H. A., 2016 Polypropylene as a promising plastic: a review. American Journal of Polymer Science 6(1):1-11.
Maione C., 2021 Quantifying plastics waste accumulations on coastal tourism sites in Zanzibar, Tanzania. Marine Pollution Bulletin 168:112418.
Ningsih N. W., Putra A., Anggara M. R., Suriadin H., 2020 [Identification of marine debris based on type and mass in the waters of Lae-Lae Island, Makassar City]. Jurnal Pengelolaan Perikanan Tropis 4(2):10-18. [in Indonesian]
NOAA, 2015 A learning guide on marine debris turning the tide on trash floating marine debris in Hawaii. Available at: https://marinedebris.noaa.gov/curricula/turning-tide-trash. Accessed: March, 2023.
Olivatto G. P., Martins M. C. T., Montagner C. C., Henry T. B., Carreira R. S., 2019 Microplastic contamination in surface waters in Guanabara Bay, Rio de Janeiro, Brazil. Marine Pollution Bulletin 139:157-162.
Pamungkas, 2019 [Turtle Bay's rubbish problem is not over]. Radar Banyumas. Available at: https://radarbanyumas.co.id. Accessed: March, 2023. [in Indonesian]
Puls J., Wilson S. A., Hölter D., 2011 Degradation of cellulose acetate-based materials: a review. Journal of Polymers and the Environment 19(1):152-165.
Rakib M. R. J., Ertaş A., Walker T. R., Rule M. J., Khandaker M. U., Idris A. M., 2022 Macro marine litter survey of sandy beaches along the Cox’s Bazar Coast of Bay of Bengal, Bangladesh: land-based sources of solid litter pollution. Marine Pollution Bulletin 174:113246.
Retama I., Jonathan M. P., Shruti V. C., Velumani S., Sarkar S. K., Roy P. D., Rodríguez-Espinosa P. F., 2016 Microplastics in tourist beaches of Huatulco Bay, Pacific coast of southern Mexico. Marine Pollution Bulletin 113(1-2):530-535.
Sadat-Shojai M., Bakhshandeh G. R., 2011 Recycling of PVC wastes. Polymer Degradation and Stability 96(4):404-415.
Sahami F. M., Cempaka S., Khair Kadim M., 2020 [Composition and density of waste at North Leato Beach, Gorontalo city]. Journal of Fisheries and Marine Research 4(3): 352-356. [in Indonesian]
SCBD, STAP-GEF [Secretariat of the Convention on Biological Diversity, Scientific and Technical Advisory Panel-GEF], 2012 Impacts of marine debris on biodiversity: current status and potential solutions. Secretariat of the Convention on Biological Diversity, CBD Technical Series No. 67, 61 pp.
Schaduw J. N. W., Bachmid F., Ronoko S., Legi K., Oroh D., Gedoan V., Kainde H. V. F., Pantouw T., Tungka A., 2021 [Characteristics of marine debris in Malalayang coastal area, Manado City, North Sulawesi Province]. Jurnal Ilmiah PLATAX 9(1):89-99. [in Indonesian]
Surono U. B., Ismanto, 2016 [Processing PP, PET and PE plastic waste into fuel oil and its characteristics]. Jurnal Mekanika dan Sistem Termal 1(1): 32-37. [in Indonesian]
Syakti A. D., Bouhroum R., Hidayati N. V., Koenawan C. J., Boulkamh A., Sulistyo I., Lebarillier S., Akhlus S., Doumenq P., Wong-Wah-Chung P., 2017 Beach macro-litter monitoring and floating microplastic in a coastal area of Indonesia. Marine Pollution Bulletin 122(1-2):217-225.

Teuten E. L., Saquing J. M., Knappe D. R. U., Barlaz M. A., Jonsson S., Björn A., Rowland S. J., et al, 2009 Transport and release of chemicals from plastics to the environment and to wildlife. Philosophical Transactions of the Royal Society B: Biological Sciences 364(1526):2027-2045.
Van Cauwenberghe L., Claessens M., Vandegehuchte M. B., Mees J., Janssen C. R., 2013 Assessment of marine debris on the Belgian continental shelf. Marine Pollution Bulletin 73(1):161-169.
Welden N. A., 2020 The environmental impacts of plastic pollution. In: Plastic waste and recycling. Letcher T. M. (ed), Academic Press, pp. 195-222.
Williams A. T., Rangel-Buitrago N. G., Anfuso G., Cervantes O., Botero C. M., 2016 Litter impacts on scenery and tourism on the Colombian north Caribbean coast. Tourism Management 55:209-224.
Zhukov A., 2017 The distribution, abundance and characteristics of plastic debris along the Coast of Grândola. Thesis, Degree Programme in Sustainable Coastal Management, Novia, University of Applied Sciences, 64 pp.

Received: 05 March 2024. Accepted: 06 May 2024. Published online: 28 July 2024.
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How to cite this article:
Hidayati N. V., Lukmanulhakim R. C., Meinita M. D. N., Hidayat R. R., Sari L. K., Husni I. A., Hendrayana, Putranto Y., Sakti G. M., Illahi N. M., Nafisah S. A., 2024 Density and composition of macro- and meso-plastic in Teluk Penyu coast, Cilacap. AACL Bioflux 17(4):1499-1509.