Size and Types Distribution of Marine Debris in the Mangrove Ecosystem of Bintan Island - Indonesia

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Abstract. Identifying macroscopic to microscopic marine debris needs to be done to mitigate environmental damage and pollution, especially in the mangrove area, an area affected by tides. This study aims to identify macroscopic and microscopic marine debris in sediments and associated biota (gastropods) in the Mangrove Area on Bintan Island and Tanjungpinang City. The sampling location was determined using the purposive sampling method in the mangrove ecosystem area close to the settlement i.e. Kampung Bugis, Senggarang, Dompak, Tembeling, Penaga, Busung, and Pengudang Villages. Macroscopic waste was taken in the Mangrove Area with a 10x10 m transect and five subplots 1x1 m. Sediment and gastropod samples were taken from each plot and transect and then brought to the laboratory to analyze their microplastic content. The results showed macro-sized marine debris such as plastic, plastic foam, glass, ceramics, cloth, metal, rubber, wood, paper, cardboard and other materials were predominant respectively. Meso-size debris found were plastic, plastic foam, cloth, metal, paper, cardboard and rubber. Microplastics were detected with different shape including fragments, fibers and films in sediments and in form of pellets in gastropods digestive track. These results confirmed marine debris apportionment occurrence in the sediments and in the associated biota in the mangrove ecosystem on Bintan Island.

Keywords: Marine debris · Microplastics · Mangroves · Bintan

1 Introduction

Marine Debris is a persistent solid material originating from activities on land or sea left in the marine environment that can affect water quality. The other problems that arise from marine debris are coastal areas becoming unpretentious, causing disease, affecting water productivity, reducing fish resources and affecting the balance of ecosystems in

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coastal areas. Marine debris was found in various sizes categorized into mega-debris (>1 m), macro-debris (1 m to 2.6 cm), and meso-debris (2.5 cm to 5 mm) as well as the micro-plastic (< 5 mm) [1]. The size of plastic waste determines the magnitude of the impact caused when it enters the environment. The process of plastic degradation into microplastics has been reported to take years, both physically, chemically and biologically [2]. Distributing marine debris in coastal areas is strongly influenced by the movement of currents that can carry waste in waters over long distances [3]. The marine debris that dominates is plastic, estimated at 60%–80% in the ocean [4]. The world's plastic production increased significantly from 204 Mton in 2002 to 299 Mton in 2013 [5] and 322 million tons in 2015, and it is predicted that the number will increase 100 times in 2050 [6].

This study pays attention to the microplastic occurrence. Microplastics are a group of plastics with sizes of less than 5 mm [7] and have variations in composition, colour, size, shape, density, and other properties. Microplastics have been distributed in open oceans such as the southern seas near Antarctica, the seas of East Asia and the Pacific and coastal waters due to the input of plastic waste that has undergone fragmentation into microplastics [8]. In Indonesian territorial waters, such as the territorial waters of the Riau and Cilacap islands, microplastic contamination with different sizes, types, and shapes has been detected [9]. Bintan Island has been contaminated with microplastics, with an average number of 122.8 $\pm$ 67.8 particles/station from 11 coastal stations around Bintan Island [10]. Microplastics can accumulate in high amounts in seawater and sediments [11]. The wide distribution of microplastics, high density in waters [12], size [13], and colours that resemble their food (white, light brown and yellow) has the potential for consumption by marine organisms, both invertebrates and fish [14]. The microplastic content in barking snails in Bintan waters was found to reach 1,136 particles/kg [15].

Coastal areas are areas that have the potential to be affected by environmental pollution. One of the main ecosystems in coastal areas is the mangrove ecosystem [16]. This area is dynamic and is influenced by tides, so the presence of plastic waste will be scattered throughout the mangrove forest area and trapped in the sediment. If the accumulation of debris occurs continuously, it will cause environmental pollution and a decrease in the aesthetic value of mangrove forests. Mangrove forests have the potential to be used as tourism areas, indeed. Microplastics such as films, fibers, fragments and pellets were found in natural mangrove forest areas and former ponds [17]. Another threat is the microplastic contamination of associated biota in mangrove forests; one of them is gastropods [18]. Gastropods live on the bottom of the water, so they can be a bioindicator of sea pollution [19]. Gastropods cannot distinguish their food, so they are very susceptible to the ingestion of microplastics [20]. Microplastics that accumulate in large quantities can affect biota's digestive tract, growth, secretory and reproductive systems [21]. This study aims to identify macroscopic and microscopic marine debris in sediments and associated biota (Gastropods) in the Mangrove Area on Bintan Island and Tanjungpinang City.

The mangrove ecosystem is one of the ecosystems in coastal areas, which is classified as the most productive in the world with high biodiversity [22] and is economically influential as a tourism object and raw material for a product. Therefore, this research can be a strategic step in ecosystem management and become a reference for making

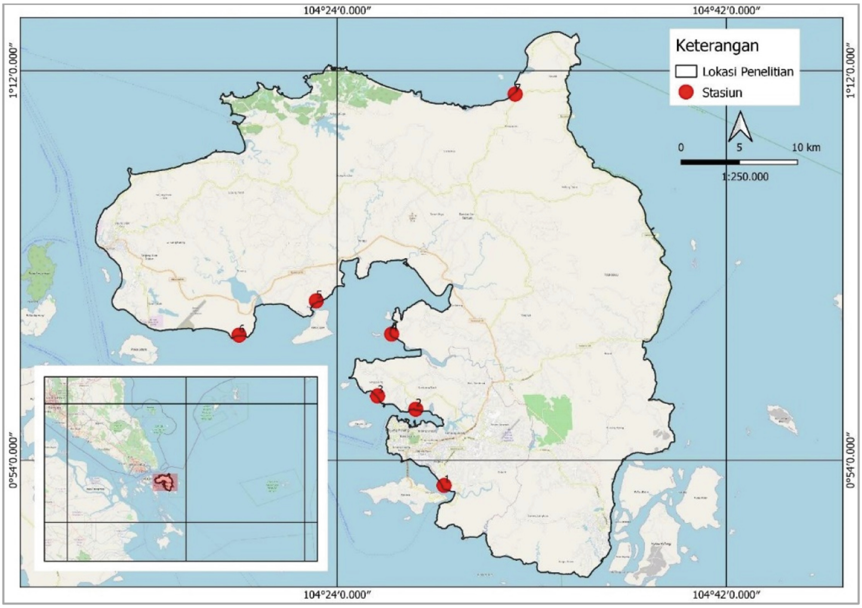


Fig. 1. Research Location Map

a policy in dealing with the problem of marine waste pollution in mangrove areas. In addition, this research also held to support a green economy by increasing coastal communities' welfare and social equality through tourism activities while reducing the risk of environmental damage to the Bintan coast due to these activities.

2 Materials and Methods

2.1 Research Sites

The research was carried out from October 2021 – December 2021, covering the preparation, implementation/sampling stages, sample analysis in the laboratory and data analysis. Sampling was carried out in the waters of Bintan Island and Tanjungpinang City, consisting of 7 stations Senggarang Village, Bugis Village, Dompak Village, Penaga Village, Busung Village, Tembeling Village, and Pengudang Village. The map of the research location is presented in Fig. 1.

2.2 Sampling Procedures

Sampling was carried out at 4 locations of mangrove areas on Bintan Island and 3 locations in Tanjungpinang City. Each study site installed three transects with a total length of 100 m. The research transect was made with a size of 10x10 m, and there were five plots in it with a size of 1x1 m [23]. Each plot identified the type and weight of waste with macro and meso sizes. Sediment samples were taken from the research plot, and the gastropod samples encountered in the plot were taken ten tails or the maximum number of each species found. Then the sample is stored in a sample container, put in an ice box and brought to the laboratory to be analyzed for its microplastic content.

2.3 Extraction and Analysis of Microplastics in Sediment

Sediment samples taken in the field are dried on aluminium foil for 24 h in the sun to obtain the dry weight of the sample. Then the dry sediment sample was weighed as much as 100 g using a digital scale with an accuracy of 0.01 g and put into a sample bottle. 50 ml of 3% H_2O_2 was added to the sediment sample and baked at 90 °C for ± 4 h or until the sediment sample was dry. $ZnCl_2$ solution (1 M) (d = 136 g/ml) was added as much as 100 ml in the sediment sample that had been oven-dried and left for one day. When the sediment floated on the surface, floating particles were transferred to the millipore paper with a dropper. Then, the millipore paper was put into the vacuum pump so the remaining water in the millipore paper was dry. After that, identify the particles on the filter paper under an electric microscope. Plastic particles were classified and counted based on the shape and colour categories (fragment, fiber, film, pellet, foam).

2.4 Analysis of Microplastics in Associated Biota (Gastropods)

Identification is made by dissecting the biota to obtain the digestive tract. The digestive tract was weighed, and H_2O_2 was added to separate the sample from other materials [24]. Samples were oven-baked for 6 h at 50 °C with one repetition to eliminate organic residues adhering to the sample. $ZnCl_2$ was added so that the microplastics floated on the surface. The solution on the surface was taken and filtered using 0.45 m filter paper. Microplastics were identified to see types based on shape [25] and colour.

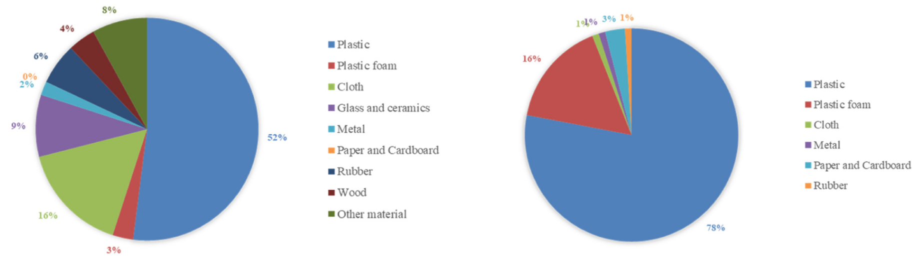
2.5 Data Analysis

The analysis of microplastic abundance was carried out using Microsoft Excel software [10], and the number of microplastics is displayed based on shape, colour and size.

3 Results and Discussion

3.1 Macro-meso Debris in the Mangrove Forest Area

Macro waste was obtained through sampling in the mangrove area by line transect. Macro waste is waste with a size of 2.5 cm – 1 m. The types of macro-sized waste were found: plastic, plastic foam, glass and ceramics, cloth, metal, rubber, wood, paper, cardboard and other materials, with a total waste of 1,179. The types of meso-sized waste were found in plastic, plastic foam, cloth, metal, paper, cardboard and rubber, with 139 particles of waste. The density of macro waste is dominated by plastic waste, with a weight of 498.67 g/m^2 (52% of the total waste), and meso, with a weight of 2.17 g/m^2 (78% of the total waste) (Fig. 2). The high plastic waste is suspected because plastic waste has a light density, is often used and is easily caught in the mangrove roots [26].



a) b)

Fig. 2. Waste Density a) Macro-size; b) Meso-size

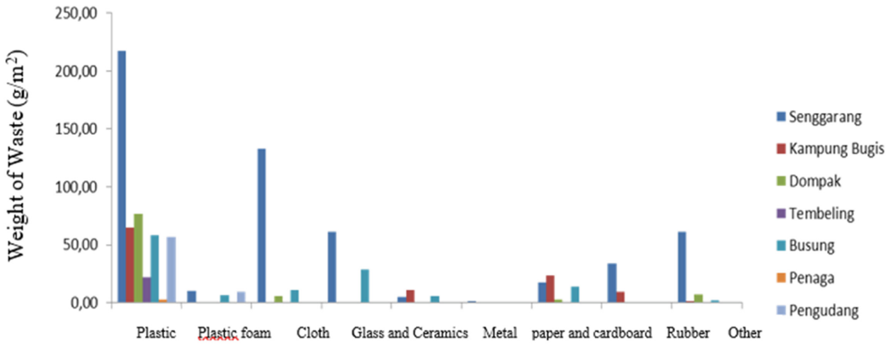
Plastic has versatile, lightweight, strong, durable and inexpensive properties, so plastic is used in every aspect of life [27]. The plastic waste floats easily, is durable and can accumulate in mangrove roots. Furthermore, the marine debris from the plastic-type has the highest composition and density value compared to marine debris from other types [28], with a composition value below 5% and a density value below 1 item/m2. The highest waste density was found at the Senggarang Village location, with a density of 540.23 gr/m2 macro size and 2.67 gr/m^2 meso size. Meanwhile, the location with the lowest waste value was Penaga Village, with a density of 2.80 gr/m^2. While, meso size waste was not found at the Tembeling Village, Busung Village, Penaga Village, and Pengudang Village (Fig. 3).

The high marine debris found in the mangrove ecosystem in Senggarang Village is thought to be due to the location close to settlements where community activities that produce anthropogenic that are dumped into the sea and can return to land are stuck in mangrove tree trunks. The high marine debris is caused by many people throwing garbage into the sea, so waste on the beach is carried away by seawater at high tide and will return from the sea to the coastal area [29].

3.2 Types of Microplastics in Sediments and Gastropods

Plastic waste will undergo degradation and other physical processes, called microplastics, into smaller fragments less than 5 mm. Sediment and gastropod samples were taken to determine their microplastic content. The results showed that microplastics in sediments were found 4509.97 particles/gr consisting of three types of microplastics, namely fragments, fibers and films (Figs. 4 and 5).

Fragmented microplastic is the dominant microplastic in sediment with a total density of 2501 particles/gr, followed by film with a total density of 1932.77 particles/gr and fiber with a total density of 76.2 particles/gr (Fig. 6a). Regarding the assessment of microplastic size sampling in Bintan island, microplastics in fragments, fibers, and films were the three most common forms of microplastics [10]. This is in line with the results which found fragments, fibers and films as the most common forms of microplastics. In comparison, the gastropods found 954.2 particles/gr consisting of four microplastics types: fragments, fibers, films and pellets (Fig. 6b).



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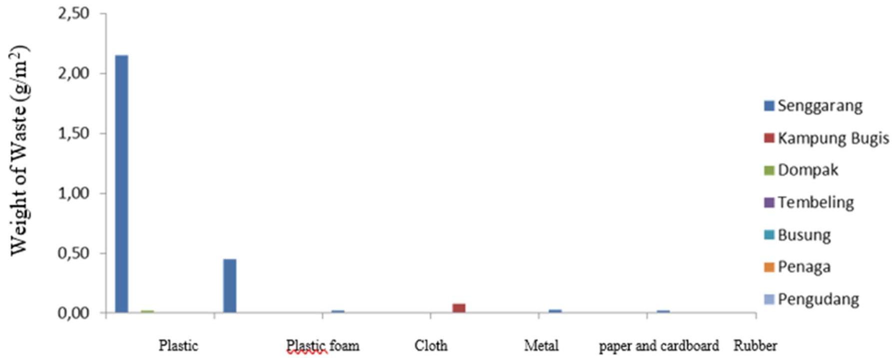
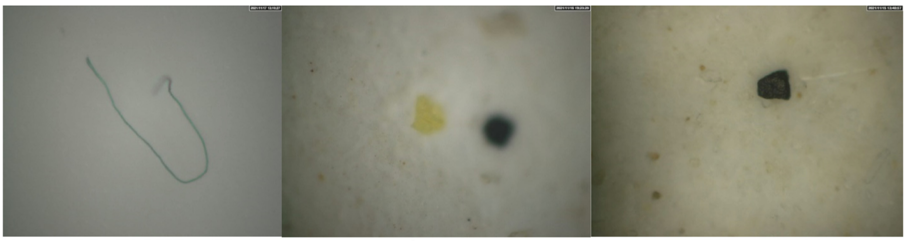


b)

Fig. 3. Waste Density a) Macro-size; b) Meso-size of Each Research Location



a b c

Fig. 4. a) Fiber; b) Film and c) Fragments in Sediment

The dominating microplastic in gastropods was found from the fragment with a total density of 385.67 particles/gr, film type 344.2 particles/gr, pellet type 186 particles/gr and fiber 38.33 particles/gr (Fig. 6b). The discovery of pellets in gastropods is thought to be because the pellet size can be accumulated in the gastropod's body [30]. Pellets

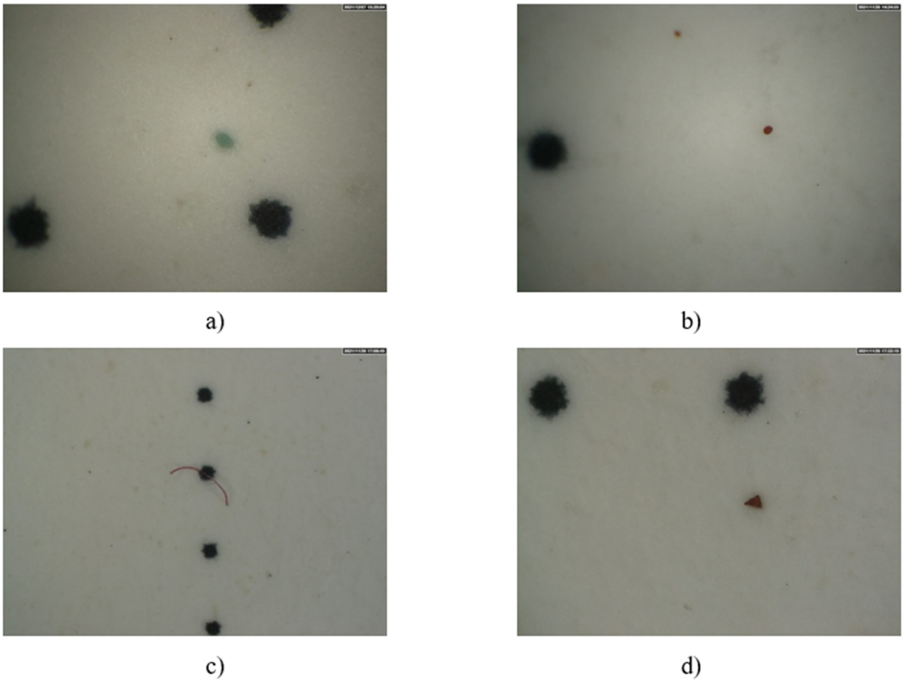
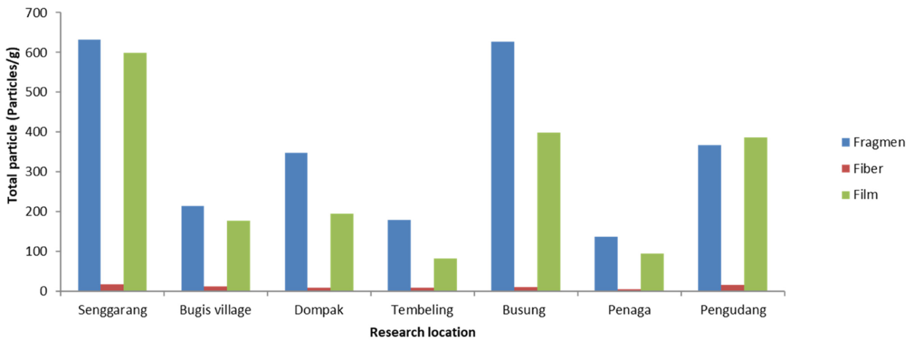


Fig. 5. a) Film; b) Pellets; c) Fiber and d) Fragments in Biota

have a round shape and a smooth surface and are part of the raw material for the plastic industry [29]. The accumulation of microplastics in sediments can harm marine life and humans [21]. For marine biota, microplastics can have an impact if they accumulate in the body by disturbing a growth system, inhibiting enzyme production, decreasing hormone function and reducing the effectiveness of the reproductive system.

Plastic waste is a type of marine debris that dominates each observation location, both macro and meso sizes. Meanwhile, the fragment is the dominant microplastic were found in each location. This is presumably because the fragment is a type of microplastic sourced from large pieces of plastic waste. Secondary source of microplastic is fragments which come from the breakdown of larger plastic items [31] and the main sources that cause microplastics contamination in the marine environment [32].

Microplastics in fragments are often found because they come from domestic waste in broken plastic bags that are rigid, such as used drink bottles, the remains of discarded jars, and small pieces of paralon pipes scattered in the coastal area from the research location. This waste can be carried away by currents and degraded into small pieces to form fragments that settle in the sediment. Some factors influence the highest number of microplastics in fragments in the sediment, i.e. the high plastic waste used by the community due to tourism and household activities such as using plastic bottles, mica packaging, and other objects [30].



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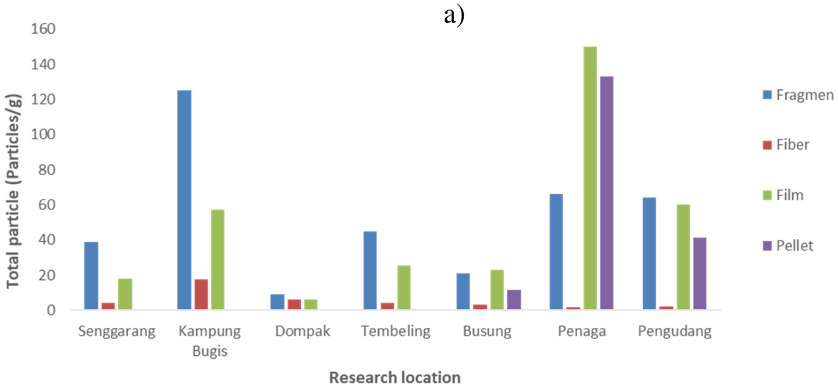


b)

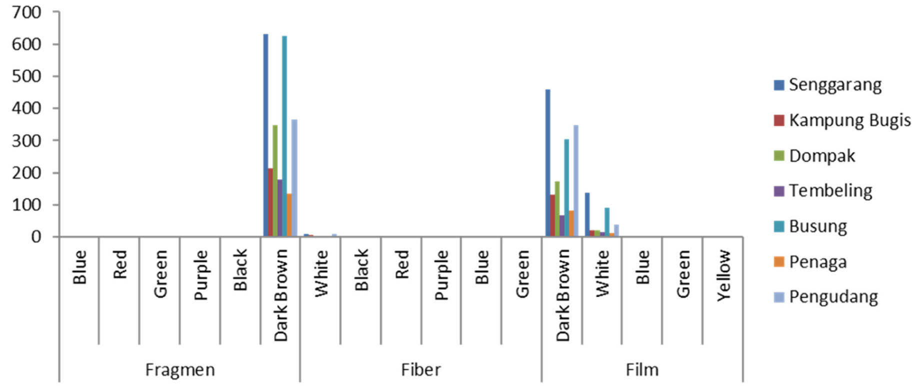
Fig. 6. Types of Microplastics a) In Sediments and b) In Gastropods

3.3 Characteristics of Microplastics in Sediments and Gastropods

Environmental and climatic conditions influence the colour of microplastics. The fragment microplastic was found in sediments with black, dark brown, red, purple, green and blue colours. The fiber is black, white, red, purple, green and blue colours. The film is brown, white, blue, green and yellow (Fig. 7).

The graph shows the dominant colour of microplastics in sediments and gastropods is dark brown with a density of 2497.9 particles/gram sediment and 226 particles/gram gastropods. The brown colour indicates contamination with oil particles around the waters and is sourced from recycled plastic. The brown plastic is made from petroleum and is LDPE (Low-Density Polyethylene) [23]. The results of the research showed that the dominant waste found on Bintan Island is Low-density polyethylene (LDPE), Polypropylene (PP) and Polystyrene (PS) [33].

The results indicated that there was an abundance of macro debris and microplastic content in the mangrove ecosystem. These two things are thought to be related to each other, and also have an impact on the food chain, so their contents are also found in the bodies of associated biota such as gastropods. As well known, the mangrove ecosystem and its associated biota have a role in increasing the economic value of a region either



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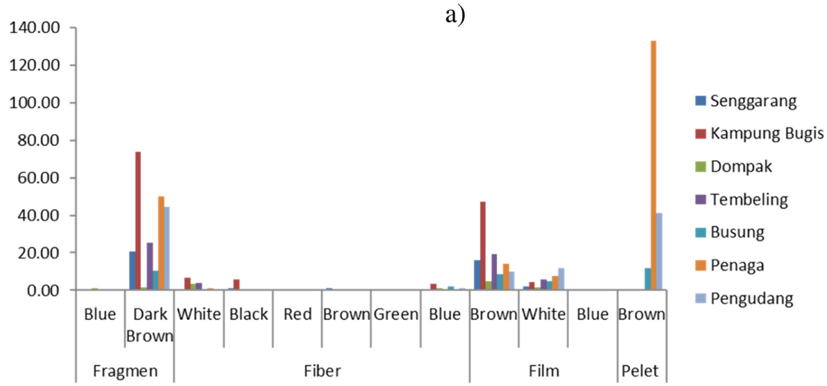

b)

Fig. 7. Colours Characteristic of Microplastics a) In Sediments and b) In Gastropods

as a provider of food raw materials or for tourism activities. It is hoped that the identification of marine debris that has been carried out can be used as basic information for disaster mitigation so that economic growth that comes from the utilization of mangrove ecosystems does not produce a large impact on the environment and supports the concept of the green economy itself.

4 Conclusion

The marine debris on the coast of Tanjungpinang city and Bintan districts has macro, meso and micro sizes. Plastic waste is each research location's most common macro and meso waste. Microplastic in the sediment was found at 1032.86 particles/gr consisting of 3 types of fragments, fiber and film. Microplastic in gastropods found at 954.32 particles/gr consists of 4 types of fragments, fiber, film and pellet. Dark brown was the most common microplastic colour found at the research location. This research can be a strategic step in ecosystem management to mitigate environmental pollution and make brief police for the problem of marine waste pollution in mangrove areas. This research hope can also support a green economy by increasing coastal communities' welfare and social equality through tourism activities in coastal and mangrove areas and reducing the risk of environmental damage on Bintan island.

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