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Research Article

Relationship between Characteristics of Marine Debris and How it Impacts to Coral Reef at three Islands in DKI Jakarta, Indonesia

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Abstract

A coral reef is one of the important ecosystems, however, the existence of coral a coral reef is one of the important ecosystems, however, the existence of coral reef is threatened. Several factors can be a threat to the coral reef, such as marine debris. Research about marine debris on coral reefs in Indonesia has not much been done. This research aims to identify marine debris that is found and impacted, to identify the impacts caused, and to identify the life forms most susceptible to being affected. This research was conducted in Kelapa Island, Kelapa Dua Island, and Harapan Island by using the Belt Transect method sized 20 x 4 m^2 with four repetitions at each station to determine coral reef life form, and type of marine debris. The data was analyzed by using the Correspondence Analysis (CA) to determine the correlation of marine debris and the affected life forms of coral reefs. The result showed the plastic marine debris was found in all stations. Six life forms were affected by marine debris, and the most susceptible life forms that affected were massive and branching. The most dominant impact category on coral reefs was tissue loss with algal growth (TLAG)

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1. Introduction

A coral reef is the one of important ecosystems in the sea, particularly in tropical waters. Coral reefs have many functions such as spawning ground, feeding ground, nursery ground for fish which is symbiosis with coral reef, and other biota that uses coral reefs as a place to protect, and breed. In addition, the coral reef can also function as a barrier to coastal abrasion due to wave impact. The existence of coral reef is highly threatened due to several factors such as climate change, destructive fishing, and pollution.

Indonesia is one of the highest diverse coral reefs in the world which belongs to the coral triangle. However, the threat to coral reefs in this area is very high, more than 85% at a threatened condition, and more than 45% at high risk of destruction due to human activities (Burke *et al.*, 2012). One of the big threats to coral reefs is pollution. There are types of pollution that can disrupt, and cause damage to coral reefs, for instance, is marine debris.

Marine debris generally can be defined as a sol- id material that entering the sea by being discarded or entering from the mainland through the river (Galgani *et al.*, 2010) reported for two descriptors (contaminants in fish and other seafood, and marine debris). Indonesia has become the largest pollutant source in the world which is ranked 2 after China (Jambeck *et al.*, 2015). One type of marine debris that is often found is plastic. According to the research by Cordova and Nurhati (2019) shows that marine debris entering the sea area from the mainland is dominated by plastic, which is 59% of the total marine debris found in this study. Currently, there are research related to marine debris still focuses on plastic pollutants, whereas marine debris can come from a variety of pollutant sources. In relation to the natural resources in Indonesia, it can be a threat to the preservation of coastal and marine ecosystem in Indonesia, including coral reefs.

The study of marine debris shows the rubbish that becomes a marine debris entering to seawater which is collected in the surface seawater can sink to the bottom, and spread with physically process such as waves and currents (Coe and Rogers, 1997; Law, 2016). The threat of marine debris can affect almost all biota in the sea. Recent study reported biota can be entangled, injured, or even accidentally ingested by organisms which can be harmful to the digestive system (de Carvalho-Souza *et al.*, 2018; Gall and Thompson, 2015; Sheavly and Register, 2007). Chemicals contained in marine debris such as plastics or rubber can have an impact on all biota, from invertebrates to biota at other trophic levels. In addition plastic debris will also adsorb contaminants, such as metals from water column

(Hankins *et al.*, 2018; Li *et al.*, 2016). Increasing pollutants that entering the waters become one of the environmental pressured causes to organisms, particularly organisms that cannot move to avoid, for example coral reefs (Chiappone *et al.*, 2005)

Coral reefs can be injured by marine debris thus, it can trap or break the reef structure (Figueroa-Pico *et al.*, 2016; Valderrama *et al.*, 2018). Marine debris attached to the coral reef can affect injury on the tissue, so it can be susceptible to disease (Lamb *et al.*, 2016). Coral reefs can lose zooxanthellae which acts as the symbiosis biota that produces nutrition from photo- synthesis, when coral reef is covered by marine debris, the sunlight intensity will be reduced so the zooxanthellae have stress, and go from coral polyps (Fachrurrozie *et al.*, 2012).

Research about marine debris that has a direct impact on coral reefs in Indonesia is rarely found. So, this research aims to identify marine debris that is commonly found, and have a direct impact on coral reefs, to identify the impact arising from marine debris on coral reefs, and to identify the life forms most susceptible to being affected by marine debris. Moreover, this research is expected to be a reference to the impact of marine debris on coral reefs needed in the other related research. Furthermore, this research is also expected to be used as a consideration of the management of coastal, and marine ecosystems that are directly affected by marine debris.

2. Materials and Methods

2.1 Location and Time of Research

Research was conducted at Kelapa Island, Kelapa Dua Island, and Harapan Island, from October 17–19th, 2019. Research stations are spread out around those islands, the research map can be seen in (Figure 1). Research stations are expected to represent the impact of marine debris on coral reef. Observation was carried out for approximately 3-4 days.

2.2 Materials

The equipment used in this research includes basic diving equipment, and Self-Contained Underwater Breathing Apparatus (SCUBA), underwater digital cameras (G12, Canon, Japan), 100 m roll, global positioning system (Garmin GPS 73), refractometer (Master-S28M, Atago, Japan), DO meter (DO-5510, Lutron, USA), and pH meter (Pen Type PH-009-A).

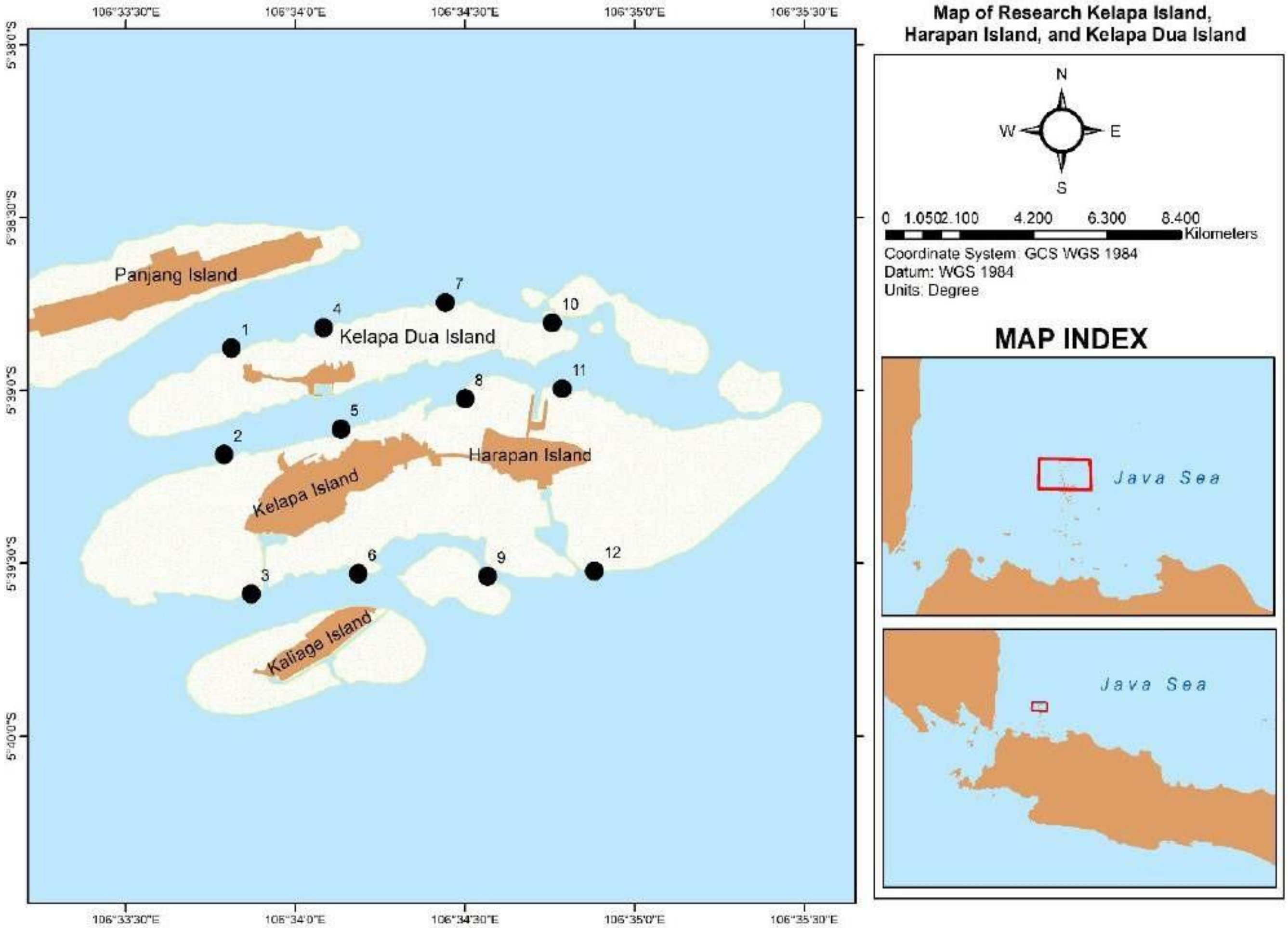

Figure 1. Map of research station at Harapan Island, Kelapa Island, and Kelapa Dua Island

2.3 Field Survey Methods

During the survey, the data was collected for four days, with three divers. The length and width of transect used a 20 m x 4 m, with four repetitions at each data collection stations that is spread out on the edge area with a depth 7-10 m. The belt transect method was implemented to record data. The width and length of the transect used based on a consideration of the amount of marine debris density in an area (Galgani *et al*., 2013; Lippiatt *et al*., 2013). The impact of marine debris on coral reefs is determined into several categories which are Fresh Tissue Loss (FTL), Tissue Loss withAlgal Growth (TLAG), Fragmentation (FR), and No Damage (ND) (Valderrama *et al*., 2018). In the FTL damage category, further elaboration is made according to Raymundo *et al*. (2008) which aims to provide a clearer description of the impact of marine debris on coral reefs. FTL damage category elaboration is divided into three types: covers Focal Tissue Loss, Multi Focal Tissue Loss, and Diffuse Tissue Loss. In addition to record the resulting impacts, the life forms data were applied to determine that life forms can be affected by marine debris.

2.4 Data Analysis

The number of marine debris found was divide into five main categories based on the basic material of manufacture, namely plastic, glass, fabric, metal, and rubber. The data result was analyzed by using the Correspondence Analysis (CA) of XLSTAT 2016 software which aims to determine the correlation of marine debris and the affected life forms of coral reefs. Furthermore, it is found out the life forms of coral reefs affected as well as the impacts, so that the most life forms are known susceptible.

3. Results and Discussion

3.1 Waters Condition

This research was conducted in Kelapa Island, Kelapa Dua Island, and Harapan Island. The research location is one of the islands that has a high population density, and is also a tourist destination. The high number of visitors can be one of the potential changes in water quality (Laapo *et al*., 2009). In addition, this island is not too far from Jakarta Bay, and in the middle of Seribu Islands. Those islands condition have the characteristics of similar water, even though the designation of those islands is quite different. Based on the result, the potential of hydrogen (pH) was approximately 7.7-7.8, the value obtained is quite low but still in the range of seawater quality standards for marine biota. The concentration of Dissolve Oxygen (DO) ranged from 5.6-7.43 mgL^{-1}, with the lowest concentration being in station 3.

The sea surface temperature recorded in this research in the range of 29.53-32.73°C, at station 2 has the highest temperature value compared to other stations. Sea surface temperature tends to be high due to the optimal standard for coral reefs which is 28-30°C. Salinity recorded range is 30.33-32.67‰. The pH and DO values in this research are in the range of standard of seawater quality specified for marine biota (Corvianawatie and Abrar, 2018)(Table 1).

Table 1. The measurement pH, dissolve oxygen (DO), temperature, and salinity parameters

Station	Parameters			
	pH	DO (mg/L)	Temperature (°C)	Salinity (‰)
1	7.70	6.40	30.37	31.67
2	7.73	5.87	32.73	32.00
3	7.80	5.60	30.73	31.17
4	7.70	7.43	30.47	31.83
5	7.87	6.03	31.23	31.50
6	7.83	6.07	31.50	31.33
7	7.80	6.87	29.53	32.33
8	7.83	7.43	30.03	32.67
9	7.83	6.40	30.30	33.00
10	7.83	7.43	30.87	32.00
11	7.83	6.70	31.57	30.33
12	7.83	7.10	31.40	31.67

Table 2. The amount of marine debris found in various life forms

Lifeform	Marine Debris					
	Plastic	Metal	Rubber	Glass	Fabric	Total
Massive	19	0	2	2	0	23
Foliose	6	1	0	1	1	9
encrusting	16	0	1	1	0	18
Branching	22	1	1	1	2	27
Mushroom	3	0	1	0	0	4
Tabulate	1	0	0	0	0	1

Table 3. The number of life forms and impacts that occur

Lifeform	Impact						
	ND	FTL	MTL	DF	TLAG	FR	Total
Massive	3	0	3	4	27	0	37
Foliose	7	2	0	5	7	0	21
Encrusting	4	0	3	4	11	0	22
Branching	8	0	1	0	23	1	33
Mushroom	2	0	0	3	0	0	5
Tabulate	0	0	0	0	1	0	1

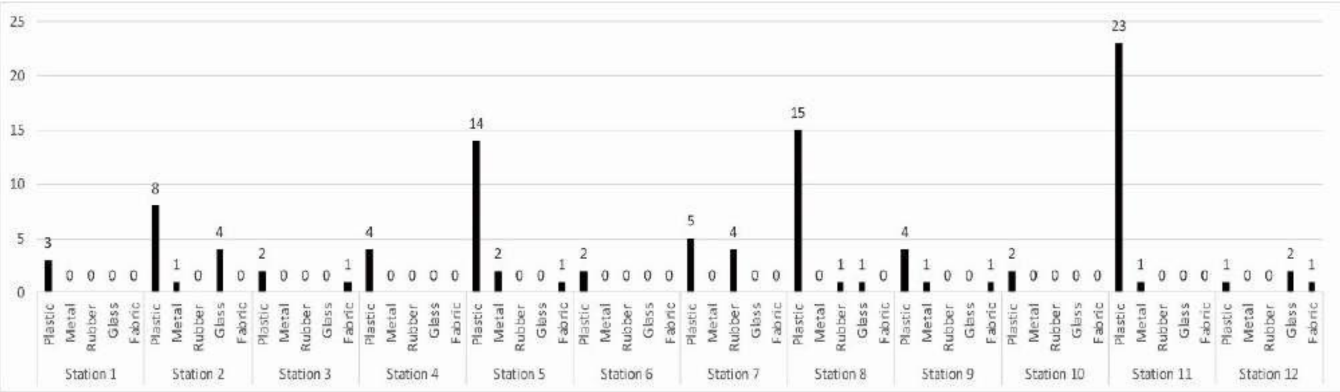

Figure 2. The amount of marine debris found at each station.

The average number of all parameters are still within the tolerance range of water quality standard for marine biota. The temperature shows the results slightly above the optimal range values. On the other hand, basically the condition of the high sea-surface temperature occurs almost evenly throughout the waters. In this research, at station 2 has high temperature values in waters which can threaten coral reefs because it can cause bleaching of coral reefs. Bleaching can occur if the temperature increases between 1-2°C above the average value over a certain period of time (Baker *et al.*, 2008; Cooper *et al.*, 2008).

3.2 Marine Debris Types

The amount of transect area is 3.840 m^2, with 104 marine debris were found at 12 stations. Each marine debris was classified into five main categories: covers plastic, metal, glass, rubber, and fabric. The main categories are used to facilitate the classification of each marine debris, then marine debris was grouped based on the basic material. In addition, marine debris at each station has a weight total of 13.14 kg. Plastics are the most commonly found type of marine debris, with a significant amount compared to other marine debris categories (Figure 2).

The derelict fishing gears, such as fishing lines, and using ropes that are used to tie floating net cages, are the most commonly found plastic category. The number of marine debris originating from fishery activities are far greater if compared with plastic waste originating from onshore activities (Butler *et al*., 2013; Chiappone *et al.*, 2002; Donohue *et al*., 2001).

The other factors are the large human population living close to coastal or rivers, and the lack of public understanding of the harmful effects of marine debris (Niaounakis, 2017). In contrast, commonly found marine debris originates from lack of management related to anthropogenic daily activities (Sheavly and Register, 2007).

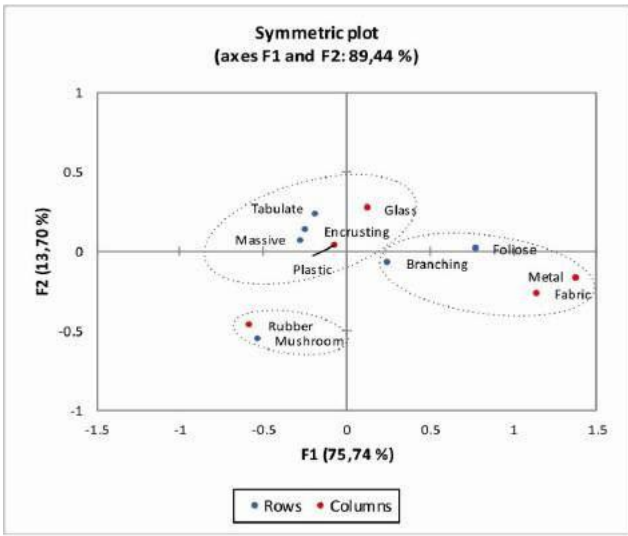

Figure 3. Life forms and marine debris category correspondence analysis chart

3.3 Coral Reefs Affected

In this research found six life forms of coral reef affected by marine debris (Figure 4). Coral reefs are affected or mostly caught up by marine debris that is branching life form. Furthermore, coral reefs with massive life forms are affected by marine debris. The Correspondence Analysis shows there are three groups related to marine debris and life forms (Figure 3). The mushroom life form had a link with marine debris rubber category which was found in the form of tires and rubber sheets. Coral reefs with a mushroom life form have a link with tires or rubber because it is generally found at the bottom of the water where marine debris in the form of a tire is generally located at the bottom of the water due to of its heavy weight. Coral reefs with a mushroom life form generally come from the genus of fungi. These coral reefs live as a single colony which have the ability to move. In other research, coral from genus fungi can move or even invade marine debris, and serve as a place to stay (Hoeksema and de Voogd, 2012; Hoeksema and Hermanto, 2018; Valderrama *et al*., 2018).

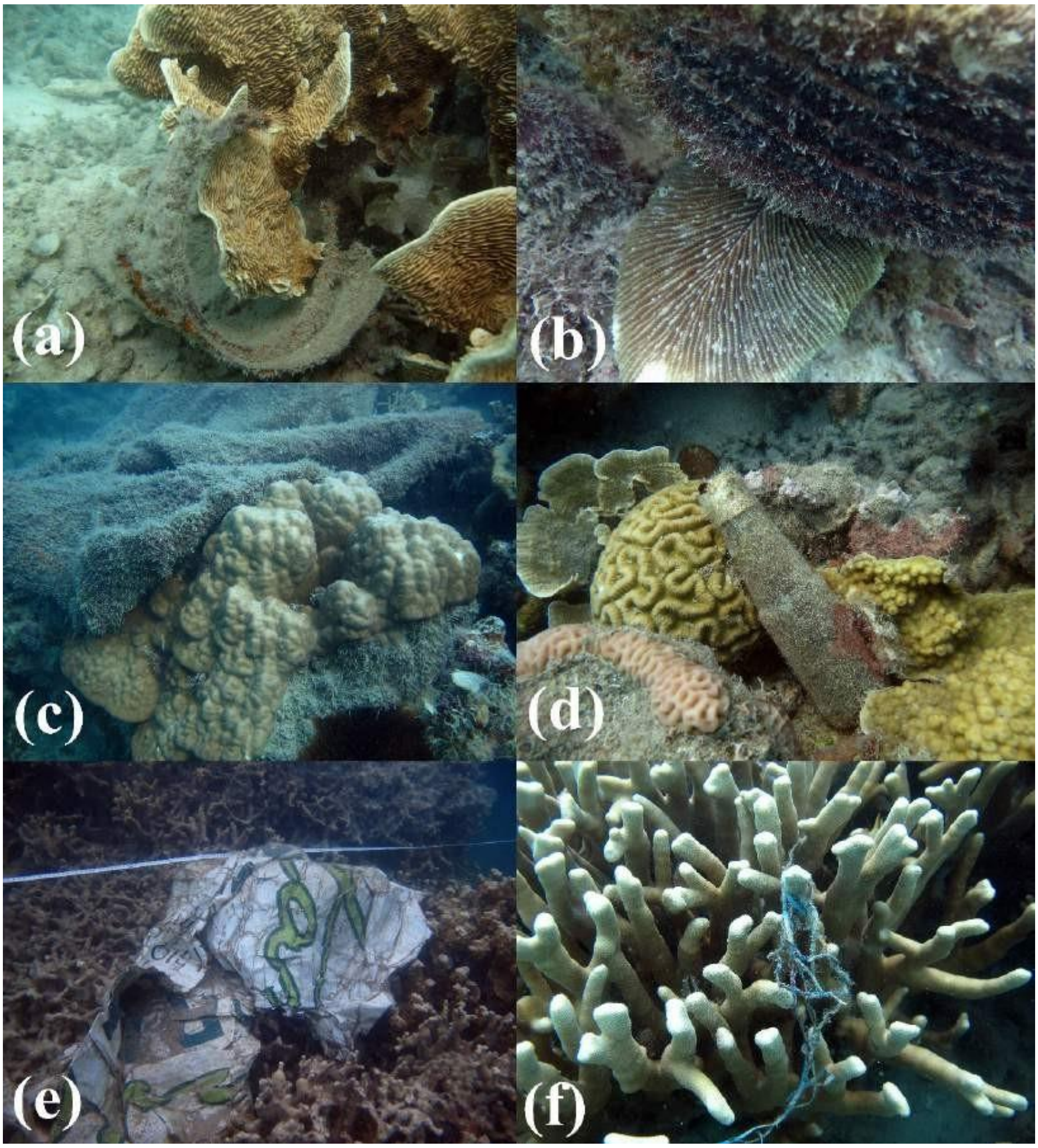

Figure 4. Marine debris caught on life forms coral reefs

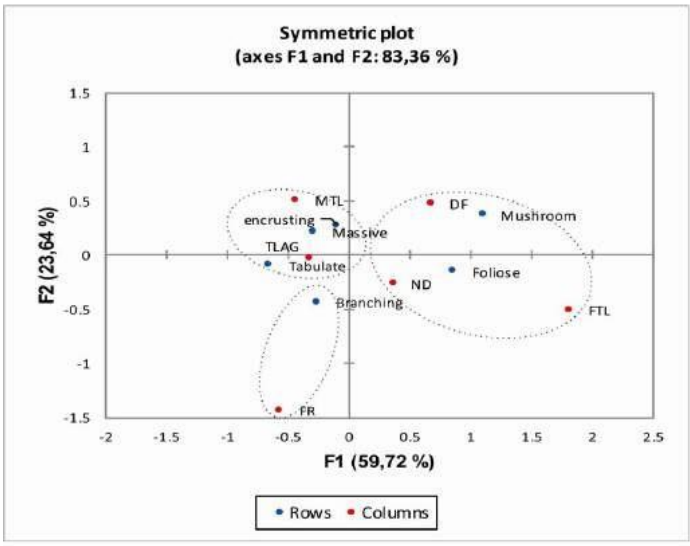

Figure 5. Correspondence analysis chart life forms, and the impact occurred

The distance of the nearest research location from the mainland is quite far, however, the number of marine debris from fishery activities and daily activities are much. There are factors that can be causing the plastic entering into the sea, for instance, less adequate waste treatment.

The next group shows that the metal category is related more to the foliose life form. The metal category has found in the form of cables and cans. The foliose life form has the form of sheets that have cavities in between, so marine debris is easily caught. The fabric category is grouped with the type of metal marine debris and the foliose life form, but the fabric category not only found in the foliose life form but also in the branching life forms (Figure 3).

Glass and plastic categories are in the same group, and associated with massive, encrusting, and tabulate forms of coral growth. Those forms of growth in the same group were found to be affected by the marine debris glass category, but the number of colonies affected was not large when compared to the plastic category. The plastic category has the most impact compared to other marine debris categories with a fairly large number of comparisons (Table 2).

The massive life form is one of the most affected by the plastic category as a result of being used by society who carry out fishing activities such as floating net cages. The ropes that are used to maintain the position of the net are hooked in massive corals used as rope moorings. Although, there are another coral reef genus that has massive life forms, genus *Porites* are the most affected. *Porites* of the coral genus are most easily found compared to another genus. Furthermore, the size of this genus colony has found with large size to be used as a mooring rope. Commonly macro debris causing a physical damage (Abu-Hilal and Al- Najjar, 2009; Sweet *et al.*, 2019).

The coral reefs in the branching life forms are among the most easily affected because marine debris is easily caught, so that is more susceptible to impact compared to other life forms (Chiappone *et al.*, 2005). However, the structure of the relatively fragile branching life forms only found one colony that has the impact of fragmentation.

3.4 Impact Caused

TLAG is the most common impact with a value compared to other impact categories (Table 3). TLAG impact categories are found in almost all life forms. The Correspondence Analysis results show that there are four groups of links between impacts and life forms. TLAG impacts were found most frequently compared to other impacts caused by plastic category, and the most dominant ones were affected, massive and branching life form (Figure 5). However, it was found that the fragmentation impact occurred in the branching life forms was only found in one case, causing the life form to become a separate group with the TLAG impact category.

The tabulate life forms are not the most susceptible and affected as the massive life form. However, due to this research, it was found that one colony affected by the TLAG impact category caused by one group with massive life forms. The impact category MTL becomes a separate group with an encrusting life form. MTL category was also found in the massive life form, yet it was not the dominant since the encrusting life form got into a separate group with similar impact.

According to research Hoeksema and Hermanto (2018), coral reefs have succession and over time, marine debris can be a substrate for coral larvae. On the contrary, the marine debris should be found immediately because it can be a source of disease (Lamb *et al.*, 2018). Physical injury in the form of abrasion on the surface can be one of the causes of coral disease as in the process of healing, the coral reefs will become weak and susceptible to disease (Lamb *et al.*, 2018). Moreover, algae that grows on the surface of marine debris and coral reefs can become competitors for coral reefs if it continues to grow and cover coral reefs. Algae can also be one of the causes of coral being attacked by coral disease, one of which is black band disease (Lamb *et al.*, 2016).

4. Conclusion

There are six life forms that are affected by marine debris such as massive, foliose, encrusting, branching, mushroom, and tabulate. The most susceptible life forms are massive, encrusting, and branching. The plastic category being the most dominant of marine debris almost found at all stations with a fairly number compared to other categories. All impact category was found of Focal Tissue Loss (FTL), Multifocal Tissue Loss (MTL), Diffuse Tissue Loss (DF), Tissue Loss with Algal Growth (TLAG), Fragmentation (FR), and No Damage (ND). Nevertheless, the TLAG impact category is the most dominant. We suggest that further research is needed in other seasons, especially in the rainy season. During rainy season, more marine debris tends to enter the mainland through rivers into Jakarta Bay to find out how the impact will be on coral reefs when the potential number of marine debris originating from the Jakarta Bay area increases.

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Authors' Contributions

All authors have contributed to the final manuscript as follows, Gilang; collected the data and drafted the manuscript. Syawaludin; designed the figures. Neviaty and Natih; devised the main conceptual ideas and did a critical revision of the article.

Conflict of Interest

The authors declare that they have no competing interest.

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