Coral recruitment on concrete blocks at Gosong Pramuka, Kepulauan Seribu, Jakarta

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Abstract. The current research was conducted to study the coral recruitment on concrete blocks at Gosong Pramuka, in Kepulauan Seribu. The concrete blocks were observed based on the wave exposure, i.e. the exposed area and sheltered area. A total of 247 coral recruits colonies was recorded on concrete substrates in Gosong Pramuka. The number of coral colonies in the exposed area (210 colonies) was higher than in the sheltered area (37 colonies). Coral recruit density in the exposed area was 1.37 colony/m^2 and in the sheltered area was 0.23 colony/m^2. A total of four genera was observed in these areas (*Acropora*, *Porites*, *Montipora*, and *Pavona*). The branching *Acropora* colonies were predominant for both areas, while encrusting non-*Acropora* was primarily found in the exposed area and massive non-*Acropora* was the major colonies in the sheltered area. The coral size of branching and encrusting *Acropora* in the sheltered area was significantly bigger than in the exposed area (P <0.05). In the exposed area, corals are found in the center of the concrete, but in the sheltered area, they are located in the corner and the edge of the concrete.

Keywords: colony size, concrete block, coral recruits, hard coral, settlement

1. Introduction

A coral reef is a dynamic ecosystem but sensitive and vulnerable to environmental changes. Coral reefs in the world are currently declining due to natural and anthropogenic disturbances, including in the Kepulauan Seribu. The coral reefs in the Kepulauan Seribu were mostly categorized in poor condition (Rachello-Dolmen and Cleary 2007, Estradivari *et al* 2007, Madduppa *et al* 2014, Baum *et al* 2015, Bramandito *et al* 2018). In the natural state, corals will respond to the environmental changes and pressure by striving to survive (resistance) and recovery. The corals' recovery process needs a long time to build a stable community (resiliency) (Obura and Grimsditch 2009). Recovery of coral reefs can be observed from the increase in hard coral cover as the main component of the formed reef. The coral restoration is also indicated by the growth of young coral colonies (juvenile) which are small in size (Babcok and Mundy 1996). Coral recruitment is an essential process in the coral population dynamics and will consider the sustainability of coral reefs (Moulding 2005, Bachtiar and Prayoga 2010).

Concrete is the most widely used material as an artificial reef (Baine 2001). Concrete blocks in Gosong Pramuka located in the Kepulauan Seribu are a suitable substrate for settlement of scleractinian corals because of its complex surface. This complexity will give more settlement orientation variation for planula larvae and protected from predation and grazing activity (Wallace 1985). Recruit coral generally can be detected after reaching more than ten months of age (Clark and Edwards 1995).

Coral recruitment is not only determined by suitable substrates but also sedimentation, grazing, and limitations of space which inhibit the corals' growth. The sedimentation can restrain coral settlement and high algae cover in the waters (Sammarco 1991). Coral recruitment prediction will be different in the exposed and sheltered areas because of the differences on sedimentation level, grazer, and alga competitors that is determined by the waves. This research was conducted to study the coral recruitment on concrete blocks at Gosong Pramuka, in Kepulauan Seribu by assessing density, genera, life form, variations in size, and coral settlement orientation of coral recruits.

2. Methods

2.1. Study site and period

This study was conducted in Gosong Pramuka, Kepulauan Seribu from September to December 2011 (figure 1). The coral recruitment process was observed on the concrete blocks in the exposed area (262 concretes) and sheltered area (279 concretes). The concrete blocks observed in this study is a breakwater which has been built in the Gosong Pramuka since 2007 and 2008. The size of the concrete block is about 50×50×50 cm (figure 2).

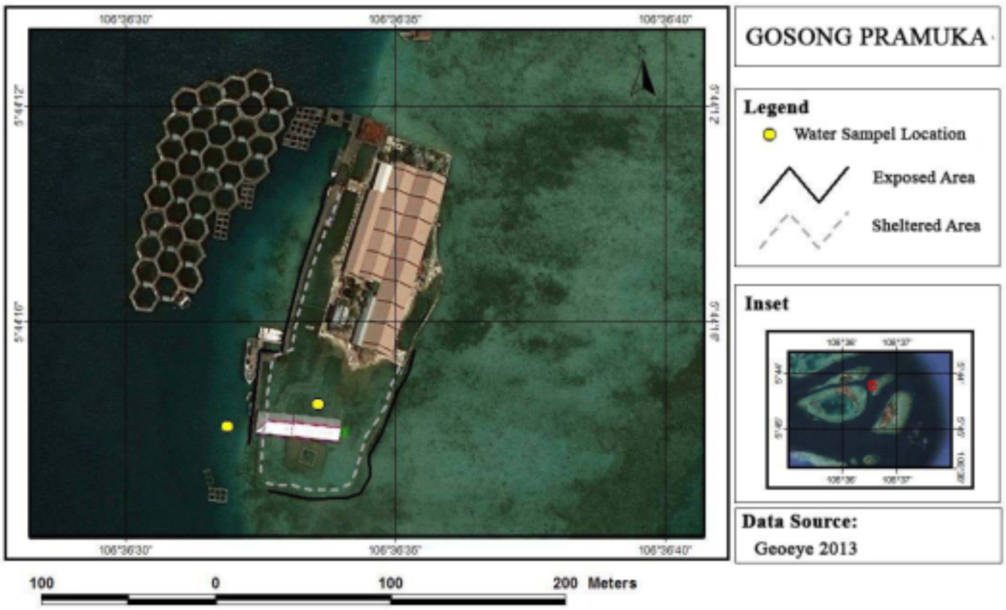

Figure 1. Research location and sampling sites in Gosong Pramuka Kepulauan Seribu.

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2.2. Observations of coral recruits and other benthic organisms

The corals and other organisms that live and settle in the concrete substrate at the exposed area (262 concretes) and sheltered area (279 concretes) were observed. Each coral recruit was counted and photographed using an underwater camera along with a ruler as a size reference. The diameter and coverage of coral colonies were performed by image analysis using the ImageJ (Abramoff *et al* 2004). Corals were identified to the genera level, lifeform, and the settlement position in the concrete substrate.

Figure 2. Concrete blocks in Gosong Pramuka, Kepulauan Seribu.

Coral health was identified by using coral reef health card, coral watch. Six categories of coral health are considered by coral reef color levels ranging from scale 1 to 6. The reef color indicates the density of zooxanthellae and chlorophyll-a. The coral reef health card was placed close to coral recruits, then be matched with the respective color level in the chart. The color level 6 and 5 describe the corals in a healthy condition, level 4 and 3 describe the less healthy coral, level 2 to 0 shows the critical healthy coral that indicated coral bleaching occurred (Siebeck *et al* 2008).

2.3. Water quality measurements

Temperature, penetration, depth, current speed, salinity, pH, orthophosphate, nitrate, and ammonia were measured.

2.4. Data analysis

The density of coral recruits in the concrete substrate obtained by calculating the number of the coral colony lived on the concrete substrate surface in each location (exposed and sheltered) with equation (1) (modified from English *et al* 1997):

$$N=\frac{ni}{A} \qquad (1)$$

Descriptions:

N = Coral density each species (colony/m^2)
n_i = Number of coral colonies i-species
a = concrete substrate coverage (m^2).

Differences in the size of corals between exposed and sheltered sites are examined by t-test, which was applied to the coral diameter at 5% significance level using Microsoft excel.

3. Results

Coral colonies lived on the concrete substrates in Gosong Pramuka were 247 colonies. Coral recruits in the exposed area (210 colonies) were higher than in the sheltered area (37 colonies) (figure 3). The density of young coral colonies was 1.4 colonies/m^2 on exposed area and 0.23 colony/m^2 in the sheltered area.

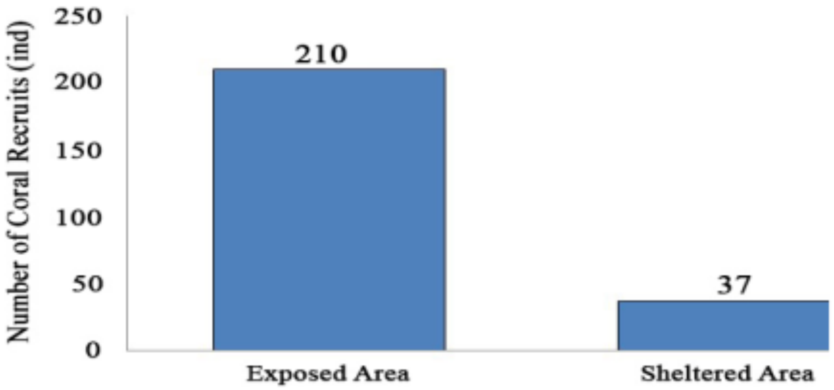

Figure 3. Number of coral recruits settled on the concrete substrate in Gosong Pramuka.

The concrete substrate in Gosong Pramuka is a habitat for coral recruits from different genera, namely *Acropora*, *Porites*, *Montipora,* and *Pavona*. The concrete substrate was dominated by *Acropora*, while *Pavona* was only found in the exposed area in a small number (figure 4).

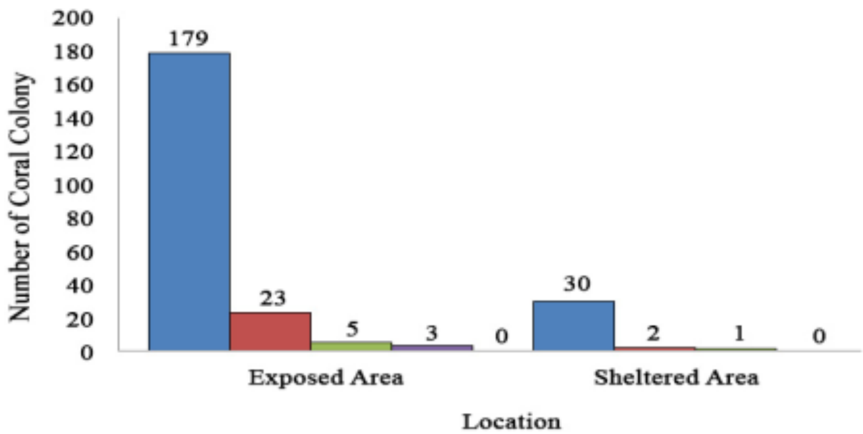

Figure 4. Genera of coral recruits settled on the concrete substrate in Gosong Pramuka (■ = *Acropora*), (■ = *Porites*), (■ = *Montipora*), (■ = *Pavona*).

The form of the coral growth is divided into two types (English *et al* 1997), which are *Acropora* and non-*Acropora*. In this study, *Acropora* corals in the concrete substrate consisted of tabulating growth form, branching, digitating, and encrusting (figure 5a). The coral settlement on the concrete substrate was dominated by branching *Acropora*. However, digitating *Acropora* was only found in the exposed area. There was almost no difference in the growth form of *Acropora* on the exposed and sheltered locations. Non-*Acropora* corals that found in this study sites had several forms, namely sub-massive, massive, and encrusting (figure 5b). In the exposed area, coral was dominated by encrusting form. In the sheltered area, the dominant coral was the massive coral.

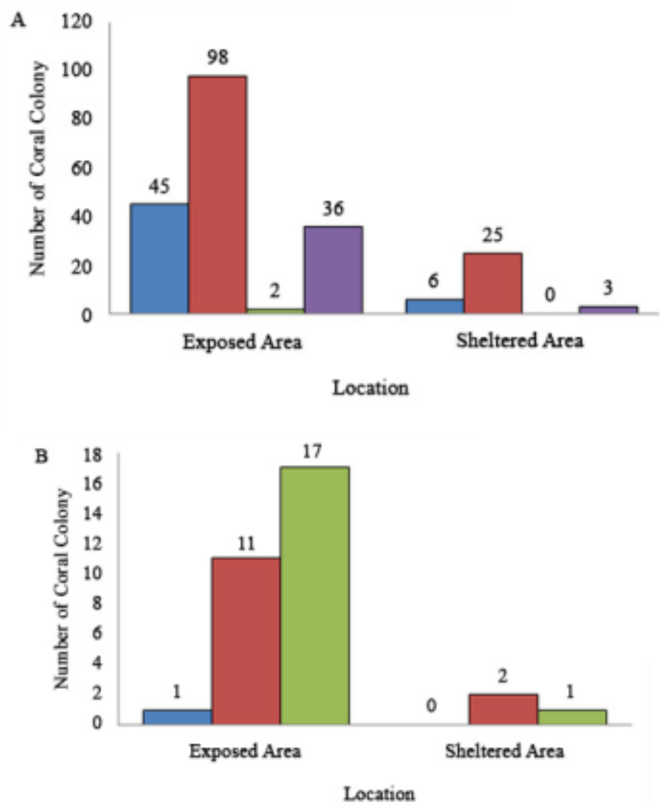

Figure 5. Density of *Acropora* (A) (■ = Tabulate), (■ = Branching), (■ = Digitate), (■ = Encrusting) and *non-Acropora* (B) growth forms on the concrete substrate in Gosong Pramuka (■ = Submassive), (■ = Massive), (■ = Encrusting).

Coral recruits living in the concrete substrate had varying sizes (figure 6). *Acropora* corals had an average diameter of 3-15 cm, relatively smaller compared to non-*Acropora* corals with the average diameter of 9-20 cm. Branching and encrusting *Acropora* forms in the sheltered area (SA) were greater than those in the exposed area (EA) (P <0,05). The diameter of the branching *Acropora* was 7.68 cm (EA) and 10.69 cm (SA). The encrusting *Acropora's* diameter was 5.82 cm (EA) and 8.46 cm (SA).

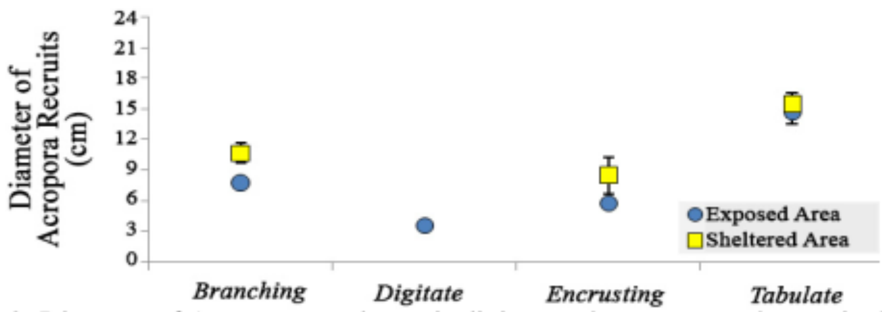

Figure 6. Diameter of *Acropora* coral recruits living on the concrete substrate in Gosong Pramuka.There are differences in the diameter of branching and encrusting *Acropora* between exposed and sheltered locations (t-test, p_{br}=0.00039 and p_{en}=0.021, $p<0.05$).

No difference in the diameter of the tabulating *Acropora* (EA=14.63cm; SA=15.39cm), *Porites* (EA=11.55cm; SA=11.42cm), and *Montipora* (EA=20.35cm; SA=20.64cm) in the exposed and sheltered area (Figure 7). Meanwhile, digitating *Acropora* and *Pavona* were only found in the exposed area, hence it could not be compared.

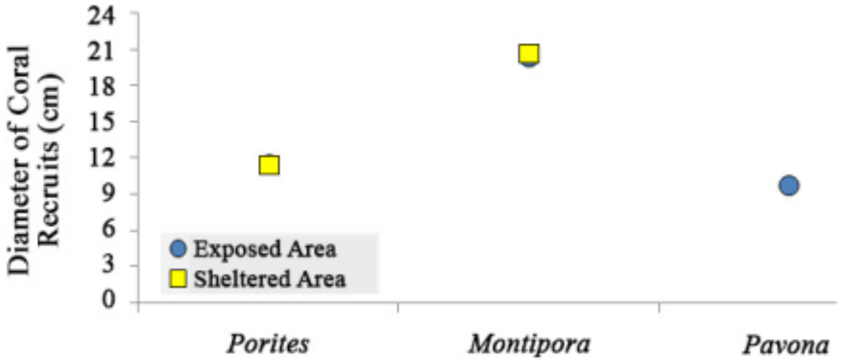

Figure 7. Diameter of non-*Acropora* coral recruits living on the concrete substrate in Gosong Pramuka.

Positions of the coral settlement were in the middle, corner, and the edge of the surface of the concrete substrate (table 1). In the exposed area, corals were found in the middle, while in the sheltered area, it appeared in the edge or the corner of the concrete.

Concrete substrate observed in this study was not only a habitat for coral recruits but also other organisms. Other benthic organisms living on the concrete substrate were sea urchins, *Padina* sp., *Caulerpa* sp., tunicates, sponges, anemone, and *Cypraea* sp. The main benthic organism found on the concrete substrate in Gosong Pramuka was Sea urchins. Sea urchins occupied 71 concretes in the exposed area, and 93 concretes in sheltered areas. Other benthic organisms were mostly observed in the concrete that has not yet been occupied by the coral recruit.

Table 1. Coral settlement positions on the concrete substrate in Gosong Pramuka.

Genera	*Coral Life Form*	Location *	Settlement Position		
			Corner	Middle	Edge
Acropora	*Branching*	EA	15	69	15
		SA	9	6	10
	Encrusting	EA	1	29	4
		SA	0	0	3
	Tabulate	EA	17	24	3
		SA	4	2	0
	Digitate	EA	0	2	0
		SA	0	0	0
Porites	*Encrusting*	EA	2	8	1
		SA	-	-	-
	Massive	EA	4	6	1
		SA	1	-	1
	Sub-massive	EA	-	-	1
		SA	-	-	-
Montipora	*Encrusting*	EA	2	3	-
		SA	1	-	-
Pavona	*Encrusting*	EA	-	1	2
		SA	-	-	-

*) EA= exposed area; SA= sheltered area

The health of coral recruits was observed with considering the level of coral colour (figure 7). The colour of *Acropora* coral in sheltered and exposed locations were classified into level 2 to 6, which represent critical condition (started bleaching) to healthy. Meanwhile, the colour of non-*Acropora* coral in both observed locations range from level 4 to 6, representing from less healthy to a healthy condition. The percentage of healthy coral (levels 5 and 6) was commonly found in sheltered locations.

The environmental condition heavily influences the survival, health, and the growth of the coral recruits. The results of water quality measurements are presented in table 2. Temperature, depth, penetration, pH, and salinity in this study site are still appropriate for microbial life, including coral. However, the concentration of nutrient parameters namely nitrate and orthophosphate is unacceptable with water quality standard for marine organisms life.

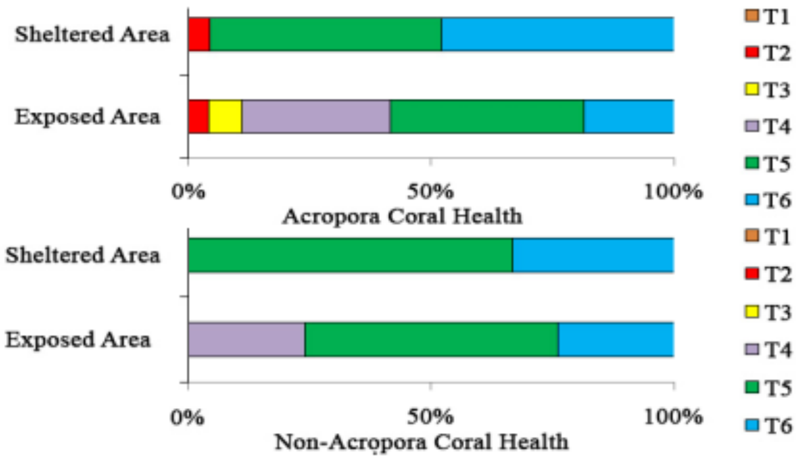

Figure 7. Health of coral recruits (a) *Acropora* and (b) non-*Acropora* on the concrete substrate in Gosong Pramuka.

Table 2. Aquatic environmental quality Gosong Pramuka in exposed area (EA) and sheltered area (SA).

No	Parameter	Unit	Standard	Concentration at	
				EA	SA
1	Temperature	°C	28-30	30	31
2	Depth	cm	-	89	88
3	Penetration	%	> 5 m	100	100
4	Nitrate	mg/L	0.01	0.294	0.236
5	Orthophosphate	mg/L	0.02	0.125	0.036
6	Ammonia	mg/L	0.3	0.161	0.186
7	pH		6.5-8.5	8	8.1
8	Salinity	ppt	33-34	32	31

*) Water quality standard for marine organisms basedon The Environmental Ministry Decree No.51, 2004

4. Discussion

Coral reef ecosystems are formed through a long and complex process. This process begins with the settlement of a variety of calcifying organisms that produce a hard substrate, such as corals and coralline algae (Suharsono 2008). The concrete substrate in Gosong Pramuka has been built since 2007 as a breakwater. This breakwater is very suitable substrate for coral recruitment because they have a complex surface. Wallace (1985) revealed that concretes with a complex surface is a good place for planula larvae because the larvae tend to settle in a complex surface in order to protect themselves from predation and grazing.

The settlement of coral larval on the substrate and their growth is very valuable to coral ecosystem sustainability (Moulding 2005). Newly settled larvae that begin to metamorphosis cannot be seen clearly, so at this stage, the recruitment has not yet happened. This process is called as the larvae settlement. Recruitment stages occurred after coral recruits can be seen clearly, usually at a few weeks to 10 months after the settlement using a microscope or direct observations (Harrison and Wallace 1990).

Coral recruitment process on concrete substrates in Gosong Pramuka was observed based on the presence of young coral colonies on the surface. Sexual reproduction of the coral will produce free-swimming planula larvae, and when the larvae find a suitable substrate to settle, it would grow and develop a new colony. Development of a new coral colony requires a sturdy and clean substrate that allows coral larvae to develop (Suharsono 2008).

These observations were conducted on the concrete substrate in two locations. The first location was in the breakwater that was exposed to waves and the second location was in the breakwater that was sheltered from waves. This study showed that differences in site characteristics affected coral recruitment. The number and density of coral colonies recruits living in the exposed area were higher than in the sheltered area because coral might be unable to tolerate a stagnant water flow. Corals need sufficient current for the distribution of nutrients, larvae, and sediments, as well as to clean themselves from the mud and rubbish (Veron 1995). Although the density of the colony of coral recruits at the exposed area was higher, it was still categorized as low-density corals (Engelhardt 2000).

Coral colonies grew on the concrete substrate consists of *Acropora*, *Porites*, *Montipora*, and *Pavona*. Research conducted by Bachtiar and Prayogo (2010) found the same thing where corals attached to artificial reefs Reef Ball^{tm} in Benete were from the family of acroporiidae namely *Acropora* and *Montipora*. They belong to the order of Scleractinians (hard corals) which is the major reef-building corals (Reid *et al* 2009). Acroporidae family is a hard coral that was found in the Kepulauan Seribu (Madduppa *et al* 2012, Madduppa *et al* 2014, Fahlevy *et al* 2017, Fahlevy *et al* 2019). *Acropora* dominated coral colonies in both locations and showed a branching growth pattern. This means that *Acropora corals* are more adaptive to the concrete substrate in Gosong Pramuka. On the other hand, non-*Acropora* corals were found only in a small number. Most of the non-*Acropora* corals in the exposed area were encrusting corals, while in the sheltered area were massive corals. Differences in coral growth patterns describe several adaptations of marine organisms to environmental condition. The diameter of *Acropora* corals was relatively smaller than the non-*Acropora* corals. Generally, there was no significant difference in size between the coral in the exposed and sheltered area, except for branching and encrusting *Acropora* which its diameter in the sheltered area was greater than in the exposed one ($P < 0.05$).

Substrates with complex surface give several settlement variations of coral larvae (Wallace 1985). The orientation of the coral settlement in Gosong Pramuka could be divided into 3 positions: in the middle, at the corner, and on the edge of the concrete substrate. Coral in the exposed area tend to settle in the middle of the substrate surface. On the contrary, coral in a sheltered area was found on the edge or corner of the substrate. The coral settlement at the edge or corner of the concrete was estimated as an adaptation to protect themselves from predation and grazing because the concrete substrate was not only occupied by coral recruits but also by other benthic organisms. Other benthic organisms lived on the concrete substrate were sea urchins, *Padina* sp., *Caulerpa* sp., tunicates, sponges, anemone, and *Cypraea* sp. Sea urchin is the primary benthic organisms found on the concrete substrate in Gosong Pramuka because it was found in the great numbers. Urchins occupied 71 concretes in exposed areas, and 93 concretes in sheltered areas. Benthic organisms were mostly found in concrete that has not yet occupied by the coral recruit.

Existence of grazer animals such as sea urchins can bring positive and negative impact on reef ecosystems. The positive impact is urchins grazing activity on algae density. Dense algae cover can inhibit larval settlement and growth due to space competition (Harrison and Wallace 1990). Besides, the fleshy algae can secrete a substance to prevent coral settlement (Reid *et al* 2009). So, if urchins eat algae, the surface of the concrete substrate will be clean, which expand the space for coral larvae settlement (Harrison and Wallace 1990, Reid *et al* 2009). However, intensive grazing activity by urchins can also destroy the young coral recruits that live surrounding the algae (Harrison and Wallace 1990).

Environmental pressures for coral reef ecosystem are coming from overfishing, high nutrient input, and sedimentation that potentially damage the structure of coral reefs. Increase in nutrient concentration causes fast algae growth on coral reef habitat. In a reasonable condition, herbivorous fish will eat algae, so the algae growth is under control. However, overfishing of herbivorous fish leads to the domination of algae in the reefs (Reid *et al* 2009).

Loss of carnivorous and herbivorous fish in reef habitat led sea urchin population to grow in a significant number. Sea urchin and major herbivore fish on coral reefs can inhibit algae growth. However, unlike the herbivorous fish that scrape the coral surface and leave a clean area for the settlement of young coral, sea urchins with its sturdy tooth (Aristotle Lantern) weaken and destroyed the overall structure of the reef (Reid *et al* 2009).

The health of coral recruits in the sheltered area was much better than in the exposed area, as more corals with pale colours were found in the exposed area. The pale colour indicates that corals were in a critical condition (started bleaching). Colour level is an indicator of reef health because the colours represent the density of zooxanthellae algae (Siebeck *et al* 2008). When the zooxanthellae algae leave coral tissue, the skeleton of coral colonies will show a pale or white colour (Reid *et al* 2009). Loss of zooxanthellae from the coral polyps can be caused by the coral diseases (Barnes and Hughes 1999), high nutrient input, sedimentation, increase on temperature, decrease on salinity, and other pollutants (hydrocarbons, metals, pesticides, chlorine) (Hawker and Connell 1992).

Under normal conditions, the zooxanthellae able to photosynthesis using coral waste products (inorganic nitrogen and phosphorus) and convert it into carbohydrate and proteins as a main product and oxygen as a by products. Almost 95% of the photosynthesis product is given to coral colonies that it can grow, reproduce, and form a carbonate skeleton (Reid *et al* 2009).

Increase in sea temperature and nutrients on the reef ecosystem under the full sunlight conditions will lead uncontrollable reaction rate. These conditions reduce the ability of zooxanthellae to process sunlight energy, so energy will eventually convert to be dangerous oxygen radical molecule that is very reactive to damage the coral tissue. Furthermore zooxanthellae will leave coral tissue to surrounding waters (Reid *et al* 2009). In addition, an increase in nutrients can trigger the growth of competitor algae on the concrete substrate even in the coral surface. This may restrict zooxanthellae in obtaining optimum sunlight to do photosynthesis. Based on the measurement of water quality parameters, the nutrient concentration in the Gosong Pramuka did not meet the standard for marine organism especially on supporting the growth and development of corals as they require natural water quality which has low nutrient concentration (Veron 1995). Changes in water quality, stream hydrology, and biogeochemical cycle will affect the structure, function, biodiversity, and resilience of coral. Increase in organic and inorganic materials was primarily derived from the mainland (Dupra 2002 in Paonganan 2008). Loading of total phosphate into Jakarta Bay reaches 6741 tons per year (Damar 2003 in Paonganan 2008).

5. Conclusion

The number of coral recruits in the exposed area was higher than in the sheltered area. Similarly, the density of coral recruits was higher in the exposed area than in the sheltered area. However, the size of *Acropora* branching and encrusting in the sheltered area was more prominent than in the exposed area. The diameter of *Acropora* corals ranged from 3 to 15 cm, and non-*Acropora* corals ranged from 9 to 20 cm. The branching *Acropora* colonies were predominant in both areas, while for non-*Acropora* colonies, there were two categories. Firstly, the encrusting form was majority found in the exposed area, and secondly, the massive form was dominant in the sheltered area. In the exposed area, corals tend to settle on the centre of the concrete, but in the sheltered area, they settle on the corner and the edge part. In general, coral in the sheltered area was healthier than in the exposed area.

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