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Coral reefs recruitment in stone substrate on Gosong Pramuka, Seribu Islands, Indonesia

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Abstract. *Lubis MZ, Pujiyati S, Tauhid M, Anurogo W, Kausarian H. 2018. Coral reefs recruitment in stone substrate on Gosong Pramuka, Seribu Islands, Indonesia. Biodiversitas 19: 1451-1458.* Gosong Pramuka is a reef distribution area located in the center of the Seribu Islands of Jakarta, Indonesia. This research was conducted from April to June 2015, located within the Gosong Pramuka area, Kepulauan Seribu, Indonesia. This location has 4 observation stations: Exposed I and II and Shielded I and II. Coral reefs identified at the study sites consisted of 95 colonies, with colonies most abundant in Exposure Station I (35 colonies), and in the genus *Acropora* and *Porites*. *Acropora* coral growth is tabulated, branching, digitate and encrusting, and *Porites* are only sub-massive and massive. The average area obtained from recruiting coral colonies had a range of 25-50 cm^2, and the average diameter of coral recruits was 9-12 cm. The results of this research determined the coral health index of the area is 2-3. Based on the CoralWatch method, the coral at the station where the research was conducted is classified as under stress conditions. The value of recalculated coral density obtained in this study was 0.22 colony/m^2 at Exposure Station I, 0.11 colony/m^2 at Shielded Station I, 0.13 colony/m^2 at Exposure Station II, and in 0.11 colony/m^2 at Shielded Station II. Temperatures in all four stations range from 30-32°C; this temperature range is within the optimum temperature range for coral growth. The depth at all four stations was in the ranged from 70-98 cm; this indicates the stations where the research was conducted is still within an optimum depth.

Keywords: *Acropora*, coral recruit, Gosong Pramuka, *Porites*, stony substrate

INTRODUCTION

Seribu Islands is one of the most important coral reef conservation areas in Indonesia's capital city, Jakarta. According to Warsa and Purnawati (2017), the area of Gosong Pramuka consists of small islands located within the Seribu Islands area and has a coral reef condition that has been declining over time since 2004-2005. This decline is due to the exploitation of rocks and sand, the use of cyanide (from the anesthesia method of catching fish), sedimentation of the seabed, and the contamination of the area from the disposal of waste (Kawaroe et al. 2015). Damage to coral reefs will continue with the presence of various pressures from the mainland coastal island of Java, especially from the coastal cities of Jakarta and Banten (Baum et al. 2015). High pollution intensity and high sedimentation inputs have resulted in continuous damage to coral reefs in the Seribu Islands with the main effect of the damage seen in the coral reefs of small islands located near the mainland. Damage to coral reefs can also be caused by natural disasters (Antoni et al. 2018, Lubis et al. 2018). Damage can also be caused by temperature fluctuations or sedimentation from one of the many interconnected coastal and terrestrial oceans (Kausarian et al. 2016; Lubis et al. 2017).

According to Obura and Grimsditch (2009), the coral reef naturally responds to various threats and causal factors such as resistance and showing recovery symptoms until the establishment of a resilient community. In nature, coral reef recovery is usually characterized by the emergence of young coral colonies (juveniles) with a relatively small colony size (Babcok and Mundy 1996). Coral reef ecosystems can repair and improve itself from damage if given the needed protection, however, recovery takes a long time. Therefore, coral reefs that have naturally maintained themselves in nature need to be preserved. One of the coral reef succession processes is coral recruitment. Coral recruitment data can be observed by recording the naturally occurring new coral growths along with the distribution and abundance of existing coral species (Connel et al. 1997). Coral recruitment can be interpreted as the attachment of larvae and growth of the coral to the size that can be seen by the naked eye. This is an important process of the population dynamics underlying the sustainability of coral reefs (Molding 2005).

According to Rudi (2006), the recruitment of corals on a substrate is simply characterized by the emergence of young coral colonies. Coral recruitment can occur naturally or artificially, and coral recruitment data can be used to obtain information about coral reef damage and form solutions to

the problem of coral reef damage. Natural coral recruitment occurs through the process of reproduction. Corals can reproduce sexually or asexually, and the larva then attached to a particular substrate and grow into complex corals or coral ecosystems (Cameron and Harrison 2016). Sexual reproduction occurs by gamete formation through gameto-genesis vents. Asexual reproduction occurs by fragmentation (splitting) or forming buds (Tunner et al. 2018; González 2016). Artificial coral recruitment occurs by creating artificial reefs that can trigger the attachment of coral larvae.

The placement of young coral attachment is strongly influenced by the substrate; and according to Doropoulos et al. (2017), complex substrate surface provides variation for the orientation of the embedded planula and simultaneously the protection from predation and grass. For this study, concrete substrate was selected as one of the suitable mediums for the growth of coral recruitment and reef ecosystem recovery due to its rough and hard surface. This is in accordance with Harrison and Wallace (1990) which states that one of the parameters for determining the success of coral recruitment in the coral reef environment is the presence of a hard substrate for the attachment of coral larvae. The initial step to monitoring and preserving the coral reef ecosystems around the study site is the collection of information on coral recruitment. This data will allow for the estimation of the sustainability of the biota that is symbiotic with coral reefs and coral recruitment, which is an important component in the recovery of coral communities. The current study aims to determine the recruitment of corals on rock substrates in Gosong Pramuka, Seribu Islands, Indonesia.

MATERIALS AND METHODS

Time and place

This study was conducted from April 2015 to June 2015 at Gosong Pramuka, Kepulauan Seribu, DKI Jakarta at coordinates 5º44'12 "LS - 5º44'18" LS and 106º36'30 "BT - 106º36'8" BT. The study sites were divided into four different stations, namely Exposure Station I and II, and Shielded Station I and II. The location map of Gosong Pramuka research area, Kepulauan Seribu DKI Jakarta is presented in Figure 1.

The difference between exposed and shielded stations is the extent of wave exposure; at the exposed stations the surface of the stone substrate is affected by the waves, while at the sheltered station, the stone substrate is not. Stone substrate is a breakwater rock that surrounds Nusa Resto. The data taken include the measurement of several parameters of water quality along with the recruiting corals on the stone substrate that serves as breakwater. The shape of the substrate to which the coral is attached can be seen in Figure 2.

Tools and materials

The equipment used consisted of basic dive equipment, Global Positioning System (GPS), underwater camera, meter, ruler, sample bottle, new top paper, stationery, thermometer, refractometer, and Coral Watch. The materials were are coral reef samples. A summary of all the tools and materials used and their functions can be seen in Table 1.

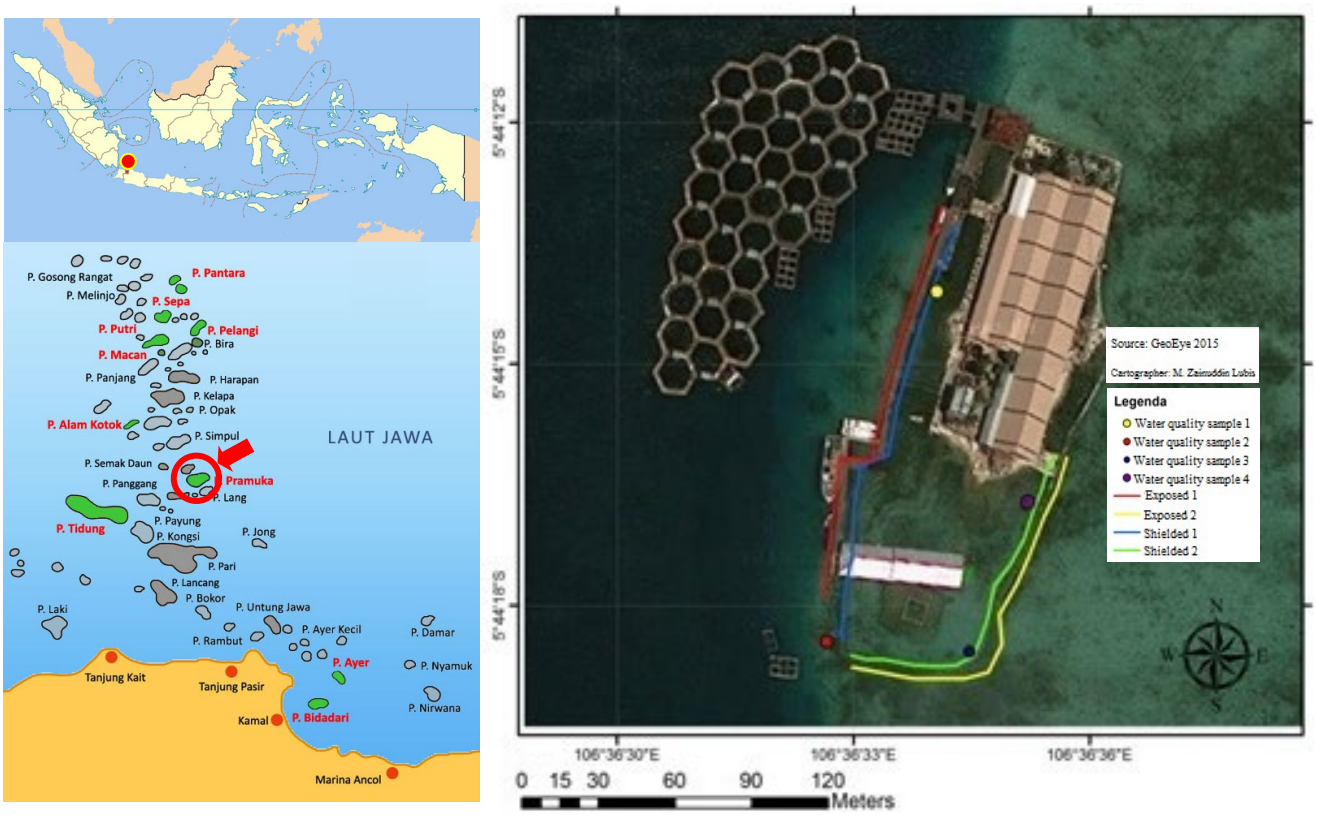

Figure 1. Map of research location in Gosong Pramuka, Seribu Islands, Indonesia

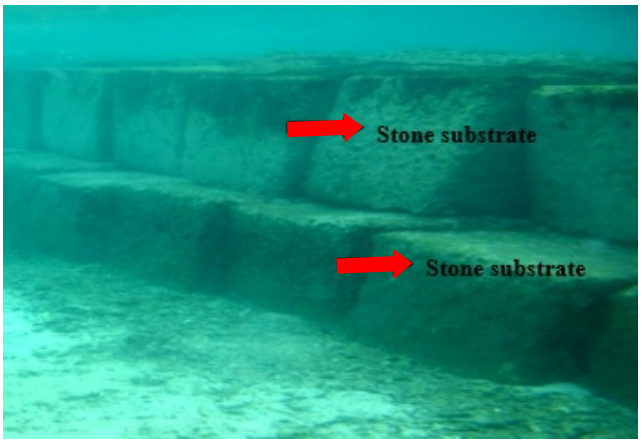

Figure 2. Stone substrate where the coral recruits are attached (arrows) at Gosong Pramuka

Figure 3. Measurement of coral colonies (asterisks) by photo techniques using rulers and coral health tables (arrows)

Table 1. Tools and materials research and function

Tools and materials	Information
Dive basics tools	Dive tool for sample identification
Global Positioning System (GPS)	Determine point of location of Station and sample taking
Underwater Camera	Documentation
Meters and Rules	Measuring instrument
Sample bottle	To take water samples
Newtop paper	Write data and observations
Thermometer	Measurement of temperature value
Refractometer	Measurement of salinity value
Coral Watch	To know the health of the reef
Sample	Coral recruits that exist in the research location

Procedure

Research activities consisted of preparation of tools and materials, observation of coral recruits, observation of the condition of the research area and data processing and statistical analysis. Parameters record during coral surveillance included identification (based on genus, lifeform, area, and diameter), coral health using Coral Watch, coral density, and other benthic biota recordings. Observations on the condition of the study area consisted of measuring the physical (including measurement of temperature, brightness, depth, current velocity) and chemical (including measurements of salinity, degree of acidity, orthophosphate, nitrate, ammonia) quality of the area. Additionally, data processing was performed to determine and measure the diameter and extent of recruited corals from the images utilizing Image Software J and graphically display the data in Microsoft Excel 2007. The data have been statistically analyzed to see the relationship and the influence of the observed parameters.

Observation of coral recruitment

Observations were made by observing each rock substrate from start to end of the station and every coral or other benthic biota found was recorded. Any coral recruits whose polyps were visible were counted and photographed using underwater cameras with macro settings. A ruler was included in the photographs as a reference measure. Reefs were photographed perpendicularly, with the ruler and Coral Watch placed next to the coral as references, can be seen in Figure 3. The coral attachment distance from the bottom of the water was measured by the roll meter. The surface area of the substrate where the coral was attached was recorded. Coral substrates were measured by width and length (as close to cube-shaped), up to ten times. After recruiting corals were photographed, the results were identified by genus, lifeform, area, and diameter.

Coral health data were obtained using Coral Watches, which are matched with the coral color which indicates the health of the coral (Siebeck et al. 2008). The density of corals in the rock substrate (breakwater) is obtained from living coral colony calculations, which were observed on the surface of breakwater rocks in each station by the formula below (modified from English et al. 1997):

$$N = \frac{n_i}{a}$$

Note:
N = Density of coral species (colony/cm^2)
ni = Number of coral colonies i
a = Breakwater stone surface area

Environmental parameter measurement

The environmental parameters measured were the physical and chemical parameters of the area. These were performed either in situ or through laboratory analysis of the environmental productivity from the Department of Water Resources Management. Physical data parameters included temperature, brightness, and depth. Water temperature was obtained by inserting a thermometer into the seawater and then reading it. This measurement was done three times at each station. The depth was measured by using a rolling meter and repeating the measurement three times at each station. Brightness was measured by using a drowned Secchi disk at the study site.

Salinity was taken directly at the study site. Salinity was obtained by dripping the sample onto the refractometer glass and then looking at the salinity value of the waters. However, the remaining chemical parameters including the degree of acidity (pH), orthophosphate, nitrate, and ammonia measurements were carried out in the laboratory by taking water samples from the study site back to the laboratory. These samples were stored at cold temperatures and protected from sunlight. All actions were made to prevent damage to the sample when testing it in the laboratory. The degree of acidity was obtained in the laboratory by dipping a pH meter into the sample. Other chemical parameters such as orthophosphate, nitrate, and ammonia were obtained by laboratory analysis using a spectrophotometer to see the absorbance value that was then used to calculate the final value.

Data processing

Photos were processed using Image J (www.imagej.gov/ij), while the data was processed and graphically displayed using Microsoft Excel 2007 Software. Photo processing of reefs in Image J Software included obtaining the extent of the station and the diameter of recruiting corals. To determine these values, a scale determination (Tool Bar Set Scale) was placed onto reef photos that had been opened in Image J, all according to the existing size reference. After that, the digitization process occurred by selecting the Polygon Selection from the Tool Bar, opening Set Measurements, and selecting Station and Feret's Diameter. The final step was to measure the digitized results by selecting Measure from the Tool Bar. The results of the measurements are then automatically displayed in the Results section.

RESULTS AND DISCUSSION

Recruitment based on genus

Phase identification of coral recruits is done up to the genus stage. Identification of reef recruits is done by referring to Veron's identification book. *Acropora* and *Porites* were the two genera found at the site. A total of 95 colonies of coral recruits were found from the four stations (Exposed I, Shielded I, Exposed II and Shielded II) (Figure 4).

This study found 18 *Acropora* recruiting coral colonies in Exposed Station I. At Shielded Station I 7 *Acropora* recruiting coral colonies were found. At Exposure Station II 19 *Acropora* recruiting coral colonies were recorded, which was the highest number of colonies in comparison to other stations. While at Shielded Station II 3 coral colonies consisted of *Acropora* and *Porites*. Exposure Station I had 17 *Porites* colonies, which was the largest number of *Porites*. At Shielded station I, 11 colonies of *Porites* recruits were documented. At Exposure Station II, 4 colonies of *Porites* recruits were found. At Shielded Station II 6 colonies of *Porites* recruits were found. The recruitment process plays a role in the addition of new individuals into the adult population so that the existence and sustainability of the population can be maintained. The coral recruitment process is characterized by the emergence of young coral colonies (juveniles) (Erwin et al. 2008).

Recruitment based on growth form (lifeform)

The growth forms of recruiting corals in the genus *Acropora* found in throughout the entire research station were tabulate, branching, digitate and encrusting. The graph of the growth form of the recruiting *Acropora* coral can be seen in Figure 5.

A total of 22 colonies of corals recruited with tabulate growth were found. Nine of these colonies were found at Exposed Station I, 2 at Shielded Station I, 5 at Exposed Station II and 6 at Shielded Station II. A total of 4 colonies of *Acropora* branching was found at Exposed Station I, Exposed Station II, and Shielded Station II, while none was found at Shielded Station I. A total of 1 colony was found in Exposed Station I and Protected Station II, while in Station Exposure II found 2 colonies. Digitate growth types were found in a total of 16 colonies. Of those 16 colonies, a total of 3 colonies were found at Exposed Station I, 4 in Shielded Station I, 6 in Exposed Station II and 3 in Shielded Station II. Coral encrusting is an early form of *Acropora* coral growth. The total number of these growth forms is 15 colonies, consisting of 5 colonies in Exposed Station I, 1 colony at Protected Station I, 6 colonies at Exposed Station II and 3 colonies found in Sheltered Station II. Growth form that can be found in all stations is tabulated, digitated and encrusting. The most common form of colonies is tabulated growth, found in Exposed Station I. The least common type of colonies were branching, found in Shielded Station I. This branched shape and slender growth are most commonly found in stations with low wave energy.

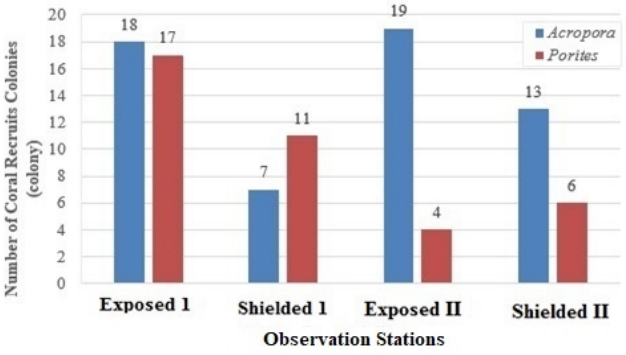

Figure 4. Number of coral reef colonies recruits of the genus *Acropora* and *Porites* at observation stations

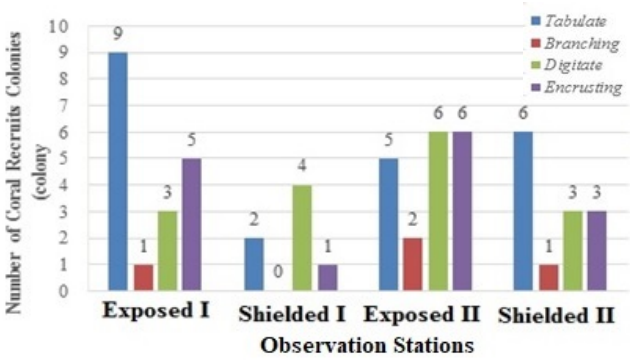

Figure 5. Number of colonies of coral recruit lifeform *Acropora* at observation stations

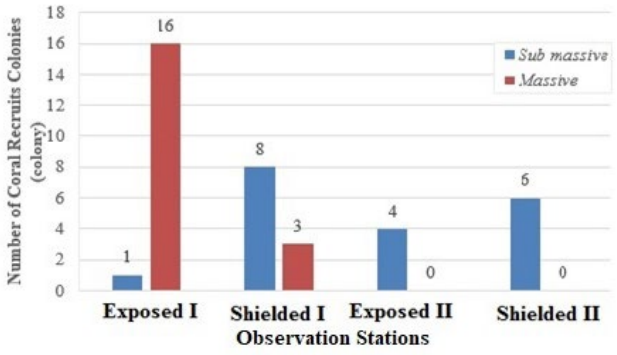

Figure 6. Number of coral colonies recruit lifeform *Porites* at observation stations

In the genera *Porites*, sub-massive and massive coral growth types were found. Sub-massive growth type was found in one colony in Exposed Station I, 8 colonies in Protected Station I, 4 colonies in Station Exposed II, and 6 colonies in Shielded Station II. A total number of 19 coral recruit colonies of the genus *Porites* with the sub-massive form were found. A total of 19 colonies of *Porites* massive growth type were found. Of these, 16 colonies were in Exposed Station I and 3 colonies in Sheltered Station I. These two forms of growth had the same total number of colonies in this study (Figure 6).

According to Baker et al. (2008), coral growth forms are divided into two major groups: (i) *Acropora*; This form consists of branching, encrusting, submassive, digitate, and tabular (bordering the horizontal). (ii) Non-*Acropora*; This form consists of branching, encrusting, foliose, massive, submassive, mushroom, millepora (all types of fire coral, consisting of a yellow color at the tip of the colony) and heliopora (blue coral, the blue color visible on the skeleton).

According to Veron (1995), each type of reef has a specific response to its environmental characteristics. Environmental factors, such as depth, strong currents and waves can affect the shape of coral growth. The rock coral growth form is generally a reflection of the surrounding environmental conditions, for example, coral species with branching forms and slender growth are commonly found in stations with low wave energy.

Recruitment by area and diameter

Known recruited reefs are grouped according to the range of values, as seen in Table 2. The most common range of recruited coral colonies is 25-50 cm^2, which is observed in 27 recruiting coral colonies, while the widest range of colonies is 175-200 cm^2 (Table 2). It can be assumed that there is a period of spawning of adjacent coral larvae for *Acropora* and *Porites* species, based on the largest number of recruiting coral colonies. On the other hand, the presence of *Acropora* recruit coral colonies in each wide range indicates the possibility of sequelae production of coral that occurs sequentially each month. It is known that Exposure Station I has the largest coral colony recruiting area of *Porites*, while for *Acropora* it is found in Shielded Station (I and II) (Figure 7).

The most common range of diameter in recruiting coral is 9-12 cm, observed at 23 recruiting colonies. The lowest colony diameter range is 0-3 cm (Table 3). The largest diameter of colonies in the *Acropora* genus is found in Exposure Station II (12 cm), whereas the largest diameter in the *Porites* genus is found in Exposure Station I (14 cm) (Figure 8).

Table 2. The wide range of *Acropora* and *Porites* coral colony recruits

Colony-wide range (cm^2)	Exposed I		Shielded I		Exposed II		Shielded II		Total
	A	P	A	P	A	P	A	P	
0-25	1	2	1	3	5	0	0	1	13
25-50	6	3	0	5	6	2	2	3	27
50-75	1	3	1	1	0	1	1	1	9
75-100	1	3	0	0	1	0	3	1	9
100-125	0	1	2	1	0	1	3	0	8
125-150	3	0	0	0	3	0	0	0	6
150-175	1	3	0	1	1	0	1	0	7
175-200	0	1	1	0	3	0	0	0	5
>200	5	1	2	0	0	0	3	0	11

Note: A: *Acropora*, P: *Porites*

Table 3. The wide range of *Acropora* and *Porites* coral colony recruits

Coral diameter range (cm)	Exposed I		Shielded I		Exposed II		Shielded II		Total
	A	P	A	P	A	P	A	P	
0-3	0	0	0	0	1	0	0	0	1
3-6	0	0	0	2	2	0	0	0	4
6-9	2	4	1	4	4	1	1	1	18
9-12	6	2	1	2	4	2	2	4	23
12-15	1	5	1	1	0	1	4	1	14
15-18	2	1	1	1	4	0	2	0	11
18-21	3	3	1	0	3	0	2	0	12
>21	4	2	2	0	1	0	3	0	12

Note: A: *Acropora*, P: *Porites*

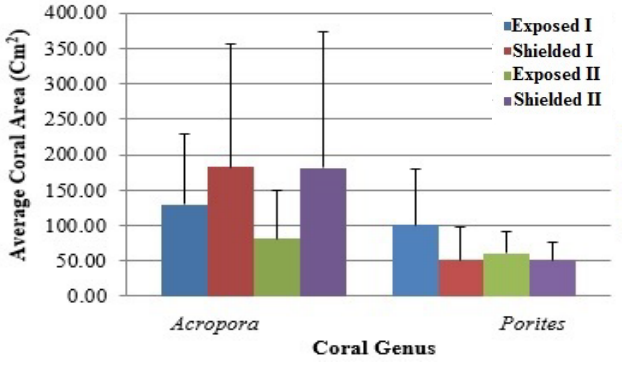

Figure 7. Average *Acropora* and *Porites* recruiting corals at observation stations

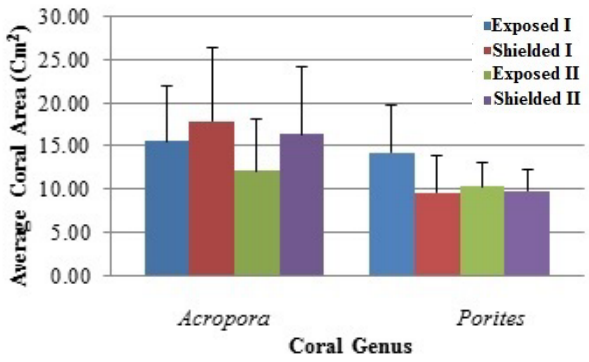

Figure 8. Average diameter of *Acropora* and *Porites* recruiting corals at observation stations

Figure 9. Coral health value reading techniques (arrows)

Coral health

Coral health values range from 0-6, and in the current study the maximum value of the coral health measurements was 6 and the minimum value was 1. The average health of coral fragments throughout the stations where the study was conducted ranged from 2-3. Exposed Station I has 11 coral colonies and Shielded Station I has 10 coral colonies that have been given a coral health value of 6, ranking these stations a 'good' stations. However, eight colonies at Exposed Station I have a coral health value of 3, and 5 coral colonies on Shielded Station I also had a coral health value of 3. This means that in Exposed Station I and Shielded Station I there are fewer healthy corals and potentially bleaching. Thirteen colonies of the corals in Exposed Station II were dominated by corals with health values of 3. This indicates that the coral in this location is in a less healthy condition. At Exposed Station II there are six coral colonies with a health value of 6, indicating a healthier reef. The condition of the reef at Shielded Station II Station is dominated by corals with values of 3 and 6, with a total of 9 coral colonies, which means that the station has an even distribution of unhealthy and healthy corals. This is evidenced by the condition of all research stations having temperatures ranging from 30-32°C, which is the optimum temperature range for coral growth. Additionally, the nitrate content at the four stations where the study was conducted ranged from 0.213 to 0.455 mg/l. These values are above the standard quality range of 0.008 mg/l which is the optimum value for recruit coral growth. The increase of nutrients in the waters can increase the growth of macroalgae, causing coral disease. Rapid macroalgae growth is also a space competitor for coral growth. The dominant recruit corals found in all research stations were attached to the center of the breakwater, with an average distance from the bottom of the water of more than 10 cm^2

According to Marshall et al. (2012), the values of 0-2 using the color scale for measurement showed that critical coral fragments and bleaching had begun to occur. A grade of 3-4 indicates a moderately healthy coral condition, and a value of 5-6 indicates healthy condition corals. An example of coral health conditions can be seen in figure 9.

Coral density

The density value at Exposed Station I was 0.22 colony/m^2. Protected Station I had a value of 0.11 colony/m^2, Exposed Station II had a value of 0.13 colony/m^2 and Protected Station II had a value of 0.11 colony/m^2 (Table 5). The coral density was the greatest at Exposed Station I when compared to the other three stations, and the lowest density value was at Shielded Station I. The density of young coral colonies can be used as a standard for measuring the level of coral recruitment at a site. Overall, the density value at all the stations where the research was conducted is still low. The low density indicates there is a low recruitment rate at all stations. This is due to the increasing number of coral colonies, which will increase the coral density of the reefs when compared to the substrate surface area of the research station. However, the amount of large substrate surface that is still available can lead to increased recruitment rates. According to Connell et al. (1997), there is a positive correlation between the number of recruiting corals and the empty and available substrate surface area.

Table 4. Density of recruiting corals in all stations of the study site

Information	Exposed Station I	Shielded Station I	Exposed Station II	Shielded Station II
Total of stones	262	279	300	272
Surface area of stone (m^2)	0.58±0.05	0.58±0.05	0.58±0.05	0.58±0.05
Total of surface area (m^2)	153.32	163.27	175.56	159.17
Density (colony/m^2)	0.22	0.11	0.13	0.11

Figure 10. Other benthic biotas. A. Horsehair (*Diadema* sp.); B. Anemone sand (*Heteractis malu*); C. Black Tail Sergeant/Abudefduf lorenzi (*Pomacentridae*) and Crustaceae

Table 5. Density of recruiting corals in all stations of the study site

Station	Temperature (°C)	Depth (cm)	Brightness (%)
Exposed I	31	98	100
Shielded I	32	87	100
Exposed II	30	70	100
Shielded II	31	84	100

Other benthic biotas

The surface of the rock that coral attaches to is not only for coral attachment, but other biota attaches to the surface as well, which can affect the survival of the reef. Other sealing organisms found in the study area were sea urchins (*Diadema* sp.), sand anemones (Heteractis shame), fish (Pomacentridae) and Crustacea (Figure 10).

The presence of grazer animals such as sea urchins (*Diadema* sp.) can facilitate larval attachment and increase the level of coral recruitment (Harrison and Wallace 1990), but intensive grass can destroy recruiting corals that live among the algae. Coral recruits are also damaged and injured due to predation by fish and sea urchins. The body cover of sand anemone (Heteractis embarrassment) can inhibit the attachment of recruiting coral larvae or decrease graduation of coral recruiting life due to space competition.

Physical condition of waters research area

Temperatures in all four stations range from 30-32°C, this temperature being within the optimum temperature range for coral growth. The optimal temperature for coral biota growth ranges from 25-32°C (Veron 1995). Most corals lose the ability to catch food at temperatures greater than 33.5°C and less than 16°C. Increasing the water temperature will increase the damage and death of coral reefs (Bramanti et al. 2005). According to Prasetia (2013), coral reefs are found in shallow waters of the tropics with an average annual water temperature of over 18°C.

The depth at all four stations is in the range of 70-98 cm, which indicates that the station where the research was conducted is within an optimum depth, as the optimal depth for reef development is less than 25 m (Prasetia 2013). All research stations had a brightness value of 100%, which is demonstrated by the ability to clearly see all the basic substrates of the waters at all locations. 100% brightness at all locations can be caused by a relatively shallow depth (between 70-98 cm) which allows the sunlight to penetrate to the bottom of the waters. One of the environmental phenomena that play a role in the development of coral reefs is the presence of bright, wavy,sediment-free waters. Brightness can affect the entry of light in the territorial waters, as incoming light can be used for the process of photosynthesis by corals. The lower the intensity of light entering the water column, the lower the rate of photosynthesis (Bengen 2002). The physical condition of the Gosong Pramuka Waters as a whole can be seen in Table 5.

Current conditions in the Exposure Station are dynamic, but in a protected station it tends to be stagnant or static. The stagnant condition is usually less favored by reefs requiring sufficient flow for the distribution of nutrients, larvae, and sediments and to clean up dirt and waste (Veron 1995). According to Dahuri (2003), current and water circulation play a role in the sedimentation process. Sediments of solid mud particles carried by surface run-off (due to erosion) cover the surface of coral reefs. This process not only has a negative impact on coral animals, but also on the living biota associated with these habitats.

In conclusion, recruitment of corals attached to rock substrates at Gosong Pramuka for June 2015 was dominated by *Acropora* and *Porites*. The *Acropora* coral recruit lifeform types were tabulated, digitate, and encrusting, while *Porites* lifeforms were submassive and massive. The range of coral recruits was 25-50 cm^2 and the diameter range of coral recruits was 9-12 cm. The factors that most influenced the coral recruitment of the genus *Porites* were depth, salinity, pH, and temperature, while the *Acropora* genus was more affected by the distance from the base.

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