The effect of type and duration of substrate collector placement to the coral genus recruitment in Saleo Beach Area, Dampier Strait, Raja Ampat, Indonesia

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Abstract. The limitation of the substrate for the recruitment of coral species at the Saleo Beach Area is limited due to historic destructive practices such as fishing using explosives and the increase of rubble cover in particular between 2016 and 2017 caused by historical and current human activities. This research was conducted for 6 months using the Coral Recruitment Tile method. This method uses an artificial substrate for coral placement placed at 5-7 meter depth with slope of the substrate of 45°. The purpose of the study was to analyze the influence of the substrate types and its placement, duration, and diversity of attached coral. The results indicated that coral recruitments included the genus Pocillopora, Porites, Seriatopora, Montipora, Stylophora and Goniastrea. The highest coral abundance was recorded in genus Pocillopora with a value of 38.10% while Stylophora and Goniastrea showed the lowest abundance with 1% each. Species diversity was classified as moderate with a value of 1.5. The analysis showed that the placement duration of tiles at sea bottom influences the recruitment of coral species. The placement of substrate for a long time would facilitate new settlements from the reproduction of coral species.

Key Words: coral recruitment, rubble cover, coral placement, species diversity, coral abundance.

Introduction. Coral reefs have many biological functions as food incubator, fishery sites, organism spawning sites, laying eggs sites and shelter for various high-value marine biotas (Nybakken 1988). However, global warming and human activities can damage coral reef ecosystems (Westmacott et al 2000; Giyanto et al 2017).

Corals have both sexual and asexual forms of reproduction. Sexual reproduction involves the fertilization of female gametes, while asexual reproduction involving a number of processes where new colony formation occurs through partial removal of the tissue by fragmentation or bailout polyps. Coral gender is distinguished by hermaphrodite and gonocoric, where hermaphrodite produces male and female gametes in one colony, while gonocoric is a coral that produces male and female gametes individually throughout its life. Corals have two reproductive models namely spawning and brooding (containing larvae) (Richmond 1997).

Raja Ampat Regency has a total area of 4.6 million hectares (Mambrisaw et al 2006), and 553 coral species (Veron et al 2009). However, there have been signs of damage due to destructive fishing (McKenna et al 2002). The Dampier Strait Area is one of the regional aquatic conservation areas (KKPD) in Raja Ampat Regency that has a total area of 336,000 hectares (KEPMEN KP 2014). However, there has been damage to the coral reef ecosystem in this area due to minor illegal fishing activities as was reported by the communities near the sites (Pada et al 2016) and the MV Caledonian Sky grounding which caused damage to a total area of 18,882 m² with a significant damaged area of 13,270 m² (Tapilatu et al 2017).
Generally, coral transplants are often carried out because these kinds of actions are relatively easy to be done. Transplants are generally seen from a biological view with a survival rate of around 50-100%, when transplanted at the same location where coral fragment were taken (Harriott & Fisk 1988). However, this activity cannot play a role in improving damaged coral reef ecosystems, so that the main factors causing coral reef degradation are understood and addressed (Harriott & Fisk 1988; Ammar et al 2013). Recruitment is an important part of the process of forming and developing communities in a coral reef ecosystem in nature. In other words, recruitment guarantees community formation and provides assurance that this population will be sustainable (Erwin et al 2008). Coral recruitment can use natural substrates or artificial substrates. Research of Harriott & Fisk (1988) used natural substrate such as slices of massive Porites spp., slices of massive Platygrya spp., thick branches of Isopora palifera, the outer of Platygrya spp. and branches of Pocillopora grandis. Therefore, it is necessary to recruit coral species using artificial collector substrates as was previously done by Birkeland et al (1981) using PVC plates; concrete, gabbro, granite, and sandstone by Burt et al (2009); ceramic substrate by Maida et al (1992) and Mangubhai et al (2007) and concrete by Tioho et al (2001).

The present study aimed to analyze the effect of substrate and its laying duration on the recruitment of coral genus and the diversity of species of coral attached. The type of corals counted for abundance and diversity was the coral genus that attached to the surface of the substrate. Harriott & Fisk (1988) in his research used natural substrates like slices of massive Porites spp., slices of massive Platygrya spp., thick branches of I. palifera, the outer of Platygrya spp. and branches of P. grandis. But there are also experiments with usage of artificial substrates. The results showed that recruitment was higher on artificial substrates compared to natural substrates as they are hard and stable (Richmond 1997), has a rough surface (Harrison & Wallace 1990), therefore can be substrates for recruitment. Field et al (2007) reported that substrate size does not produce proportional levels of recruitment. Reproductive time and different larval planulae competition periods in each genus, can affect the time of laying the substrate.

Time of corals reproduction in Indonesia can be grouped into three types of seasons: spawning before the rainy season (October-November), spawning during or after rainy season (January-April) and spawning or planula release throughout the year. Coral spawning is generally influenced by lunar rotation that occurs after full moon while planulae release by brooding coral in the new moon to full moon (Munasik 2002). Research conducted by Harriott & Fisk (1988) approximately 20 weeks, during the time of the predominant seasonal spring/summer in two reef area (forereef and backreef) showed that the highest attachment was found in the backreef compared the forereef. Brooding coral normally release larvae that contain zooxanthellae and lipids for food reserves. As a result larvae have a competition period of approximately 100 days after release and before sticking to the substrate (Richmond & Hunter 1990). Conversely on coral broadcast-spawning (Acropora tenuis) has a period of only 20 days (Richmond & Hunter 1990). This finding is supported Mangubhai et al (2007) by its research conducted for 20 months, who showed 4294 recruitments consisted of Pocilloporidae (4024 ind.), Poritidae (139 ind.), Acroporidae (58 ind.), Faviidae (5 ind.), other (14 ind.) and unknown (54 ind.).

Material and Method

**Description of the study sites.** The study was conducted from August 2018 to February 2019 in the Saleo Beach Area, Raja Ampat District Dampier Strait Area, Indonesia (Figure 1).
Framing and substrate setup. In this study the substrates consisted of andesite stone, unglazed ceramic substrate and mild iron drum (Figure 2).

The substrate was in a square form with the size of 20 x 20 cm. The method used was Coral Recruitment Tiles (modified from Hill & Wilkinson 2004). The location of the study was determined by using purposive sampling method that determined the location of data collection based on the consideration of individuals or researchers at the research location. The substrate collector was placed on an iron frame used for one of the binding sites for the substrate to avoid excessive sedimentation of the substrate surface or lost due to sweeping currents and placed 10-15 meters apart from each other at a depth of 5–7 m. The collector substrates were tied to the frame three pieces per substrate type with a total of nine substrates (Figure 3). In addition, measurements of water physical parameters (temperature, salinity, depth and velocity of the current) were measured as well as the percentage of coral cover (Hill & Wilkinson 2004; Manuputy & Djuwarlah 2009) as supporting data.
Samples were taken at 2 months, 4 months and 6 months after placement (MAP) on each frame where it was tied and then withdrawn to be observed at the Biology Laboratory of SMA Negeri 1 Raja Ampat in Waisai.

Figure 3. The placement of the collector substrates on the frame. (a) Ceramics; (b) Plate of mild iron drum; and (c) Andesite stone.

**Formulas and statistical analysis.** The formulas were used to calculate the abundance and diversity of coral larvae recruitment types as follows:

**Abundance.** The abundance of coral larvae was calculated using a formula adopted from Odum (1983) as follow:

\[ \text{KR} = \frac{\text{Ni}}{\text{N}} \times 100\% \]

- **KR** : Individual abundance
- **N** : Total number of individuals
- **Ni** : Number of individuals

**Diversity.** The diversity of coral larvae attached to the collector substrate was calculated using the Shannon & Wiener diversity index (Krebs 1989) as follow:

\[ H' = -\sum\{(\text{n}_i/\text{n}) \ln (\text{n}_i/\text{n})\} \]

- **H’** : Diversity Index
- **n_i** : Number of individuals
- **n** : Total number of individuals

With criteria as follow:

- **H’<1** : shows a low level of diversity
- **1<H’<3** : shows a moderate level of diversity
- **H’>3** : shows a high level of diversity

Observation of the condition of coral reef cover was then processed by using the formula of percentage of coral cover (Manuputty & Djuwariah 2009) as follow:

\[ \% \text{Cover} = \frac{\text{number of each component}}{\text{total komponen (50)}} \times 100\% \]

Coral cover category was obtained (Giyanto et al 2017) as follow:
All data were tested for assumptions of normality and homogeneity of variance by the Levene test. In addition, the non-parametric analysis of the Kruskal-Wallis Rank test (<0.05) was performed to see the difference in number of coral genus attached in each substrate type at different exposition durations. Statistical analyses were performed using SPSS software version 25.

**Results.** Oceanographic parameters at the study site such as water temperature ranged from 29.7 to 33.2°C (31.4±1.76), salinity from 26.9 to 30.2‰ (28.8±1.69), with 100% brightness and current velocity was between 81 and 125 mm/s (106.7±24.09) (Table 1).

The attachment of coral species to the three types of substrate during the study period is presented in Table 2. In this study, six genus were found consisting of the genus: Pocillopora (8 ind./38.10%), Porites (5 ind./23.81%), Seriatopora (4 ind./19.05%), Montipora (2 ind./9.52%), Goniastrea (1 ind./4.76%) and Stylophora (1 ind./4.76%). The diversity was classified as moderate (1.5).

The recruitment of coral genus during the observation on each substrate type is presented in Figure 4. The health of coral reefs in the research location was classified as poor, with a percentage of live coral cover of 14%. The analysis of the data shows that the coral recruitment was affected by the exposure time of substrate collector (<0.05), while the type of substrates did not affect the recruitment of coral species (>0.05).
Figure 4. Recruitment of coral genus. (A). Months after substrates exposure and (B). Type of substrate.

**Discussion.** Coral reefs live at temperatures above 18°C in the temperature range between 23 to 30°C and at short-term can tolerate temperatures of 36-40°C (Nybakken 1988; Nontji 2005; Romimohtarto & Juwana 2007; Giyanto et al 2017). Richmond (1997) argues that good salinity for recruitment ranges from 32 to 40‰ and when water movement tends to be calm. Penetration of sunlight affects the photosynthesis process, which results from photosynthesis in the form of carbohydrate that contributes to the reproduction process (Abrar 2011). Recruitment of coral planula larvae is influenced by several parameters including reproductive timing, planula larvae competition period, current pattern and velocity, substrate availability, predator density and competition (Richmond & Hunter 1990). The abundance of recruitment on andesite substrate had the highest attachment of 11 individuals (52.4%), unglazed ceramics and mild iron drum each of 5 individuals (23.8%). However, the analysis showed that the substrate had no effect on the recruitment of coral species (>0.05). Research conducted by Golbuu & Richmond (2007)
showed that biofilm layers might facilitate coral larvae attachment. Furthermore, Sneed et al (2014) explained that coral planula larvae would stick to the biofilm layer as a natural response. The existence of macro algae, barnacles and other organisms could create habitats that are less suitable for attaching coral species (Ritson-williams et al 2010).

In the present study, the existence of the substrate as the recruitment of coral species was very limited in the study location. The percentage of fault cover was higher in the study location with 24% with the percentage of live coral cover of 14% (bad/damaged category). The survey conducted and organized by Conservation International (CI) Indonesia reported that there is still a significant amount of coral rubble that increased significantly from 22.5% (2014) to 31.6% (2016). The abundance of coral species recruitment differed between observation periods (Table 1). In the 6 MAP (February 2019) there were attachments of 15 ind./71.4%, while the attachment in 2 MAP (October 2018) and 4 MAPs (December 2018) were similar at 3 ind./14.3%. The data analysis showed that the duration time of substrate collector laying affected the coral species recruitment (<0.05). The attachment was dominated by the Pocillopora genus as much as 8 ind./38.10%, while the genus Goniastrea and the genus Stylophora were represented by 1 ind./4.76%, respectively.

Veron (2000) in Rahman et al (2014) stated that corals from Pocilloporidae were one of the pioneering corals in coral reef ecosystems and their existence greatly determines the success of other types of coral recruitment. In addition, it can be seen from the reproductive period of the Pocillopora genus that it occurs throughout the year (Richmond 1997; Munasik 2002). Moreover, the study of Harii et al (2002) showed that the genus Pocillopora (P. damicornis) had a period of competition for 100 days. The study conducted by Mengubhai et al (2007) also found Pocillopora genus recruitment of 93.7% for 28 months (May 2003-August 2005). Goniastrea genus (Goniastrea retiformis) has a reproductive period in October after full moon (Munasik 2002). The Baird et al (2003) study showed that Goniastrea retiformis and Coelastrea aspera were predominantly attached to a depth of 2 meters. This is supported by Veron (2000) in Rahman et al (2014) that the genus Goniastrea is included in several genera that are tolerant of direct air exposure.

The Stylophora genus has a long reproductive period from December to July (Rinkevich & Loya 1987). This genus is spread in shallow areas (Suharsono 2008) and has a higher diversity in the western Pacific Ocean and Red Sea than in the central Indo-Pacific (Veron 2000 in Rahman et al 2014). Furthermore, Richmond (1997) explained further that the genus Goniastrea and the genus Stylophora have sequential hermaphroditic sexes where is a different sperm and egg maturity time. The diversity of coral species attached to the substrate during the study had a moderate diversity (1.5). Research of Phardana et al (2013) obtained a moderate diversity at a depth of 5 m and low to moderate diversity at a depth of 10 m. This is predicted due to spawning events that are less simultaneous due to a region's annual temperature range (Munasik 2002). The simultaneous occurrence of coral spawn in the GBR occurs in the range of the annual temperature of 12°C (Babcock & Heyward 1986).

Conclusions. The highest abundance of coral larvae recruitment on the substrate collector was Pocillopora (38.10%), followed by Porites (23.81%), Seriatopora (19.05%), Montipora (9.52%) as well as Stylophora and Goniastrea (4.76% each). The diversity of coral species recruitment was in the medium category. The type of substrate used did not affect the recruitment of the coral species attached. The exposure time affects the recruitment of coral larvae. Recruitment of coral genus can guarantee the existence of coral reef ecosystems in nature that have an impact on the availability of fish resources for the needs of the community.

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