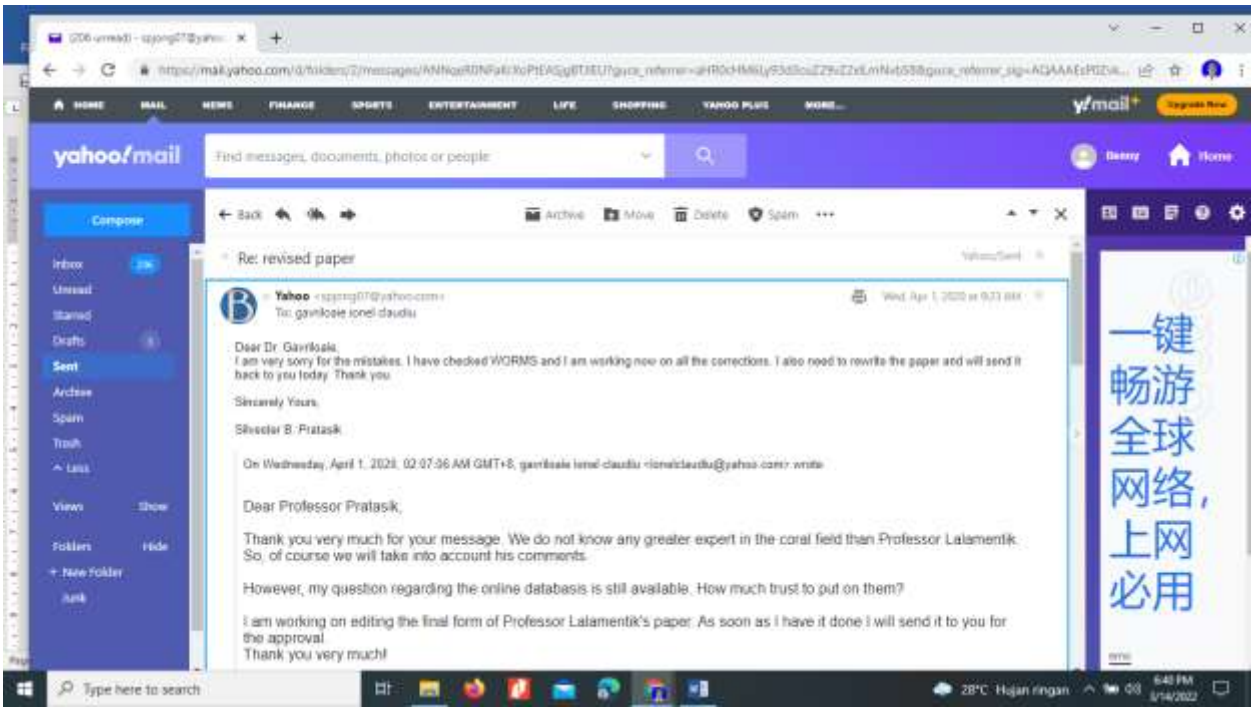

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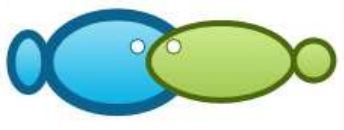

Faviidae coral colonization living and growing on agricultural waste-materialized artificial substrate

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Abstract. A study on colonization of Faviidae corals on the agricultural waste-materialized artificial substrate was conducted in Selat Besar, Ratatotok district, southeast Minahasa regency, North Sulawesi. Nine artificial substrates moduls made of mixture of cement, sand, padi husk, and bamboo were placed for about 5 years on the sea bottom of Selat Besar waters. All corals of family Faviidae found on the artificial substrate were collected. Results showed that Faviidae corals could live and develop on those substrates. Fifteen species of 5 genera of Faviidae, *Favia pallida, F. laxa, F. stelligera*, *F. matthaii Favites pentagona, F. russelli, F. complanata, F. bennetae, Echinopora gemmacea, E. lammelosa, Goniastrea aspera, G. favulus, G. pectinata, Platygyra daedalea,* and *P. senensis* were recorded in the present study. Mean number of colonies of Faviidae corals was 3 col.mod^{-1}, while mean diameter of the corals attached on the artificial substrate was 7.45 cm long. The distribution pattern of Faviidae corals was clumped. The diversity of Faviidae corals on the artificial substrate was low (H' = 0.677 < 1). The dominance index showed no dominant species (D = 0.23). In addition, the artificial substrate modul in this study could become an alternative technique to rehabilitate the degraded coral reefs.
Key Words: diversity, dominance, distribution pattern, Selat Besar.

Introduction. Corals are animals belonging to phyllum Cnidaria (Reid et al 2009), while coral reef is an ecosystem built by calcium carbonate-producing marine biota, especially coral animals, together with other biota living on the sea bottom or water column, such as mollusks, crustaceans, echinoderms, porifera, tunicates, and other biota free-living in surrounding waters including plankton and fishes (Giyanto et al 2017; Lalamentik 1995). According to Barus (2013), coral reef is one of the unique communities that are entirely formed from biological activities. It is one of the main coastal and marine ecosystems that possess the highest productivity and biodiversity so that it is often called as tropical marine forest.

Coral Triangle (CTI) is known as center of world marine biodiversity with the highest coral diversity, 76% of total coral species. The region inside the ecological boundary of Coral Triangle covers nearly 73,000 km^2 of coral reefs (29% of total world coral reef area) distributed in six countries, Indonesia, Malaysia, Filipina, Timor Leste, Papua New Guinea and Solomon Islands (Burke et al 2012). As part of the CTI, Indonesia is an archipelagic country with 16,056 islands, 1,922,570 km^2 terrestrial area and 3,257,483 km^2 water in the west Indo-Pacific (BIG 2016). Indonesia that is located in the coral triangle area is recognized as one of the countries with high biodiversity consisting of more than 80 coral genera and 596 species, particularly in North Sulawesi waters that has been recorded more than 80 genera (Suharsono 2008).

Coral taxonomic and distribution studies in North Sulawesi were carried out by several scientists (Lalamentik 1998; Halidu et al 2016; Nasaru et al 2017; Suleman et al 2017; Lalamentik & Rembet 2018). So far, there is no study on corals of family Faviidae living and growing on the artificial substrate, especially in North Sulawesi waters. Hence, present study focuses on Faviidae coral colonies on the artificial substrate with the

objectives of identifying the coral species, analysing the density and the diameter of the coral colony, the ecological index, and assessing the distribution patterns. This finding is expected to be one of the references in coral development studies, concerning Faviidae coral colonization on the artificial substrate. Besides, it could provide alternative artificial substrates in coral reef rehabilitation program.

Material and Method

Study site. This work was accomplished in Selat Besar waters, Ratatotok district, southeast Minahasa regency (Figure 1), North Sulawesi. Selat Besar is flanked by Totok bay and Moluccas Sea. The study site was laid on 0°51'34.945''S and 124°44'14.416'' E (Figure 1) using Global Position System (GPS).

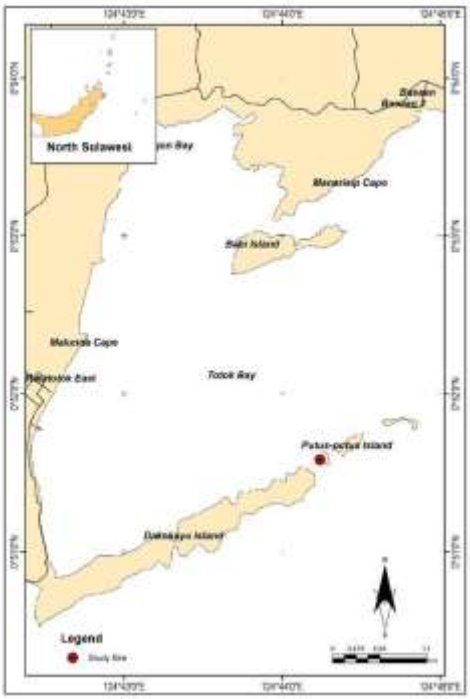

Figure 1. Sampling locality.

Artificial substrate construction. In this study, 9 artificial substrate moduls were set on the sea bottom, approximately 7-8 m depth. Sheehy (1986) stated that one of the major roles of artificial substrate placement in the water is to create new habitats similar to artificial reefs to be inhabited by target species. The use of artificial substrate as coral new habitat had been conducted in Singaporean waters in order to restore the coral reefs (Ng & Chou 2017). Each modul consists of 10 concrete blocks made of mixture of padi husk, sand, and cement. The block frames were made of bamboo. The use of bamboo in concrete construction has been done before as mentioned in Glenn (1950) and Mehra & Ghosh (1965). One of the properties that would make bamboo a good substitute to steel in reinforced concrete is its strength (Varma, 2017). The block had a dimension of 100 cm leng, 15 cm width, and 15 cm height. The blocks were set in such a manner to yield a modul. Each modul is estimated to have an area of 4.5 m². These 9 moduls were placed since June 2014. Sample collections were carried out in July 2019 (after 5 years of

deployment). The period of 5 years is determined because the massive coral growth is slow. This duration is considered enough to see whether there is Faviidae coral capable of adhering and growing on the artificial substrate.

Sample collection and handling procedures. All massive coral species found to attach on the modul substrate were taken using a chisel and hammer. The samples were then put into labelled bag as the modul number. All corals were collected by using SCUBA equipments. All activities were documented by using an underwater camera.

Before species identification, the coral specimens were soaked in bleach-containing freshwater for 24 h in order to kill the coral and to prevent the presence of fungi. The corals were then cleaned under the running water to remove the attached dirts so that the clean coral and the bleaching coral skeleton were obtained. The corals were placed under direct sunlight to get dry to ease the identification.

Species identification. Coral identification was done following Veron (1986; 2000), Suharsono (2008), and Veron et al (1977). The specimens of Faviidae corals were examined through morphological observations under the SZ51 Olympus microscope on the characteristics of paliform lobe, septa cleats, coralite type, number of first septa, second septa, and third septa. The measurements of width of paliform lobe, coralite size, and calix size used a multitoyo digital caliper.

Data analysis. Faviidae coral colonization data were directed to ecological index analyses as follows:

Dominance index. This index was employed to know the dominant species in data sampling boundary. The present study applied Simpson dominance index (Krebs, 1989):

$$D = \sum_{i=1}^{s} \left[\frac{ni}{N}\right]^2 \quad \text{..... (1)}$$

Where D = dominance index, ni = number of *i* individuals, and N = total number of individuals.

Dominance index ranges between 0 and 1, if D approaches to 0, it indicates no dominance and the community structure is in stable condition, and if D approaches to 1, it indicates the presence of species dominance.

Density. The population density was calculated using Krebs (1989) as follows

$$K = \frac{Ni}{A} \quad \text{..... (2)}$$

Where, K = density (ind.modul^{-1}), Ni = number of individuals, and A = number of moduls where samples were collected.

Diversity. The diversity index of genus *Favia* Oken 1815 was calculated using Shannon-Wiener equation (Krebs 1989):

$$H = \sum_{i=1}^{s} \frac{ni}{N} \left(\frac{\ln ni}{N}\right) \quad \text{..... (3)}$$

Where H = Shannon-Wiener diversity index, ni = number of individuals *i*, N = total number of individuals, and s = number of genera.

Distribution pattern. The distribution pattern of Faviidae corals were estimated using Morisita index (Krebs 1989):

$$Id = q \frac{\sum_{i=1}^{q} ni\ (ni-1)}{N\ (N-1)} \quad \text{..... (4)}$$

Where Id = Morisita index, ni = number individuals in each plot, n = total number of individuals in all plots, and N = number of plots, in which Iδ = 1 is categorized as random distribution, Iδ>1 as clumped, and Iδ < 1 as uniform.

Results and Discussion

Water conditions of Selat Besar. Water quality is crucial for colonization of macroinvertebrates (Orwa et al 2018). Water temperature is one of the limiting factors for aquatic organisms to live, one of which is coral. Field measurements found that water temperature in the study site ranged from 29° - 30ºC. This range is still suitable for coral development. According to Kurniawan (2011), corals, in general, can live at the temperature above 18ºC, while growth, they require an ideal water temperature, between 25°-32ºC. Most coral reefs exist where salinity is stable and where average salinity is that of normal seawater 34-36°/₀₀ (Sheppard et al., 2017). Water salinity in the study site was between the range of 30-31°/₀₀. Guntur (2011) found that water salinity for ideal coral growth in Indonesia ranged from 29 to36°/₀₀. Therefore, water salinity in Selat Besar highly supports the coral to grow well. Light intensity does not influence larval settlement, and their response to light intensity may be species-specific (Mundy & Babcock 1998). This study was done in shallow water, about 8 m deep, so that light intensity is not a limiting factor for coral settlement. The study did not also focus on the coral settlement in relation with the light intensity.

Corals of family Faviidae recorded on the artificial substrate. Physical and biological factors are important for recruitment success (Doropoulos et al 2016), As many as 15 coral species of 5 genera were recorded in this study. *Favia* and *Favites* had the highest number of species, each with 4 species, followed by genus *Goniastrea* with 3 species, then *Echinopora* and *Platygyra,* 2 species, respectively. Table 1 demonstrates the coral species of Faviidae encountered on the modul substrate with mean number of colonies of 3.00 per modul. Even though these numbers are less than those reported by Kilfoyle et al (2008), 13 col.mod.$^{-1}$, the colonies comprised several coral families. The coral genera of Faviidae inhabiting the artificial substrate apparently come the coral reef around Selat Besar waters. It is reasonable, since Faviidae is coral family generally found in Selat Besar waters (Lalamentik 1996;1997;1998).

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Table 1

Faviidae coral species encountered living on the artificial substrate modul

No	*Species*
1	*Echinopora gemmacea* (Lamarck, 1816)
2	*E. lammelosa* (Esper, 1795)
3	*Favia laxa* (Klunzinger, 1879)
4	*F. matthai* (Vaughan, 1918)
5	*F. palida* (Dana, 1846)
6	*F. stelligera* (Dana, 1846)
7	*Favites bennetae* (first record for Central Indonesia)
8	*F. complanata* (Ehrenberg, 1734)
9	*F. pentagona* (Esper, 1794)
10	*F. russelli* (Wells, 1954)
11	*Goniastrea aspera* (Verrill, 1864)
12	*G. favulus* (Dana, 1846)
13	*G. pectinata* (Ehrenberg, 1834)
14	*Platygyra daedalea* (Elis & Solander,1786)
15	*P. sinensis* (Edwards & Haime, 1857)

Favites bennetae recorded in the present study is the first record found in the coral reef of Central Indonesian waters. This species was previously mostly found in the northeast of Australian waters (Veron et al 1977). Moreover, genus *Favia* was found having the highest mean number of colonies, 1.11 col.mod^{-1}, followed by *Goniastrea,* 0.67 col.mod^{-1}, and the lowest was found in *Platygyra,* 0.22 col.mod^{-1} (Figure 2). Variations in number of Faviidae colonies per modul are dependent upon the abundance of larvae that survive and settle on the substrate. Faviidae tends to have good adaptability to occupying the available artificial substrates. Bachtiar et al (2011) found that Faviidae is one of the coral families capable of surviving in the reef ball deployed on the sea bottom.

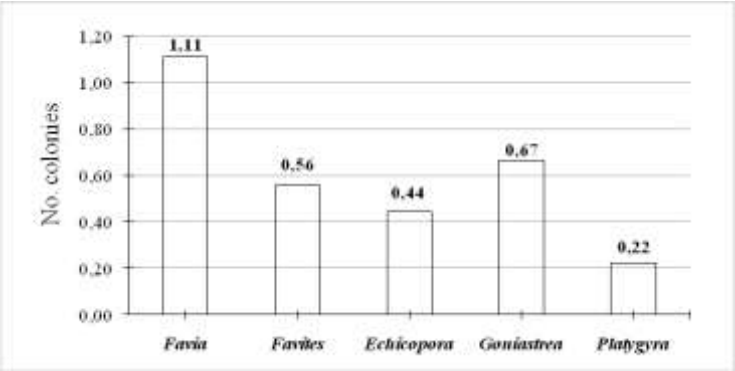

Figure 2. Mean no. colonies of *Faviidae* per modul.

Mean diameter of the coral colony on the artificial substrate was 7.45 cm with the largest recorded in *Favia laxa,* 10.5 cm and the smallest in *F. palida,* 3 cm. In comparison among genera, mean diameter of Faviidae corals attached on the artificial substrate ranged from 5.88 to 8.50 cm. Genus *Platygyra* has the largest mean diameter, 8.50 cm, and *Echinopora* had the smallest one, 5.88 cm (Figure 3). Variations in colony size could result from different sequence of planular settlements. This condition, according to Bachtiar et al (2011), indicates that coral colonization on the artificial substrate sustainably occurs.

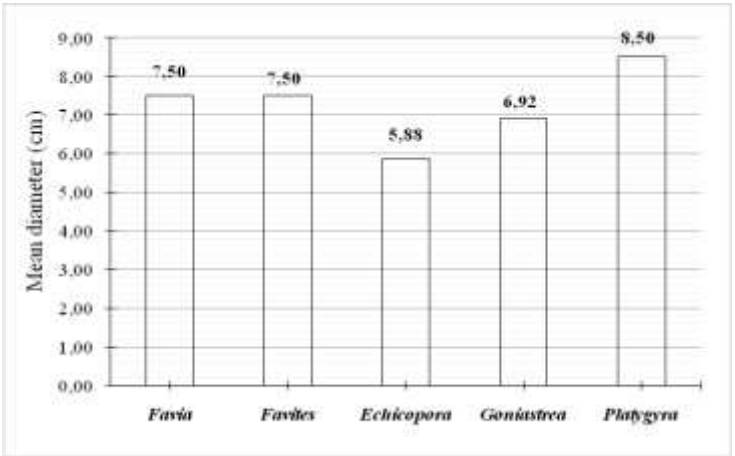

Figure 3. Mean diameter of Faviidae corals living on the artificial substrate.

Ecological index. The present study measured dominance index (D) and diversity index (H') of Faviidae corals thriving on the artificial substrate. The data are given in Table 2.

Table 2

Ecological index of Faviidae corals

No	*Ecological index*	*Value*	*Remarks*
1	Dominance Index (D)	0.23	No dominance
2	Distribution pattern (Iδ)	1.79	Clumped
3	Diversity index (H')	3.64	high

The dominance index of Faviidae corals is 0.23 (Table 3). It means that no species outnumbers the others. Selat Besar waters is still capable of supporting the coral life, and there is no competition that could make certain species be dominant (Muqsit et al 2016). The diversity index is 3.64. This value is supported by low species dominance index, in which there were 15 Faviidae species found. These numbers are high enough due to small study area cover. This finding is in agreement with Rondo et al (2014) that high diversity will cause low species dominance.

Distribution pattern analysis found that Faviidae in the study site had clumped distribution (Id = 1.79 > 1). This pattern could result from the fact that there were four moduls not occupied by Faviidae corals. In Indonesia, stdies on coral colonization was also done by Razak (2008) using Eco-reef modul in Manado bay waters, North Sulawesi, and found that the artificial substrate used are, in fact, inhabited by hard corals. Hence, the artificial substrate could be recommended as an alternative in coral reef rehabilitation program.

Conclusions. Fifteen coral species were found settling on the agricultural waste-materialized artificial substrate, *Favia pallida, F. laxa, F. stelligera*, *F. matthaii, Favites pentagona, F. russelli, F. complanata, F. bennetae, Echinopora gemmacea, E. lammelosa, Goniastrea aspera, G. favulus, G. pectinata, Platygyra daedalea,* and *P. senensis.* They had mean 3.00 col.mod^{-1} with mean diameter of 7.45 cm. The ecological index also indicated that the available artificial substrate could support various coral species to grow. In this study, Faviidae corals growing on the available artificial substrate have reflected clumped distribution. Thus, this type of modul could be used for coral reef rehabilitation.

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