

# Coral diversity on artificial reef from coconut shells in northern Bali, Indonesia

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**Abstract.** Ampou EE, Setiabudi GI, Widagti N, Prasetia IND. 2020. Coral diversity on artificial reef from coconut shells in northern Bali, Indonesia. *Biodiversitas* 21: 4331-4338. Coral reef ecosystems are very vulnerable to damage and require treatment such as artificial reefs. Artificial reef from natural product *bioreeftek* is very easy to apply and can be found in many tropical coastal areas namely coconut shells with natural coral recruitment. The purpose of this study was to calculate the percentages of coral cover, ratio and clustering of corals. At the two research sites in northern Bali, on the Pemuteran-Napoleon Reef at reef slope, depth of 5-6 m was found 13 species of live coral from 9 *bioreeftek*, deployed period 2009-2010: *Porites* sp. 32%, *Pocillopora damicornis* 13%, *Seriatopora* sp. 10%, *Acropora palifera*, *Acropora* sp., *Goniastrea* sp., *Favia* sp., *Pachyseris* sp. = 6%; *Montipora* sp.-*Echinopora* sp.-*Favites* sp.-*Fungia fungites* and *Leptoseris* sp. = 3%. At the Lovina-Adirama Temple at reef flat, depth of 6m comprised by 14 species from 14 *bioreeftek*, deployed period 2014: *Acropora palifera* 24%, *Pocillopora damicornis* 21%, *Porites* sp. 7%, *Montipora* sp. 4%-*Acropora* sp.-*Pavona* sp. = 3%, *Platygyra* sp. 2%, *Acropora humilis*-*Millepora* = 1%. Cluster Analysis showed that all corals at the two sites are correlated in percent cover, characteristics, influences and occurrences. Artificial reefs with natural materials such as coconut shells may be used to address the degradation of coral reef ecosystems. The added value of *bioreeftek* is insertion method of coral.

**Keywords:** Artificial reef, coconut shells, coral, Indonesia, Lovina, Pemuteran

## INTRODUCTION

Indonesia has vast marine waters encompassing 6.400.000 km<sup>2</sup> bordering a coastline of 108.000 km, and approximately 17504 islands (Geospatial Information Agency 2018). Indonesia has the highest category in the world in terms of coral reef biodiversity, which is estimated at 50.200 km<sup>2</sup>, although up to now it needs to be revised. Indonesia has various types of reefs including barrier reefs, fringing reefs and atolls (Tomascik et al. 1997). In addition to its high biodiversity, coral reefs in Indonesia also have a very high level of ecological complexity and are included in the center of the world's coral triangle or better known as the Coral Triangle Initiative (CTI) which includes Indonesia, Malaysia, Philippines, Timor Leste, Papua New Guinea and Solomon Islands. More than 500 coral species are spread out of a total of 70% in the Indo-Pacific (Veron et al. 2009; Foale et al. 2013; Asaad et al. 2018). Bali has a variety of coral reefs, with a total of 406 reef-forming coral species (hermatypic) (Turak and DeVantier 2012). This area also has a high level of reef fish associations and which needs to be managed in a sustainable way (Allen and Steene 1994; Nañola et al. 2011; Cruz-Trinidad et al. 2014), and globally as a supplier of tropical marine biodiversity (Turak and DeVantier 2003; Putra et al. 2018).

Coral reefs ecosystems are very vulnerable to damage. Some factors that can threaten the existence of this ecosystem are sedimentation, pollution from industrial and

household waste, fisheries activities that are not environmentally friendly (using explosives and poisons), tourism activities, and also climate change in natural factors such as increased sea surface temperatures which can cause bleaching coral if it occurs for a long time period (Hoegh-Guldberg 1999; Grimsditch and Salm 2006; Tito et al. 2019), even some of them experienced coral severe by bleaching and followed with disease (Douglas 2003; Raymundo et al. 2008; Plass-Johnson et al. 2015; Ampou et al. 2020).

The one approach in overcoming the degradation of coral reef ecosystems is to use artificial reef methods (Goreau 2009). Implementation of artificial reefs in Bali has been applied out such as several reef ball units (Fox et al. 2005), Biorock in Pemuteran which is also supported by the local community (Arifin et al. 2017; Trialfhianty and Suadi 2017), several Hexadome units in Buleleng (Yunaldi et al. 2011), artificial reef spider are so-called MARRS (Mars Assisted Reef Restoration System) at Nusa Dua (Ampou et al. 2019), and *bioreeftek* (Andayani and Ampou 2018).

In this study, we focus on artificial reefs by utilizing natural materials that were relatively not widely used. A large number of coconut trees growing in the coastal areas of Indonesia, in this case, coconut shells, which will become a medium to recruit new coral individuals naturally is an alternative in supporting coral reef rehabilitation programs. This technology is called *bioreeftek*. This

artificial reef means green and simple technology that utilizes natural product of coconut shell as a media for attaching coral planula larvae into new individual colonies or reefs (Ampou and Widagti 2018)

The objective of this study was analyze the percentages of coral cover recruitment, composition, and clustering of corals on artificial *bioreeftek* substrata on hard corals (*Scleractinia*) in Pemuteran and Lovina, northern Bali.

## MATERIALS AND METHODS

### Study location

Survey activities were carried out in March and September 2018 in northern Bali at two research sites Pemuteran and Lovina, northern Bali, Bali Province, Indonesia (Figure 1). *Bioreeftek* (Figure 2) at Pemuteran, dive site Napoleon Reef (NR) (8°07'55.5"S, 114°40'28.0" E), the number of *bioreeftek* units monitored = 9 units on the reef slope area, depth 5-6m, substrate: rock-rubble. *Bioreeftek* at Lovina dive site Adirama Temple (AT) (8°09'52.9" S, 115°00'45.8" E). The number of *bioreeftek* units monitored = 14 units on the reef flat; depth 6 m with substrate of fine sand.

### Data collection

Sampling procedures are using SCUBA (Self-Contained Underwater Breathing Apparatus) equipment,

underwater camera, diving slate, and boat. Field data collection has done by using an underwater camera and visual census (English et al. 1997; Bianchi et al. 2004; Ampou 2016). Every single individual coral that was seen recruited on the *bioreeftek* was shot with underwater camera: Photo transect habitat (Andréfouët, 2008; Scopéltis et al. 2011; Ampou et al. 2018; Putra et al. 2018).

### Data analysis

Data were collected then analysis by using the following formula:

To calculate Percentage of each coral individual on *bioreeftek* using the formula (Bluman 2012):

$$f/n * 100\% \quad (1)$$

Where: f: frequency of corals; n: total coral identified

For the calculation of the coral recruitment ratio in the *bioreeftek* in AT and NR using the formula adaptation from Larson and Farber (2012):

$$CR = \frac{CbP}{CbL} \times 100 \quad (2)$$

Where: CR: Coral Ratio; CbP: Number of coral *bioreeftek* Pemuteran; CbL: Number of coral *bioreeftek* Lovina.

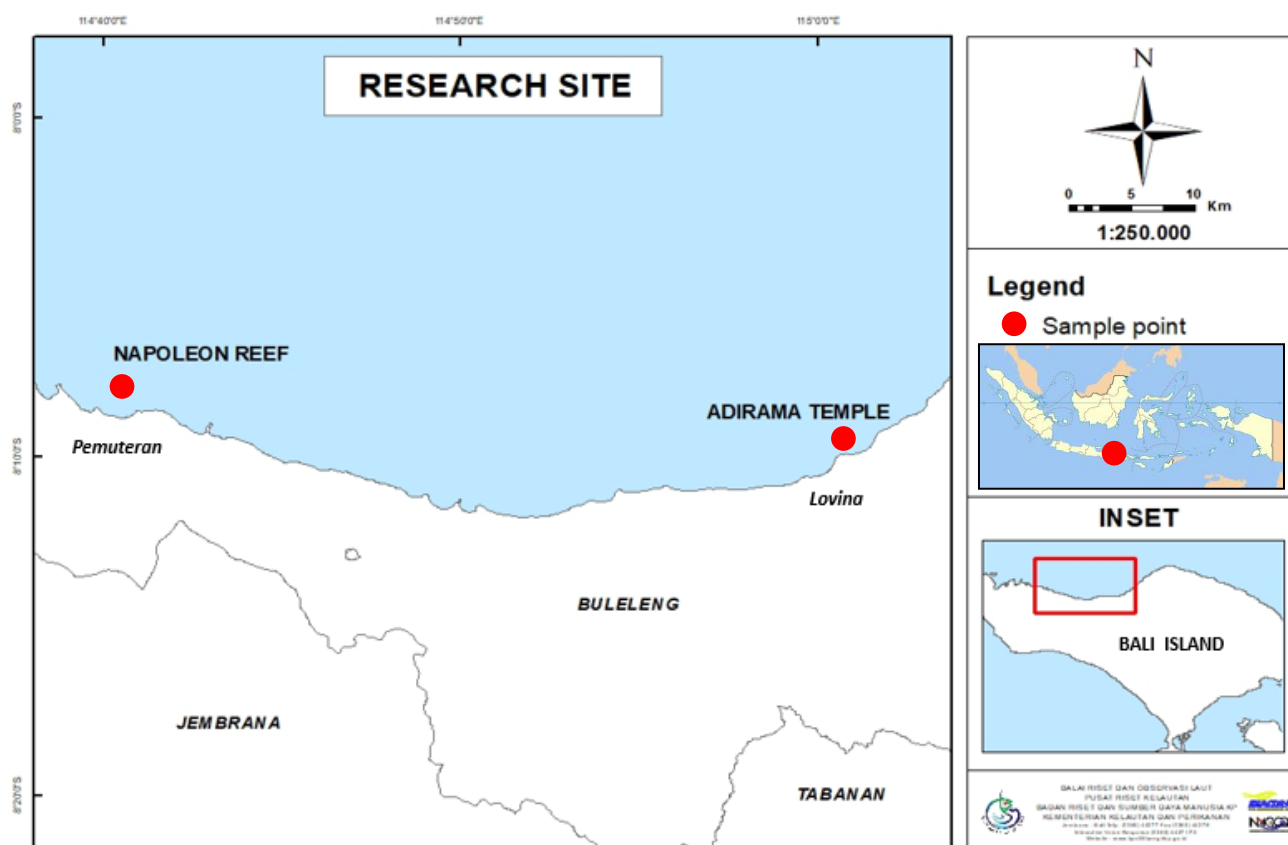
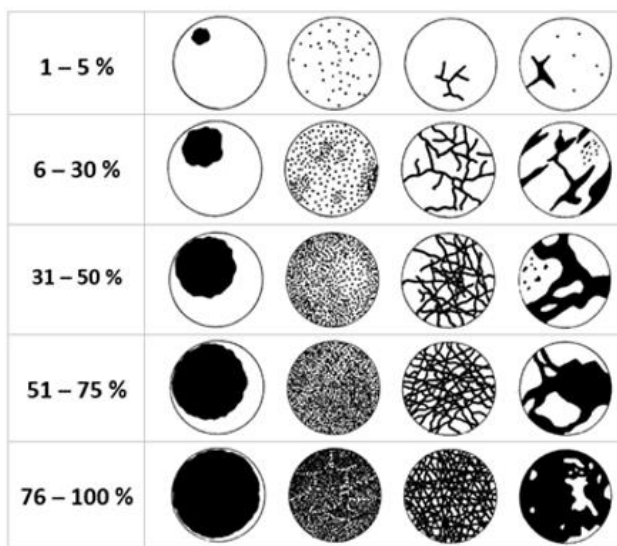


Figure 1. Study site in northern Bali, Indonesia, i.e. Napoleon Reef of Pemuteran and Adarima Temple of Lovina



**Figure 2.** Illustrate some different amounts and types of coral cover (Dahl 1981) is the visual tool used to assess the % of coral cover on *bioreeftek*

To identify dense and well-separated and to defined as the ratio between the minimal inter-cluster distance to maximal intra-cluster coral on *bioreeftek* by using Dunn index (1974); Saha and Bandyopadhyay (2012). For each cluster partition can be calculated by the following formula:

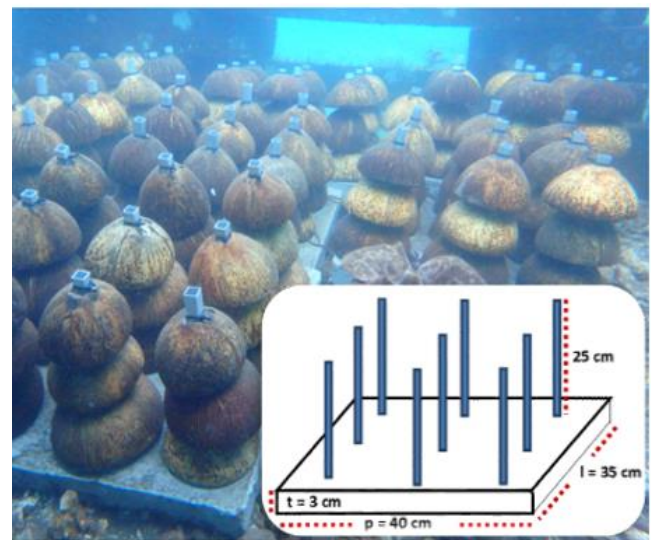
$$D = \frac{\min_{1 \leq i < j \leq n} d(i, j)}{\max_{1 \leq k \leq n} d'(k)}, \quad (3)$$

Where:  $d(i, j)$ : represents the distance between clusters  $i$  and  $j$ , and  $d'(k)$ : measures the intra-cluster distance of cluster  $k$ .

The inter-cluster distance  $d(i, j)$  between two clusters may be any number of distance measures, such as the distance between the centroids of the clusters. Similarly, the intra-cluster distance  $d'(k)$  may be measured in a variety of ways, such as the maximal distance between any pair of elements in cluster  $k$ , in this case, the type of coral among NR and AT.

#### Natural product artificial reef (*bioreeftek*)

This invention relates to a structure for the natural recruitment of coral, especially the structures for the used coconut shells. The structure has a concrete plate on which is mounted vertically a number of aluminum pipes that have a rectangular cross-section with a certain distance to arrange on each of the aluminum pipes a number of half coconut shell containing a mortar that has a translucent hole in the middle. So that the coconut shell half containing the mortar cannot be separated from the aluminum pipe, the aluminum pipe is bound near the top surface of the vertical arrangement of the coconut shell half containing the mortar with a binder. The structure can be combined with other similar structures through hooks available on the concrete slabs of each of these structures. The structure can be



**Figure 3.** The structure of *bioreeftek* (submerged)

placed on a seabed permanently or moved to another seabed after corals grow on the structure and can be adjusted depending on diameter of the coconut shells (Ampou 2012) (Figure 3) and can be applied in large quantities (Ferse et al. 2013).

## RESULTS AND DISCUSSION

### Results

The characteristics of the research sites, especially in the coastal waters of Pemuteran, NR and Lovina, AT are the reef flats, reef slopes and patch reef. *Bioreeftek* at NR was deployed in the period 2009-2010, while in AT was deployed in 2014. All results are described as follows:

The percentage of coral on *bioreeftek* at Pemuteran-NR depth 5-6m on the reef slope found 13 species of live coral from 9 *bioreeftek* dominated by massive coral *Porites* sp. = 32%, followed by coral species *Pocillopora damicornis* = 13%, *Seriatopora* sp. = 10%, while *Acropora palifera*, *Acropora* sp., *Goniastrea* sp., *Favia* sp. and *Pachyseris* sp. have the same percentage value = 6%, and the lowest identified are *Montipora* sp., *Echinopora* sp., *Favites* sp., *Fungia fungites* and *Leptoseris* sp. with the same value also = 3%. (Figure 4). In contrast to Lovina-AT, depth of 6m on the reef flat was found 14 coral species from 14 *bioreeftek* which is found as a dominant is *Acropora palifera* = 24%, then also found the same type of coral in Pemuteran with a different percentage *Pocillopora damicornis* = 21%, then *Porites* sp. = 7%, *Montipora* sp. = 4%, *Acropora* sp. and *Pavona* sp. = 3%, *Platygyra* sp. = 2%, *Acropora humilis* and *Millepora* = 1% as undominant (Figure 4).

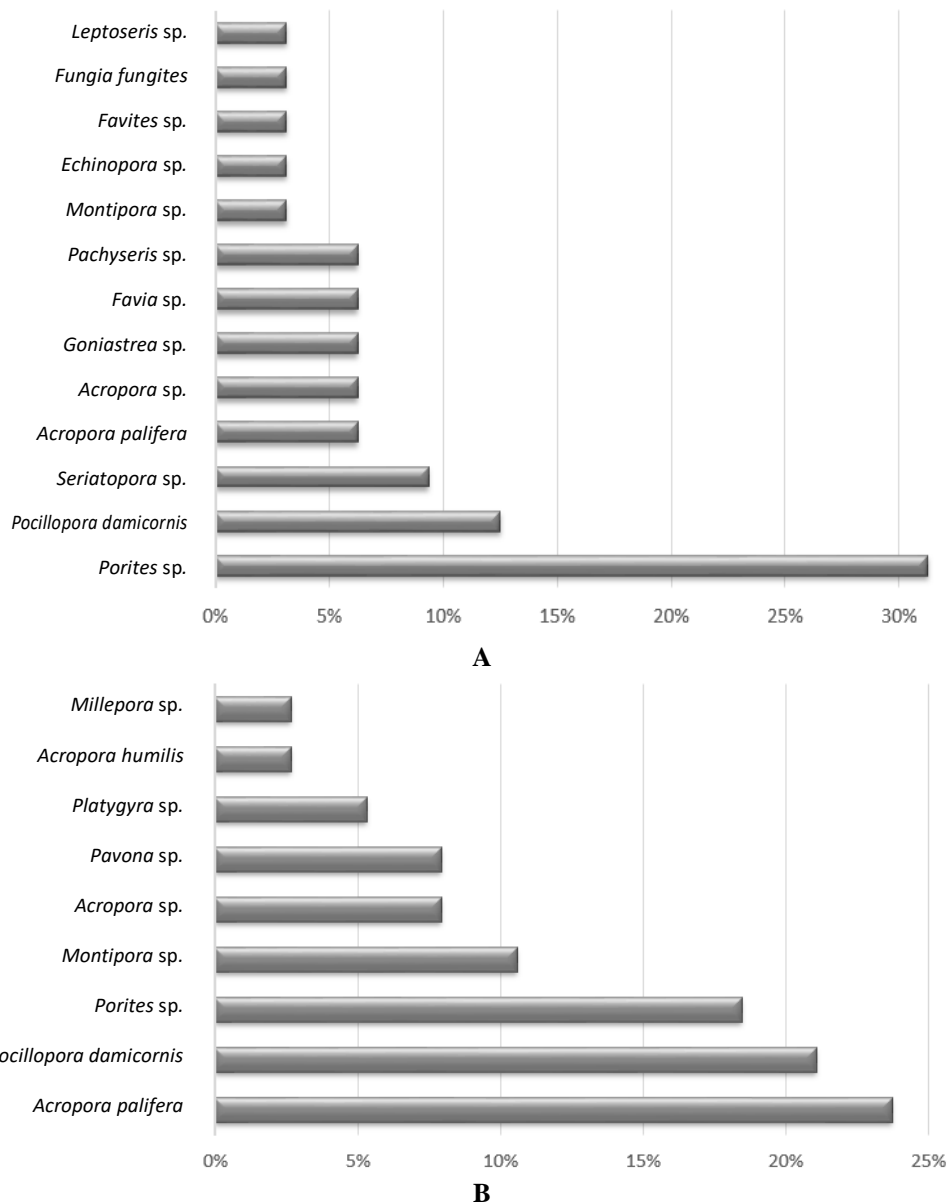
Otherwise, the Coral recruitment ratio (CR) on the *bioreeftek* in NR and AT shows that the most diversity is in NR, whereas in AT the distribution of coral diversity is relatively lower, is this because there are 13 coral types at NR, and 9 coral types at AR (Figure 5).

Based on cluster analysis value illustrate that: *Acropora palifera* and *Porites* sp. were dominant species-*Acropora* sp. (in between) and occurred in two sites; *Pavona* sp.-*Platygyra* sp. (influence-only occurred at Lovina-*Porites* sp. (massive-influence); *Acropora humilis*-*Millepora* sp. (same value-only occurred at Lovina)-*Porites* sp. (massive-influence); *Pocillopora damicornis*-*Porites* sp. (dominant-occurred in both sites)-*Seriatopora* sp. (in between-occurred in *bioreeftek* Pemuteran); *Goniastrea* sp.-*Favia* sp. (same value-massive-occurred only in *bioreeftek* Pemutera)-*Porites* sp. (massive-influence); *Pachyseris* sp. (occurred in *bioreeftek* Pemuteran)-*Montipora* sp. (same shape-between-occurred both sites)-*Porites* sp. (massive-influence); *Fungia fungites*-*Leptoseris* sp. (same shape-occurred only in *bioreeftek* Pemuteran); *Echinopora* sp.

and *Favites* sp. (invisible) which is undominant species on *Bioreeftek* (Figure 6).

### Discussion

All the type of corals that settles on *bioreeftek* it's natural recruitment except C and D particularly species *Acropora palifera* (e.g. 5,7), one of the adjacent natural coral species on that location. A coral that is separated from natural habitat and inserted between the sidelines of the *bioreeftek* by local diver (Figure 7), which means propagation techniques can be implemented (Barton et al. 2017) also on *bioreeftek*. Artificial reef also really need to be developed for larger scale coral reef rehabilitation programs, more specifically in marine conservation area such as CTI (Williams et al. 2019).



**Figure 4.** The diversity of coral on *bioreeftek* in northern Bali, Indonesia: A. Napoleon Reef of Pemuteran, B. Adarima Temple of Lovina

Recruitment of coral larvae grows well on *bioreeftek* at reef slopes (Figures 7.A, 7.B). Some structures show that there is little occupation by microalgae, turf algae, crustose coralline algae (CCA), and ascidian. These conditions may cause competition of other biota occupied the space and then larval settlement becomes low. Gomez-Lemos et al. (2018) stated that CCA and some microbes have a role in the success of coral larvae recruitment. Some of these

studies may be a subject of deeper discussion, to see the extent to which spatial competition and natural associations affect the success rate of recruitment. Given that the natural product in *bioreeftek* has the possibility to be overgrown by various types of organisms (Burt et al. 2009). These facts can be recommendations for restoration efforts that require fast time.

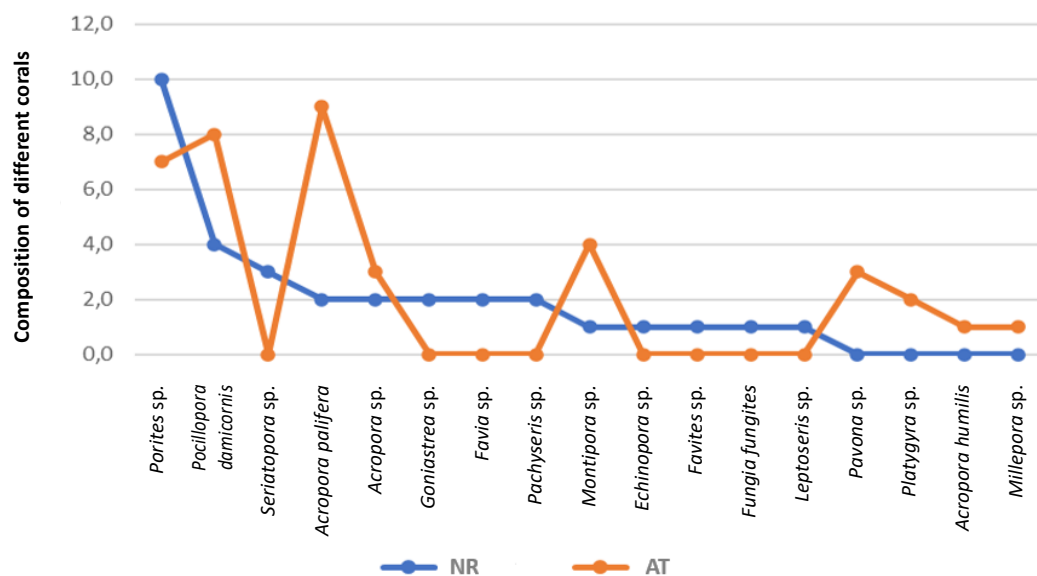


Figure 5. Composition of ratio the number of coral species encountered on *bioreeftek* between Pemuteran (NR) and Lovina (AT)

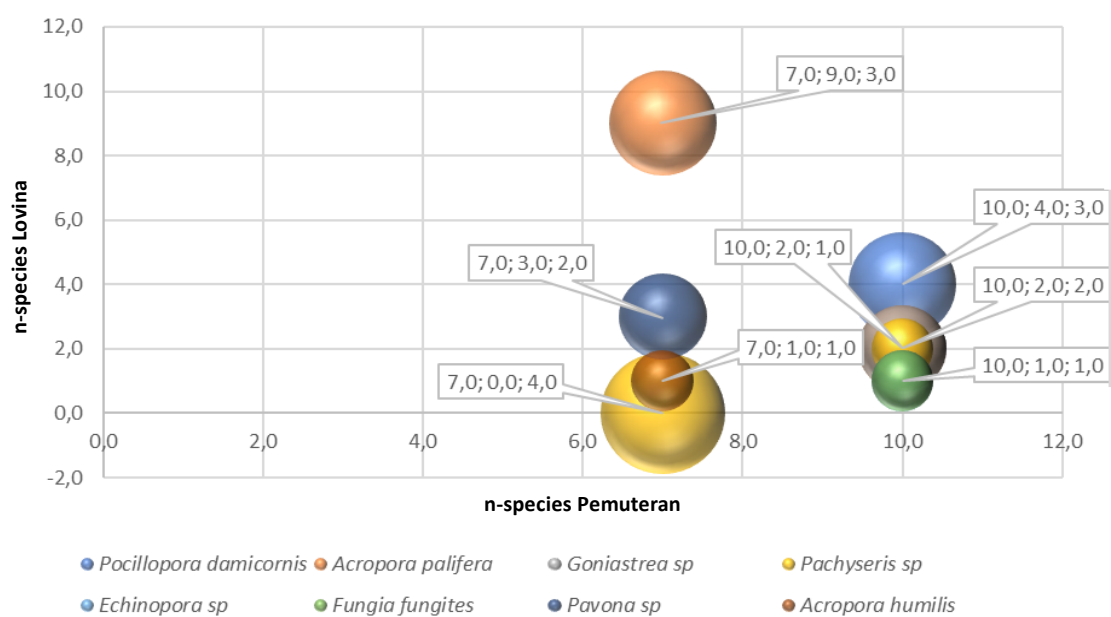
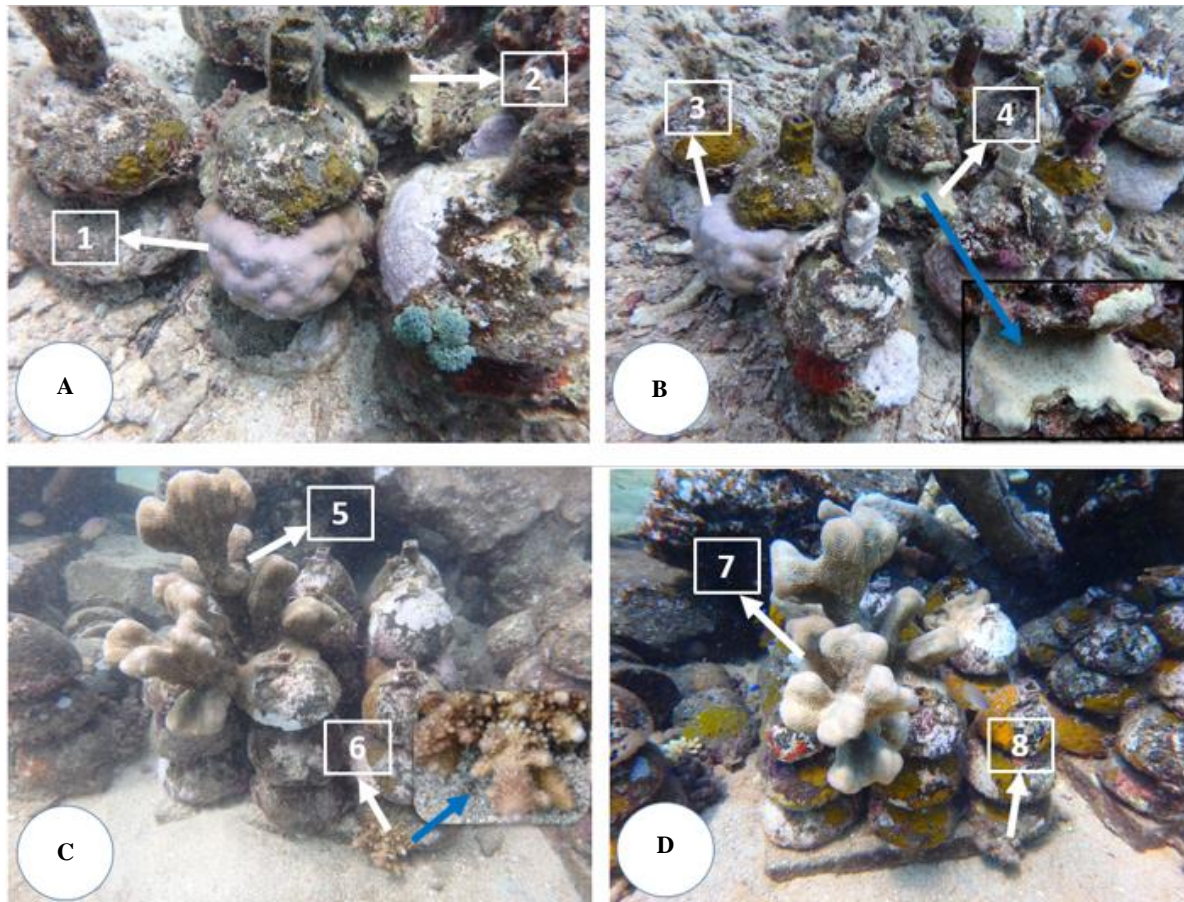


Figure 6. Clustering between types of coral encountered on *bioreeftek* in Pemuteran (NR) and Lovina (AT) of northern Bali, Indonesia





**Figure 7.** A. Monitoring March 2018 (1. *Porites* sp.; 2. *Montipora* sp.); B. Monitoring September 2018 (3. *Porites* sp.; 4. *Montipora* sp. with zoom macro-blue arrow) Dive site NR, Pemuteran; C. Monitoring March 2018 (5. *Acropora palifera*; 6. *Acropora humilis* with zoom macro-blue arrow); D. Monitoring September 2018 (7. *Acropora palifera*; 8. *Acropora humilis*) Dive site AT, Lovina

The distribution patterns of coral species in particularly hard coral (*Scleractinian*) and community structure at two locations are generally relatively similar because the area is homogeneous as same as in the Komodo Archipelago also in the Lesser Sunda Island chain, Indonesia (Fox 2004; Turak and DeVantier 2012). Corals of the *Acropora* genus grow fastest and develop on some artificial reefs by transplantation methods (Bongiorni et al. 2011; Munasik et al. 2020). Likewise, on artificial reefs *biorock* there were deployed in the waters of Buleleng which dominate by *Acropora* branching (Arifin et al. 2017) and same as in *bioreeftek* in NR, Pemuteran and AT, Lovina which is dominated by the genus *Porites*, *Pocillopora* dan *Acropora*. The addition of new recruitments of coral is growing fast. The extent of cover to the structure is higher if the reef fracture is inserted. In fact, in some structures, the insertion is done with dead coral. The resulting cover is the same as the insertion with live coral reefs. This is an important note that the placement of artificial reef structure on coral reefs will accelerate the closure of these structures. The condition of coral reefs, the location of initial placement, will influence coral cover of the *bioreeftek* structure. Coral recruitment at two sites is different, because the deployment time is different between the two, where NR has entered 10 years, while AT 6 years, which

greatly influences the recruitment process of coral planula larvae on artificial reefs, in this case, *bioreeftek*.

Based on observation inserted method particularly the surviving genus of *Acropora*, the growth rate of coral cover is relatively fast. A month since it was inserted, *Acropora* has covered  $\pm 70\%$  in coconut shells *bioreeftek*, despite before being inserted, the coconut shells have been covered by microalgae and ascidians. This does not apply to inserted with dead coral and overgrown with microalgae. However, the genus of *Porites* and *Pocillopora* grow naturally on *bioreeftek*, so consideration should be given to the placement of new *bioreeftek* to use the inserted method of dead corals. In addition, it shows the ability to compete with CCA, microalgae and ascidian (Barott et al. 2011; Cleary et al. 2016; Gómez-Lemos et al. 2018).

The main concept of the product is if there is a coral larva attached to the *bioreeftek* substrate then what should be done is: Placement of *bioreeftek* must be in areas of coral reefs that are relatively rich in diversity, and it is also possible to do coral propagation by tying coral saplings to the top of *bioreeftek* aluminum poles; Move all media to areas where coral diversity is relatively lacking, in this case, the coral reef ecosystem and its associations, or it can also move each substrate in this case the coconut shells (removed one by one from the aluminum pole) to be

tagged/adopted (for tourism, etc.) then peg in the middle hole of the coconut shell with bamboo or other environmentally friendly material; Using the base media with aluminum substrates and it can be reused with new coconut shells; Last but not least the process relocation must be determined and discuss in advance related to appropriateness area where to deploy. Ideally, monitoring should be carried out by periodic observation (English et al. 1997; Bianchi et al. 2004; Ampou et al. 2019), every 3 or 6 months, more often is better. The next step by camera and video to document the growth and development of planula larvae that attach to the *bioreeftek* substrate over time.

As an ecosystem that is very vulnerable and as an indicator to see the level of health, it is necessary to arrange sustainable ecosystem for future management actions (Hill and Wilkinson 2004; Lazuardi et al. 2012; Dee et al. 2014), such as reef rehabilitation. The concept of coral reef rehabilitation is very necessary, especially in ecosystems damaged by natural factors or human activities such as dynamite fishing, blast fishing, etc., and also studies related to the pattern of ocean currents are needed in looking at the distribution of coral planula larvae attached to artificial reefs (Fox 2004). An innovative ecological engineering strategy is needed in minimizing damage to coral reef ecosystems (Burt et al. 2011; Firth et al. 2016; Heery et al. 2018). So, this research suggests using natural materials to built artificial reefs such as coconut shells in addressing the degradation of coral reef ecosystems due to climate change, human activities, etc., also to minimize sea pollution and environmentally friendly. The more value of this *bioreeftek* structure with other artificial reefs besides natural product, natural recruitment, and propagation/transplants is the *insertion/inserted* method (Figure 7.C5; Figure 7.D7).

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