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# Used Evaluation of Stone Ash and Clamshell as Concrete Material of Artificial Reef at Pasir Putih Beach, Situbondo Indonesia

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**Key words:** Waste, artificial reef, coral reef, rehabilitation, ecosystem, clamshell, density

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**Abstract:** Stone ash and clamshell are a material that comes from the nature and is very rarely used as a mixture of artificial reefs made from concrete. This study uses stone ash and clamshell because high silica content in stone ash can strengthen the artificial reef concrete while the use of clamshell is expected to reduce the abundant waste in coastal areas. In order to know the potential of both media types of artificial reefs stone ash and clamshell as a place to live or attached to marine biota needs to be evaluated, evaluation seen from result of biota number, type composition, density and rate of attachment of biota which has been obtained after 3 months of media placed in waters. The results of data processing and statistical analysis of Mann-Whitney U test performed showed significant value of 0.755 or $p>0.05$ which means no significant difference indicating that both types of artificial reef media using stone ash and clamshell have a role to resemble the characteristics of natural reef as a place to live, a place to eat, a shelter and a place to spawn for marine biota which then repair or replace the ecosystem that has been damaged.

## INTRODUCTION

A coral reef is a habitat or shelter for any marine biotas. Coral reefs damage have negative impacts to ecosystem and many types of shellfish its caused by some factors such as: uncontrolled tourism activities, developments at coastal region, illegal fishings, pollutions and sedimentations are the main cause of coral reefs damage (Saputra, 2016). According to a study of Department of Marine and Fisheries of East Java Province in 2009 found many coral reefs damage in East Java Ocean due to covered by turf algae and sediment. This damage could decrease both ecologycal functions and its social-economy and produce an environmental imparity.

A coral reef recovery needs a long time to be a normally condition, recovery activities begin with a rehabilitation program to restore lost of nature characteristics or damage ecosystem in social, economical or ecological values (Edwards and Gomez, 2007). A rehabilitation activity by deployment artificial reefs in many types of materials with a concrete material is one of the best materials (Seaman, 2000).

An artificial reef is a structure in a seabed which is built to provide a habitat, a place for searching any food sources, a place for spawning and a coast protection against seawaves as well as a natural reef (Guntur, 2011). The utilisation of a concrete media as an artificial reef has a long endurance beneficial and can form a stable structure for an ecosystem in

addition it is also needed an eco-friendly mix material and has a potency as a biota attachment media.

Stone ash and clamshell are materials coming from the nature and their abundance amount were very rarely used as a mix of concrete material artificial reefs. The use of stone ash today is only limited as a mix material in making of bricks and paving blocks. The granite stone ash had silica content up to 64%, the high silica content in stone ash could function to strengthen concrete in artificial reefs (De Ferri *et al*., 2011). The abundance amount of clamshell wastes all this time were only their small part that were utilised as animal feed and raw materials for traditional handicrafts but most of them couldn't be used or thrown away (Agustini *et al*., 2011). Clamshell consists of a lot of Calcium ($CaCO_3$) which is a primary substance of reef builder, so, hopefully the use of stone ash and clamshell can strengthen artificial reefs and accellerate biota attachment and coral planula process.

This research was aimed to know the potency of stone ash and clamshell material for mix material of concrete material artificial reef as a habitat or an attachment place for sea biotas by determining type composition, density and attachment rate of biota inhabiting two artificial reef media types.

## MATERIALS AND METHODS

This research was carried out in November 2016, February 2017. The site of research was at Batu Lawang waters, Pasir Putih, Situbondo, East Java (Fig. 1). The concrete used in this research is pyramidal artificial reef with 60 cm height dimension, base width 60 cm, width of 30, 7 cm thick and 7 cm circle diameter (Fig. 2). The mixture of the building material in the weight volume per 1 $m^3$ of concrete on the artificial reef of stone ash is cement 315.4 kg, sand 751.8 kg, stone ashes 1127.8 kg and water 205 L while the artificial reefs shells are cement 315.4 kg, sand 1503.7, 375.9 kg and 205 L of water (Akhwady and Ridho, 2017).

The biota observation was employed at 10 pyramid artificial reef media, i.e., 5 stone ash media and 5 clamshell media. A pyramid media had 4 outer surface sides but in this research only 2 outer surface sides observed at each pyramid media, i.e., offshoreward and onshoreward position. The selection of 2 outer surface sides at each pyramid media was due to the placement of clamshell mix material pyramid artificial reef media differed from other media placements, i.e., by arranged parallel back and forth which made observations of 4 media outer surface sides were impossible. The documentation of media was done from afar or the entire surface of artificial reef media, biotas found then photographed either in macro or close-up so it's more convenient in identification. Position of artificial reef stacking on seabed can be showed in Fig. 3.

Data obtained from observation results of two stone ash and clamshell artificial reef resulted in biota amount values which then used for biota type composition, density and attachment rate calculation.

The calculation of type composition was employed to determine the percentage of individual biota in artificial reefs using a formula as follow (Curtis and McIntosh, 1950):

$$\text{Type composition (\%)} = \frac{n_i}{N} \times 100$$

Where:

$n_i$ : Individual amount of each observed type

N : Total amount of biota type

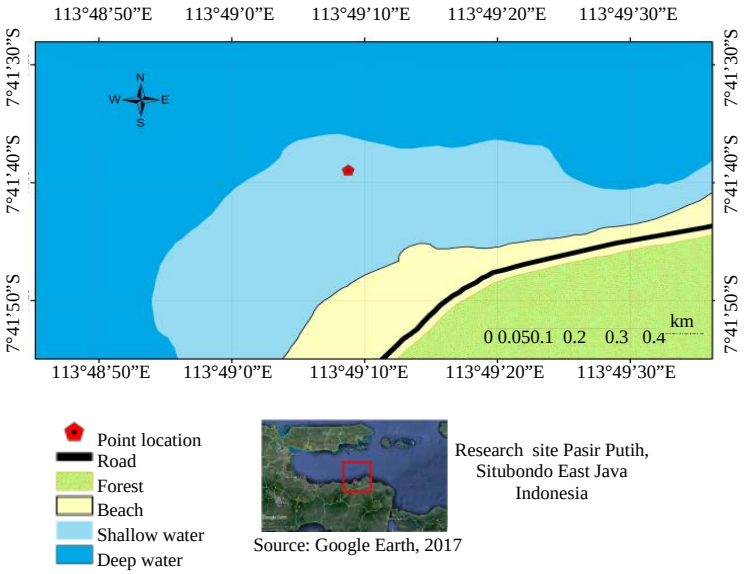


Fig. 1: Site location

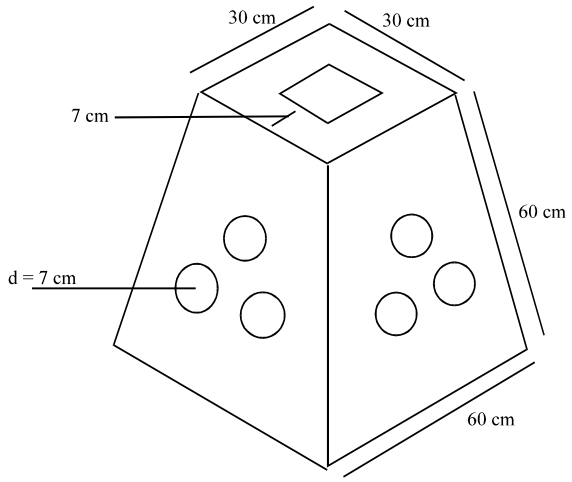


Fig. 2: Dimension of artificial concrete reef

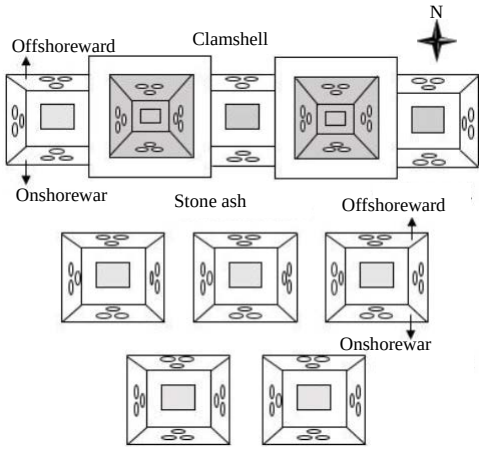


Fig. 3: Illustrations of media positions appear from above

The calculation of biota density was done to determine biota mean number per meter square of artificial reef area, using a formula as follow (Curtis and McIntosh, 1950):

$$K = \frac{N_i}{A}$$

Where:
K : Density (individual/$m^2$)
$N_i$ : Individual amount
A : Area of 10 artificial reef outer surface sides ($m^2$)

The calculation of biota attachment rate was done to determine biota attachment amount per month, during November 2016, February, 2017, using a formula as follow (Hoar *et al*., 1991):

$$L = \frac{I_a - I_0}{t}$$

Where:
L : Attachment rate (individual/month)
$I_a$ : Individual amount at final research
$I_0$ : Individual amount at initial research
t : Time (month)

To determine whether there was a significant difference between the calculation of biota type composition, density and attachment rate at two stone ash and clamshell artificial reef media types, then it was necessary doing a stastistic analysis of u test mann-whitney from biota amount, thus, it was easier to decide whether stone ash or clamshell material which was potential as mix material of concrete material artificial reef.

## RESULTS AND DISCUSSION

**Type composition:** Observations biota were performed on two outer surfaces in each of the 5 stone ash and clamshell artificial reefs media found in several biota such as bryozoan, barnacle, oyster, tunicate, sponge, Coralline algae, nudibranch and sea urchin. Biota which is visible on the artificial reefs and then documented with underwater camera, recorded and calculated the number of biota using hand counter. The results of the calculation of the number of biota obtained on the stone ash media and clamshell media are presented in Fig. 4 in the form of bar charts.

The amount and type of biota obtained at artificial reef media of stone ash (Table 1) and clamshell (Table 2) originated from 2 surface sides, i.e., offshoreward and onshoreward position.

Biotas found at stone ash media (Table 1) amounted to 8 phylums and classes, i.e., bryozoan in the Gymnolaemata class, barnacle in the Cirripeda class, oyster in the Bivalve class, tunicate in the Ascidiacea class, Coralline algae in the Rhodophyceae class, sponge in the Demospongiae class, nudibranch in the Gastropoda class and sea urchin in the Echinoidea class. Biotas found at the clamshell artificial reef media, Table 2 amounted to 5 phylums and classes, i.e., bryozoan in the Gymnolaemata class, barnacle in the Cirripedia class, oyster in the Bivalve class, tunicate in the Ascidiacea class and Coralline algae in the Rhodophyceae class. Coral recruitment at clamshell artificial reef media was also not found as same as at stone ash artificial reef media.

Biotas amount obtained then used for the calculation of type composition at those two stone ash and clamshell artificial reef media by counting the amount of one biota type and dividing it by the total of all biota types to know the percentage of biota composition at one artificial reef media type. The calculation of type composition at stone ash media was showed in Fig. 5 and clamshell media in Fig. 6 and displayed in a circle diagram.

Table 1: Biota amount of stone ash media at offshoreward and onshoreward position

| Names | Filum | Classes | Offshoreward position | Onshoreward position | Amount |
|---|---|---|---|---|---|
| Bryozoan | Bryozoa | Gymnolaemata | 35 | 42 | 77 |
| Barnacle | Arthropoda | Cirripedia | 300 | 203 | 503 |
| Oyster | Mollusca | Bivalvia | 1019 | 574 | 1593 |
| Tunicate | Chordata | Ascidiacea | 4 | 0 | 4 |
| Coralline algae | Rhodophyta | Rhodophyceae | 5 | 7 | 12 |
| Sponge | Porifera | Demospongiae | 1 | 2 | 3 |
| Nudibranch | Mollusca | Gastropoda | 1 | 0 | 1 |
| Sea urchin | Echinodermata | Echinoidea | 0 | 1 | 1 |
| | | Total amount | 1365 | 829 | 2194 |

Table 2: Biota amount of stone ash media at offshoreward and onshoreward position

| Names | Filum | Classes | Offshoreward position | Onshoreward position | Amount |
|---|---|---|---|---|---|
| Bryozoan | Bryozoa | Gymnolaemata | 109 | 105 | 214 |
| Barnacle | Arthropoda | Cirripedia | 117 | 116 | 233 |
| Oyster | Mollusca | Bivalvia | 878 | 822 | 1700 |
| Tunicate | Chordata | Ascidiacea | 0 | 42 | 42 |
| Coralline algae | Rhodophyta | Rhodophyceae | 21 | 41 | 62 |
| | | Total amount | 1125 | 1126 | 2251 |

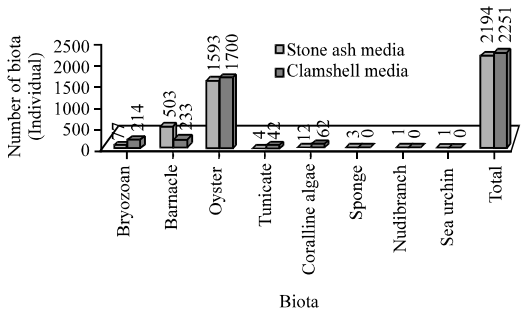


Fig. 4: Comparison the number of biota both of artificial reefs

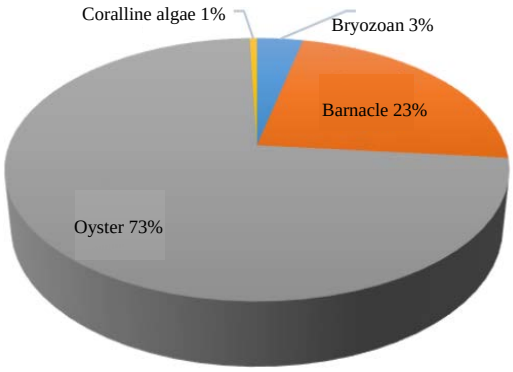


Fig. 5: Comparison of biota in stone ash-concret media

The calculation result of biota amount found at stone ash and clamshell material artificial reef, showed there were 3 biotas at those two artificial reef media types whose amounts were more than other biotas, i.e., barnacle, bryozoan and oyster. The barnacle larvae or teritip was included as a light-sensitive biota, from three teritip species examined in his research, those three teritip were types which avoided light. A barnacle larvae or

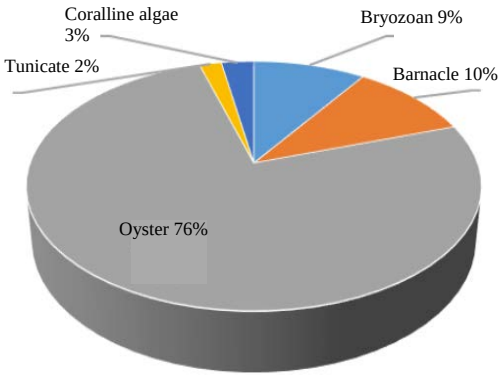


Fig. 6: Comparison of biota in clamshell-concrete media

teritip used its antenna as a sensor before doing an attachment to a substrate (Visscher, 1928). Oyster was a fairly strong biota it wasn't only found in an intertidal environment but many oysters were also found in a subtidal environment, signaled that oyster could inhabit within a region with a minimum light (Bartol and Mann, 1997). There were some biotas tended to inhabit or attach in deep waters, i.e., bryozoan, serpulids, cirripedia and ascidian (Thorson, 1964). In another research, also demonstrated that bryozoan in the *Plagioecia patina* species which employed in the research tended to select dark places or avoid light. Those researches signaled, 3 biotas whose amounts were abundance at 2 types of stone ash and clamshell artificial reef media were included as a biota which could live or survive with a minimum or little light (McKinney and McKinney, 2002).

There was amount difference in some biotas, one of them were barnacle found at stone ash media were higher than at clamshell media, this might occur due to silica content in stone ash material was preferred by the barnacle biota. According to a research carried out in two different types media, barnacle were found more at a

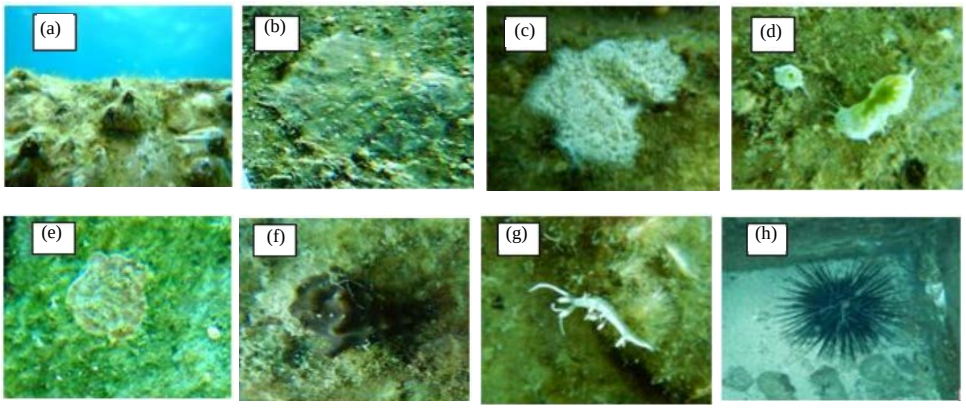


Fig. 7(a-h): (a) Barnacle, (b) Oyster, (c) Bryozoan, (d) Tunicate, (e) Coralline algae, (f) Sponge, (g) Nudibranch and (h) Sea urchin

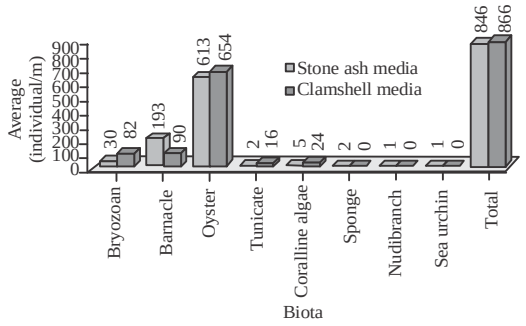


Fig. 8: Density comparison in both of concrete material

media with a higher silica content. Other biotas having amount difference at two artificial reef media types were sponge that only found at stone ash material artificial reef media as much as 3 individuals while at clamshell material wasn't found (Boesono, 2008). The silica content existed in stone ash material artificial reefs wasn't only preferred by barnacle but also by sponge biota, waters with a high silica content, the sponge amount found were more (Aziz *et al*., 2011). The silica content in stone ash material artificial reefs, very influenced barnacle and sponge attachment at those media.

There were two biotas having amount difference at clamshell media, i.e., tunicate and Coralline algae. Tunicatecommonly inhabited inorganics-rich regions and hidden places to avoid predators (Monniot *et al*., 1991) and Coralline algae consisted of carbon organics compound like cellulose obtained from a photosyntesis and also calcium compound (calcareous) from $CaCO_3$ sedimentation results (Littler and Littler, 2013) those two literatures signaled that clamshell material in an artificial reef had acontent which could affect tunicate and coralline algae attachment. There were two biotas only found at stone ash material artificial reef, i.e., nudibranch and sea urchin with the biota amount found as many as 1 individual each. Different fom other biotas whose life were attached and stayed at artificial reefs, nudibranch and sea urchin were animals living or move slowly to find any food at stone ash material artificial reef media.

Type composition obtained at artificial reef media of stone ash Fig. 5 and clamshell Fig. 6 displayed in diagram. Type composition values at stone ash media only got 4 biotas, i.e., oyster, barnacle, bryozoan dan Coralline algae. Other biotas found at stone ash artificial reef media were tunicate, sponge, nudibranch and sea urchin but these 4 biota types had type composition values <1% due to the amount found were <5 biotas. Coral recruitment which wasn't found at stone ash artificial reef media also had no type composition value. There were 5 biotas at clamshell artificial reef media which had type composition value, i.e., oyster, barnacle, bryozoan, tunicate and Coralline algae. Other biotas which had no type composition values were sponge, nudibranch, sea urchin and coral recruitment due to at clamshell artificial reef media those biotas were not found. Some biotas showed such as Fig. 7.

**Biota density:** The biota density was obtained from the biota amount found when attached and inhabited at 10 artificial reef surface sides, then divided by the areas of 10 artificial reef media outer surface sides, thus gained the comparison result of biota density at stone ash and clamshell artificial reef media Fig. 8.

The biota density obtained at two stone ash and clamshell artificial reef media types Fig. 8 described that at each 5 media were dominated by barnacle, bryozoan and oyster with the total density value was 836 individual/$m^2$ at stone ash media and 826 individual/$m^2$ at clamshell media. Furthermore, the second highest biota was gained by Coralline algae with a density value 5 individual/$m^2$ at stone ash media and 24 individual/$m^2$ at clamshell media. Other biotas only found at stone ash

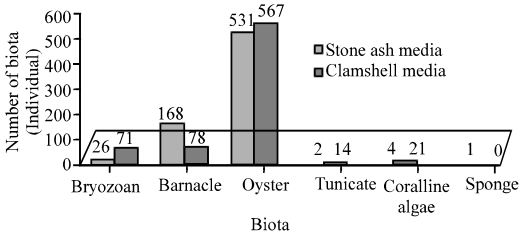


Fig. 9: Comparison of the biota attachment rate

Table 3: The waters phyisical-chemical parameters

| Parameters/unit | Data November 2016 | Data February 2017 |
|---|---|---|
| Temperature (°C) | ±29.42 | ±30 |
| Brightness (m) | ±8.05 | ±6.80 |
| Current (m/sec) | ±0.097 | ±0.25 |
| Dissolved oxigen (mg/L) | ±5.11 | ±9.41 |
| Salinity (%) | ±32.22 | ±32 |
| pH | ±8.60 | ±8.60 |
| Phosphate (mg/L) | - | ±4.38 |
| Nitrate (mg/L) | - | ±0.31 |
| Sedimentation (gr/cm$^2$/day) | - | 0.308 |

media were sponge with a density value 2 individual/m$^2$, along with nudibranch and sea urchin which had a density value 1 individual/m$^2$ each. Biota possessing a density value 0 individual/m$^2$ at two stone ash and clamshell artificial reef media types was coral recruitment because it wasn't found at those 2 media.

The total amount of biota individual density at each 10 sides of 5 media had density value 846 individual/m$^2$ at stone ash media and 866 individual/m$^2$ at clamshell media, those 2 artificial reefs media had a slight different in total biota density. The high silica content in a stone ash articial reef media affected both the growth and the amount of barnacle and sponge at that media (Boesono, 2008), so as there was biota amount difference which caused the high density value of barnacle and sponge at two artificial reef media types. An organism possessing the highest density value meant the biota had an ability to adapt with an environment it inhabited while the low density meant the biota couldn't adapt and compete with other biotas, thus, couldn't neither occupy space nor reproduce rapidly (Odum, 1993).

**Attachment rate:** The calculation of biota attachment rate was carried out to determine the biota attachment amount had been obtained during 3 months (November 2016, February, 2017), then a diagram of biota attachment rate comparison was gained Fig. 9 at both stone ash and clamshell media types.

The result of attachment rate obtained was almost same as density and type composition values result in which there were 3 biotas more dominated, i.e., oyster, barnacle and bryozoan. Nudibranch and sea urchin biotas didn't exist in the attachment rate diagram due to those biotas were biotas living non permanently at those two media types, so their attachment rate couldn't be counted. The sponge biota at clamshell media had no attachment rate because there weren't found any sponges at that media. Coral recruitments at stone ash and clamshell artificial reef media weren't found, therefore, they had no attachment rate.

The biota attachment rate was affected by 2 factors, i.e., brightness and stream velocity, whether the higher, stream velocity and brighthness in waters influenced on the biota attachment abundance (Fajri *et al*., 2011). The attachment or habitat of oyster, bryozoan and barnacle biotas were affected by low light intensity or diffuse light (Boesono, 2008; McKinney and McKinney, 2002; Visscher, 1928). The high amount and the high attachment rate of oyster, bryozoan and barnacle biotas in this research were affected by two artificial reef surface side locations directed offshoreward and onshoreward, whether those two surface side locations weren't neither directly exposed nor in the same direction with the direction of incident sunlight.

**Waters physical-chemical parameter:** Physical and chemical parameters obtained from the research had been carried out during November 2016, February, 2017 as an additional information of waters environment condition was displayed in Table 3.

Waters phyisical-chemical parameters resulted at the research site were still in safety limit for sea biotas, except waters nitrat and phosphate level were higher than the quality standard (Hidup, 2004, 2010). The high concentration of nitrats and phosphats were much affected by antrophogenics source and river discharge inputs in the surface layer would be lower than in a region close to the waters bottom, this is because nitrats in the surface layer were more utilised by phytoplanktons. The potency of explosion (blooming) of algae population was a negative effect resulted when nitrat level in the waters was so high (Risamasu and Prayitno, 2012). The abundance of phytoplanktons due to high nitrat concentrations in the waters became one of the causal factors for the high oyster amount found at those 2 artificial reef media types because phytoplanktons were food sources for oyster.

**Mix material evaluation:** Results obtained from the calculation of biota amount, type composition, density and attachment rate at two media types were not much different, therefore it was necessary to do a statistic analysis of u test mann-whitney to determine significant difference as an effect of the stone ash and clamshell mix material using. From u test mann-whitney obtained a result "sig. (2-tailed)" 0.755, at which the result showed the value of $p>0.05$ which meant $H_0$ was accepted. That statistic analysis result demonstrated that two stone ash

and clamshell artificial reef material types had no significance result difference/not much different as of those 2 types of artificial reef media affected biota amount obtained or equally had a potency as mix materials of concrete artificial reefs.

Utilization of clamshell waste abundant in the coastal areas of the peeled clamshell products, can help reduce environmental pollution and can increase economic value while the stone ash used can reduce the use of sand in the process of making artificial reefs and high silica content adds to the level of strength of concrete. The high silica content also affects coral cover and the rate of coral attachment (Guntur, 2011). Coralline algae found in both types of artificial reef media, can be an indicator that the artificial reefs of stone ash and clamshell can potentially serve as a medium for recruiting biota and coral planula. Before doing an attachment at a substrate, Coralline algae gave chemical signals (chemical cues) which then catched by coral planula to start an attachment stage. Chemical signals given by Coralline algae then responsed by coral planula before selected its habitat for attachment activities and metamorphosis (Harrington *et al*., 2004; Pilly *et al*., 2013).

## CONCLUSION

Biota types composition, density and attachment rate at two stone ash and clamshell artificial reef media types obtained weren't different significantly which were dominated by 3 biotas, i.e., oyster, barnacle and bryozoan but coral recruitments weren't found at two artificial reef types. Biota found in both types of artificial reefs illustrate that the media of artificial reefs of stoneash and clamshell resembles the characteristics of natural reefs as a place to live, a place to feed, shelter and spawning places for marine biota which then repair or replace the damaged ecosystem as well as Coralline algae found in stone ash media and clamshell, can serve as an early indicator of the potential attachment of coral larvae on artificial reefs.

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