Degradation of coral reef in Indonesia is very serious. One-way to overcome its problem standing up today that with developing the coral reef rehabilitation program. In the attempt of rehabilitation, the method of artificial reef and coral transplantation were applied. Coral transplantation has been studied in waters of Kepulauan Seribu, Jepara, and Bali. To supporting coral transplantation, it’s needed of back-up data research particularly on techniques, specific kind of coral which viable and grow fast, and identification of site characteristic suit with each coral. The study aims are to analyze growth response of P. verrucosa in various sites and zones of coral reef and to determine some environmental parameters that influence the growth rate of P. verrucosa. There were two sites of observation and each site has three zones. Each units of experiment was placed in each site and zone with three replications. The coral growth observed after two months transplantation. The growth rate of P. verrucosa in different sites and zones of coral reef or their interaction analyzed by analysis of variance (factorial patterns); and to determine environmental parameters (habitat characteristics) that influence the growth of P. verrucosa used multivariate analysis (Principal Component Analysis), which confirmed with Cluster Analysis. This research showed that there were not significance growth rate across sites (P≥0.05), but across zones, founded significant (P≤0.05). The effect of site and zone interaction showed that the high growth rate of P. verrucosa was found in both sites, which transplanted in zone 1 and 2. This was closely associated with environmental parameters, i.e. high pH, temperature, current velocity, sedimentation, phosphate, dissolved oxygen, salinity and ammonia, and low TOM and turbidity.

**Key Words:** P. verrucosa, coral transplantation, coral growth, habitat characteristics
1. Site I, with has coral reef critical condition and sheltered from west monsoon wave;
2. Site II, with has good coral reef condition and exposed to west monsoon wave.14)

In each site, the animals were placed in three zones, that are:
1. Zone 1: transition zone of mix community of corals and sea grasses with 0.5 – 1 m in depth;
2. Zone 2: reef slope zone with 3 – 5 m in depth;
3. Zone 3: reef base zone with 7 – 8 m in depth.

Experiment design

Each of experiment units was placed in each zone (1, 2, and 3) and site (I and II) with three replications randomly. The animal is caged in a 5m-distance between experiment units.

Measurement of environment parameters
(Habitat characteristics)

Habitat characteristics observations have carried out by physical and chemical parameters measurement, which can bring effect to corals. These parameters are temperature, salinity, turbidity, current velocity, sedimentation rate, dissolved oxygen (DO), pH, phosphate (P-P04), nitrate (N-NO3), ammonium (N-NH4) and total organic matter (TOM) that measured in two weeks interval for along research.

Data analysis

The growth rate was analyzed according to zones, and sites. Afterwards, growth rate was computed in reference to the Huisman’s formula16). The coral growth response, then analyzed by used variance analysis (two-way ANOVA). Interaction between coral growth and habitat characteristics were analyzed by Principal Component Analysis, PCA.17) and then confirmed with the hierarchical classification (Cluster Analysis). The calculations have done with STAT-ITCF software.

Results and Discussion

The analysis result to weight growth rate of coral in each site, zone and their interaction in Barrang Lompo island coral reefs was showed in Appendix 2.

This study result also shown the weight growth rate average in both sites did not significance (P≥ 0.05). But there are inclined that site II is higher than site I, relatively. This is caused shown that in environment condition exposed to heavy wave action (site II), coral growth and calcification density are dense with their branches are stunted as a form of adaptation. Contrary, in sheltered environment condition, the growth of coral branches are thin and open or their calcification are not solid or more porosity.18-19)

The significance difference of average growth rate (P≤0.05) was found between zones. The growth rate patterns its shown decrease with depth increasing. Variance analysis result also had shown a significance interaction between locations and zones. A combination of two experiment factors which has the highest growth rate (0,8165 %) was found in site II that transplanted in zone 2 (II-2), and has significance different interaction between I-3 and II-3 (P≤0,05), but has no significance different with others interaction (P≥ 0,05). The high growth rate of coral in zone 1 and zone 2 especially caused by the high of light intensity for supporting zooxanthellae photosynthesis process which living in coral polyps tissue. The high rate photosynthesis will produce high energy for the life necessities and give the high growth rate of coral. In the coral Stylophora, from a hundred parts of zooxanthellae product only 1.4 % it’s used for their growth and 98.6% transported to coral tissue. From those transported value, 67.1% for respiration, 5.7% for excretion and 25.7% for polyp growth.9)

Another factor that support high growth rate is the lower stress of coral for along transplantation period. This is caused by the environment condition place for coral transplantation (zone 1 and 2) has relatively similar with the coral initial place, so the energy for adaptation process is needed very little than another zones, especially with regard to light intensity for coral necessity along period for adaptation which needed 2-3 weeks.8) and as along as adaptation period will occurred decreasing of respiration rate and furthermore caused the lower growth rate. High level of ammonium and low turbidity also supported to coral growth in zone 2 typically.

The results of PCA and CA were be able to grouping observation point’s based on zones with habitat characteristics respective and coral growth rate (Appendix 3 and 4). Three represented main axis’s were used well-to-do explain 64.5% of variance between coral growth and habitat characteristics of observation point’s.

Zone 1 that has high adequate of environment variance shown a grouping according to their site, namely a group in site I that characterize by the high of real volume growth, whereas a site II group characterize by the high of coral weight growth.

The coral volume growth in zone 1 (0.5-1.5 m depth) is higher than another zones, whereas the higher weight growth was found in site II - zone 2. Several environment characteristics in zone 1 such as high rate of turbidity and sedimentation were given the negative influence to coral growth. High of turbidity in environment will decrease light penetration, and to be estimated that the high of sedimentation has forced the coral to produce much more mucus with its function to clean the coral colony surfaces from sediment exceed. Nevertheless, another environment factors such as high of current velocity, phosphate, temperature (light intensity), dissolved oxygen, and pH precisely gives a significance contribution to coral growth. Negative effect of turbidity level and sedimentation in zone 2 could be reduced by the high of current velocity that help coral polyp to clean sediment and exceed mucus. Water movements also give the important contribution in nutrient transportation that contributes in zooxanthellae photosynthesis and also its give adequate oxygen to their growth. So, make their growth better than sheltered and quiet place.20-21)
In zone 2 is characterized by the high rate of weight growth, which is closely related to high temperature (light intensity). Several environmental factors as a character such as high ammonium and low turbidity have supported coral growth excitedly in this zone. The colony of *Pocillopora elegans* have uptake nitrate and ammonium compound actively both in day and night, and also ammonium uptake are twice than nitrate.22)

Another case in zone 3 that characterized by low of real volume and weight growth rate. Environment factors as a character such as pH, temperature, dissolved oxygen; current velocity and low phosphate didn’t give support to coral growth in this zone. Even though, the environment factors that can support to coral growth recorded in this zone is high nitrate concentration didn’t give significance contribute in coral growth. This is caused by low light intensity in this zone; therefore the high nitrate concentration didn’t used in maximal by zooxanthellae in their photosynthesis.

Conclusions

1. The high growth rate of *P. verrucosa* was found in zone of mix community between sea grasses and corals (zone 1) and reef slope (zone 2) which has either good or critical condition of coral reef.  
2. The high growth rate of *P. verrucosa* in zone 1 and 2 were closely with the high current velocity, pH, temperature, dissolved oxygen, phosphate, ammonium, and low total organic matter and turbidity.

References


16. Huismann, E.A. Food conversion efficiencies at maintenance and production levels for carp (*Cyprinus carpio*, Linn.) and rainbow trout


Appendix 1. Map of site research in coral reef of Barrang Lompo island waters.
Appendix 2. The average of daily growth rate of the stony-coral *Pocillopora verrucosa* in some sites (a), zones (b), and their interactions (c) in coral reef of Barrang Lompo island (the same alphabet superscripts at each raw implies not significant, $P \geq 0.05$)

<table>
<thead>
<tr>
<th>Factor</th>
<th>The average of daily weight growth rate (%)</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>$(0.3107 \pm 0.2411)^a$</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>$(0.4699 \pm 0.3848)^b$</td>
<td>0.098</td>
</tr>
<tr>
<td>Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$(0.5530 \pm 0.0870)^a$</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>$(0.5507 \pm 0.3955)^a$</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>$(0.0672 \pm 0.0292)^b$</td>
<td>0.001</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-1</td>
<td>$(0.5862 \pm 0.1176)^{ab}$</td>
<td></td>
</tr>
<tr>
<td>I-2</td>
<td>$(0.4015 \pm 0.1791)^{ab}$</td>
<td></td>
</tr>
<tr>
<td>I-3</td>
<td>$(0.0611 \pm 0.0307)^{bc}$</td>
<td></td>
</tr>
<tr>
<td>II-1</td>
<td>$(0.5198 \pm 0.0424)^{ab}$</td>
<td></td>
</tr>
<tr>
<td>II-2</td>
<td>$(0.8165 \pm 0.4119)^b$</td>
<td></td>
</tr>
<tr>
<td>II-3</td>
<td>$(0.0734 \pm 0.0327)^{bc}$</td>
<td>0.029</td>
</tr>
</tbody>
</table>
Appendix 3. The graph of Principal Component Analysis based on physical and chemical waters parameter, and daily growth rate of *Pocillopora verrucosa*. a. Correlation between physical and chemical variable; b. Distribution of point’s observation.

( → active variable;  ← supplement variable)

Appendix 4. The result of Cluster Analysis in point’s observation based on physical and chemical waters parameter and daily growth rate of *Pocillopora verrucosa*.