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Depth Influence on the Zooxanthellae Abundance and Primary Productivity of Branching and Massive Corals on Bama Beach Baluran National Park

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Abstract

Baluran National Park is a high diversity conservation area. Some areas are used for research, tourism and coral rehabilitation purposes. Analysis of the abundance of zooxanthellae and primary productivity is used as a supporting variable to the potential of coral reefs in this region. The purpose of this research was to determine the effect of depth on the abundance of zooxanthellae and the primary productivity of branching and massive coral groups, and to analyze the contribution of depth towards the abundance of zooxanthellae and primary productivity in the branching and massive coral groups. The research was conducted in East Java waters, Baluran Park in the period of July-August 2018. Sampling was taken at a depth of 1-10 m. The main variables measured were zooxanthellae density and primary productivity, in branching and massive corals while the supporting variables were salinity, temperature, do, light and pH. The research was conducted in 3 different locations namely conservation areas, tourist areas, and coral rehabilitation areas. The results showed that the location of the research did not affect the abundance of zooxanthellae and primary productivity, while depth influenced the abundance of zooxanthellae and primary productivity. The highest value of zooxanthellae abundance is at a depth of 10 m as well as primary productivity. Depth has a relationship with zooxanthellae abundance and primary productivity. Both types of coral, branching and massive share the same pattern.

Keywords: zooxanthellae, primary productivity, depth, branching and massive corals

INTRODUCTION

Baluran National Park is a conservation area with high diversity in the form of coral reef and sea grass ecosystems. The type of coral reef on Bama Beach Baluran National Park is an edge reef, having a depth of 0.5 meters to 40 meters (TNB, 2014). Meanwhile seagrasses are found to be living quite well around the coast with sufficient intensity to reach a spread of 5 to 12 meters towards the coral reef area. Furthermore, it is informed that coral reefs in Baluran National Park area have around 145 species of coral. In addition to economic benefits for tourism purposes, coral reef ecosystems also have a coastal protection function from abrasion and damage by breaking waves that lead to the coast. Coral reefs also contribute to the fishing sector by providing spawning and nurturing areas, providing food and protecting marine biota (Juniarsa, 2013).

Coral reefs live in symbiosis with zooxanthellae microalgae which are located in endodermal tissue. These micro algae have the ability to supply energy in the form of bound carbon compounds and are very important for the growth and survival of their hosts in limited nutritional conditions. Coral reefs are a collection of reef corals, living in the bottom of the water and produce lime CaCO3 (Supriharyono, 2007). Zooxanthellae is often found in large quantities in each polyp, living in symbiosis and giving color to polyps, and supplying energy of photosynthesis and 90% of carbon needs. Zooxanthellae accepts essential nutrients from corals and providing 95% of its photosynthetic energy and nutrients. For zooxanthellae, coral is a good habitat because it provides inorganic substances (proteins, carbohydrates, and CO2) for photosynthesis and a good shelter from the threat of predators. Respiration is needed by corals as a source of energy. Organic carbon channeled by the zooxanthellae symbion is the result of photosynthesis used for respiration..

One measurement of the integrity of coral reefs is the potential / ability to spread vertically to the inside. Vertical distribution is a reflection of coral patterns that are able to adapt to changes in the surrounding environment including the use of the environment. To describe this, it uses at least the structural and functional benchmarks of coral life by measuring the abundance of zooxanthellae and primary productivity. Correlation is needed to evaluate the problem of the status of coral reefs in the Baluran National Park area. The purpose was to determine the effect of depth on zooxanthellae abundance and primary productivity on branching and massive coral groups, and analyze the relationship of depth to zooxanthellae abundance and primary productivity in branching and massive coral groups..

MATERIALS AND METHODS

The material used in this research is stony corals. As for the equipment, the following tools are needed: BOD bottles, pipettes, pH, microscopes, haemocytometers, cylinders, Erlenmeyer flasks, TDS meters, Sechii dick, roll meters, stationery, snorkeling equipment, refractometers, thermometers, digital cameras, sample bottles, millimeter block, glass cover, syringe. coral colonies, seawater, aluminum foil, 40% formalin, H2SO4, MnSO4, NaOH in KI, Na2S2O3, 0.025N, starch and distilled water.

This research applies a correlation method in which a research does not only aim to describe the correlation of the object of research, but also to analyze the relationship between variables to get the expected goals. The research location is in the waters of East Java Baluran National Park (Figure 1). The research was conducted in the period of July-August 2018. It was conducted at 3 different locations, namely location 1, a conservation area located at the coordinates 144027'41 "E and -7051'36.26" S; Location 2, a tourist area at the coordinates 144027'35.47 "E and -7051'35.99" S; Location 3, a reef rehabilitation area at the coordinates 144027'37.10 "E and -7051'35.45" S.

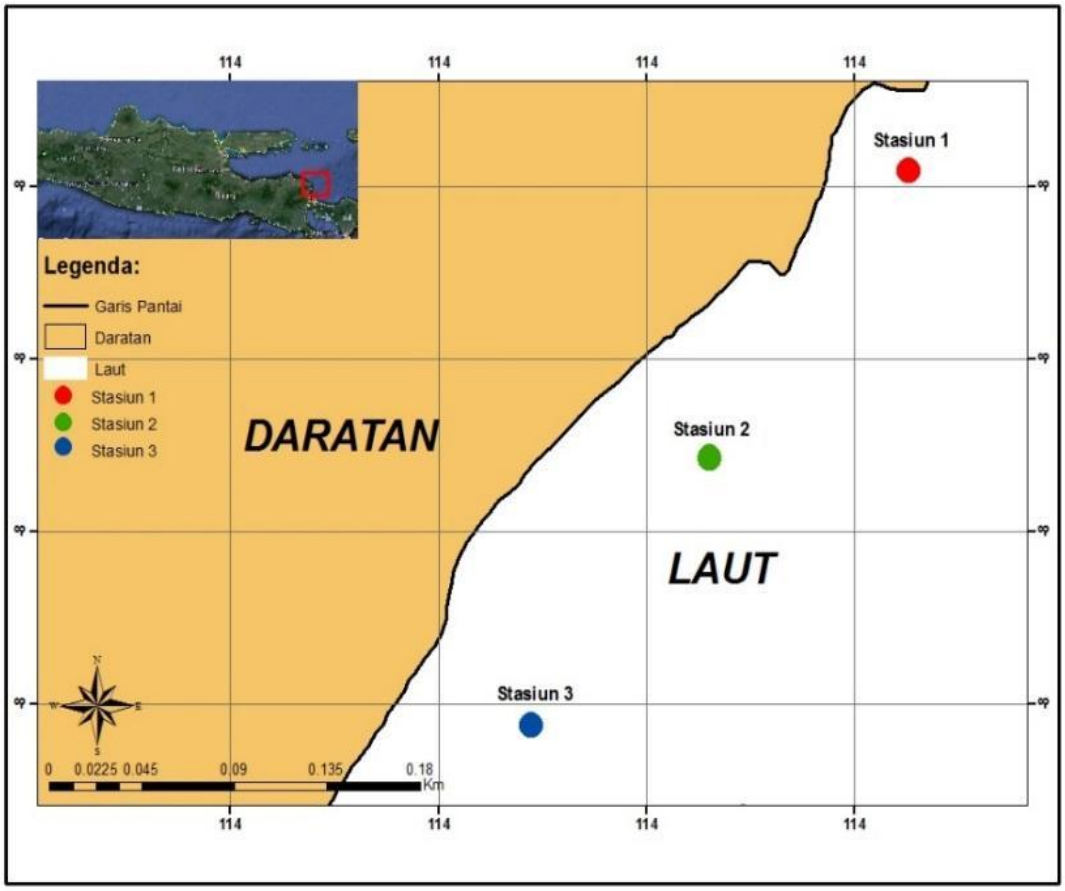


Figure 1. Map of the research site

Coral colonies were taken at 3 types of depth and 2 types of coral in each location and to get the results of the research, 3X repetitions were carried out. The part of the coral taken is the polyp part of the coral, then rinsed with sea water, after which zooxanthellae is released using watterpik (Johannes and Wiebe, 1970). The results obtained were given 40% formalin before being observed. Observation of zooxanthellae abundance was carried out directly with a microscope using a haemocytometer. Calculation of surface area is used to measure the abundance of zooxanthellae using aluminum foil wrapped on coral, then measured on millimeter blocks (Fachrurrozie, 2012). The amount of zooxanthellae is calculated based on the area. According to Manuputty

(2009), the density of zooxanthellae cells is obtained based on the calculation of the formula as follows:

$$D = \frac{QxPx10000}{L}$$

Descriptions :

D : Density of *Zooxanthellae*

Q : Quantity

P : dillution

10000 : a conversion of 0.1 mm3 to 1 cm3

L : Area of Coral Fragment

The measurement of primary productivity is performed by measuring oxygen using the winkler method. Incubation is carried out for 5 hours. The value of primary water productivity is measured using the following formula (Alianto 2008):

$$NPP = \frac{(O_2BT - O_2BA)\ x\ 1000\ x\ 0.375}{PQ(t)}$$

Description :

NPP : net primary productivity (*mg C/m3/hour*)

O2BT : oxygen in the bright bottles after incubation (*mg/l*),

O2BA : oxygen in the dark bottle (*mg/l*),

PQ : photosynthesis coefficient,

t : time for incubation (*hour*),

1000 : a unit conversion of liter to *m3*,

0.375 : conversion coefficient of oxygen to carbon.

As for the supporting information, a number of water quality variables are measured, such as temperature, salinity, pH, DO, light, and depth. The data evaluation to explain the purpose of the research requires 2 test models, which is a type of test analyzing a variety of 2 factors within the interactions of location and depth. To evaluate the relationship between abundance of zooxanthellae and primary productivity, regression analysis is performed using SPSS 19 software.

RESULTS AND DISCUSSION

1. Result

1.1. Coral Reef Cover

Baseline cover on coral reef ecosystems and their quality is a measure of variables used for the status of coral reefs. The results of the research on the quality of the baseline cover of the research location are shown in Table 1.

Table 1. Baseline cover at the waters of the research site

	Location	Depth		
		1	5	10
Living Corals	1	54%	66%	75%
	2	6%	15%	58%
	3	60%	77%	83%
	Location	Depth		
		1	5	10
Dead Corals	1	34%	29%	21%
	2	84%	73%	38%
	3	36%	23%	15%
	Location	Depth		
		1	5	10
Sand	1	12%	5%	4%
	2	10%	12%	4%
	3	4%	0%	2%

The percentage of living coral at location 3 at a 10 meter depth is 83%, this percentage is due to its location in the reef rehabilitation area with a minimum number of tourism visits to the area, while the lowest percentage is in location 2 at a 1 meter depth by 6%. The highest percentage of dead corals was found at location 2 at a 1 meter depth by 84%, while the lowest percentage of dead corals was found at location 3 at a 10 meter depth. The lowest percentage of sand in location 3 at a 5 meter depth is 0%. while the lowest percentage of living coral is at a 1 m depth in location 2, where this location is a tourist area of Baluran National Park which is also the most strategic area.

1.2. Zooxanthellae Abundance

Zooxanthellae is a symbiotic dinoflagellate capable of supplying energy to its host in the form of bound carbon compounds. The energy supply is used for the growth and survival of the host in limited nutritional conditions. Coral reefs are physical structures

formed by the activity of microalgae (zooxanthellae) living in large colonies and form a common limestone skeleton. Coral reefs in Baluran National Park share two growth types, namely branching and massive.

a. Branching coral group

The results of zooxanthellae abundance on branching corals in Baluran National Park are as in Table 2.

Table 2. The abundance of zooxanthellae (cell/cm^2) on branching coral at NTB waters

Depth	Location 1	location 2	location 3
1	94 x10^6	12 x10^7	66 x10^6
	43 x10^6	58 x10^6	73 x10^6
	13 x10^7	18 x10^6	19 x10^6
Average	92 x10^6	68 x10^6	53 x10^6
5	61 x10^6	19 x10^7	88 x10^6
	30 x10^6	13 x10^7	14 x10^7
	19 x10^7	96 x10^6	27 x10^7
Average	95 x10^6	14 x10^7	16 x10^7
10	70 x10^6	23 x10^7	18 x10^7
	14 x10^7	12 x10^7	36 x10^7
	17 x10^7	18 x10^7	13 x10^7
Average	12 x10^7	18 x10^7	22 x10^7

The table of abundance of zooxanthellae above has the highest average value at location 3 at a depth of 10 meters with an average of 22 x107 cells / cm2. The lowest average value is at a depth of 1 meter at location 3 which is 53 x 106 cells / cm2. The results of the research were tested using two way ANOVA analysis to determine the effect of location and depth on the abundance of zooxanthellae and followed by regression analysis to determine the relationship of depth to the abundance of zooxanthellae using SPSS 19 software.

The results of statistical analysis showed that the effect of the location on the abundance of zooxanthellae was not significant ($\alpha > 0.05$), meanwhile, the depth affected the abundance of zooxanthellae ($\alpha < 0.05$). Based on the results of the analysis, which was

then followed by testing the zooxanthellae abundance response to the depth. The test results are as shown in Figure 2.

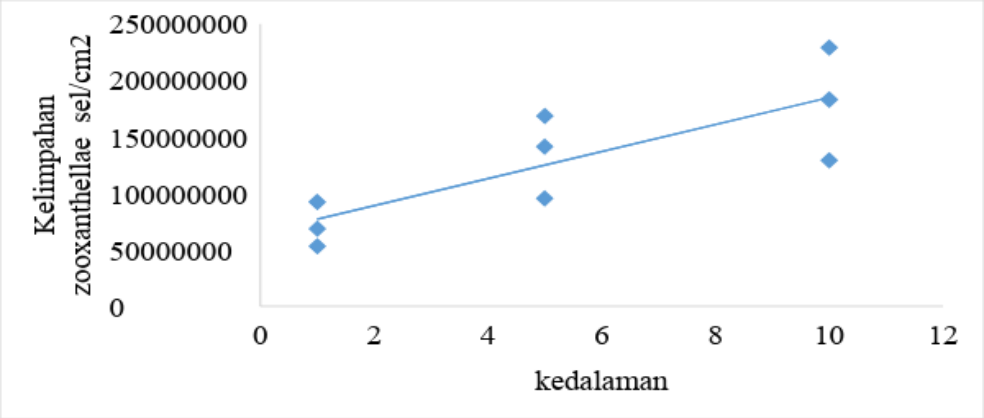


Figure 2. The graph of correlation between depth and the abundance of zooxanthellae on branching coral

The regression results share the equation Y = 64995074 + 11977118 X (α <0.05), and the value of R2 is 0.6619. This value shows that the relationship between depth and abundance of zooxanthellae is classified as strong.

b. Massive coral group

The results of zooxanthellae abundance on massive corals in Baluran National Park are as shown in Table 3.

Table 3. The abundance of zooxanthellae (cell/cm^2) on massive coral at NTB waters

Depth	location 1	location 2	location 3
1	0	0	0
	0	0	0
	0	0	0
Rata-rata	0	0	0
5	10 x10^7	51 x10^6	13 x10^7
	67 x10^6	89 x10^6	10 x10^7
	36 x10^6	14 x10^7	10 x10^7
Rata-rata	69 x10^6	94 x10^6	11 x10^7
10	18 x10^7	18 x10^7	37 x10^7
	16 x10^7	12 x10^7	35 x10^7
	13 x10^7	15 x10^7	27 x10^7
Rata-rata	16 x10^7	15 x10^7	33 x10^7

The table of results of zooxanthellae abundance above shows the highest average value at location 3 at a depth of 10 meters with an average of 33 x 107 cells / cm2. The lowest average value is at a depth of 1 meter in locations 1, 2, and 3. The results of the research were further processed by variation analysis to determine the effect between location and depth on the abundance of zooxanthellae using SPSS 19 software. the influence of depth on the abundance of zooxanthellae can be seen from the table above where the significance value of 0,000 is smaller than 0.05. Location and depth are very influential because many types of massive coral growth in Baluran National Park are often found in deep waters. the results of the analysis, then processed using the zooxanthellae abundance response test to depth. The test results are as shown in Figure 3.

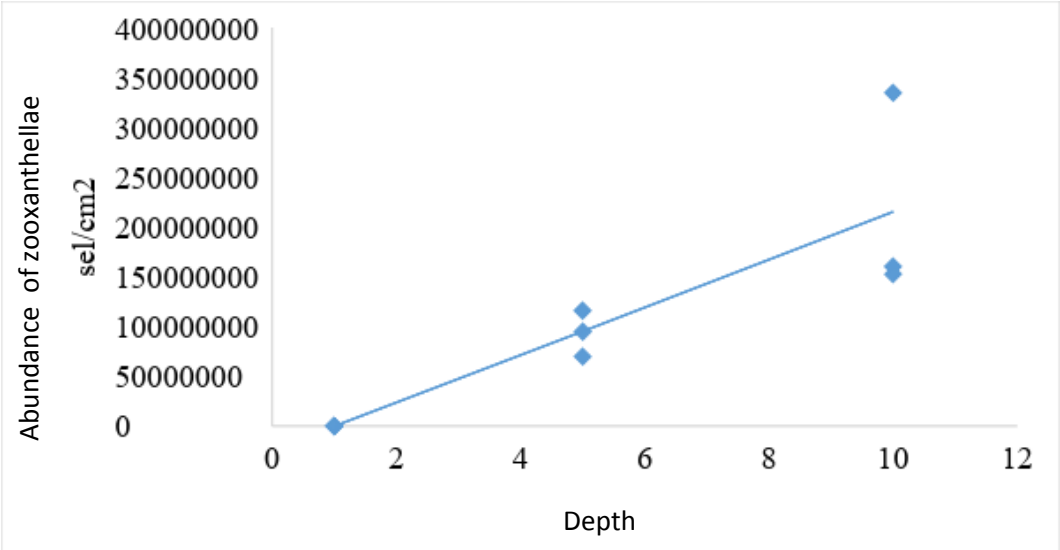


Figure 3. The graph showing correlation between depth and the abundance of zooxanthellae on massive coral

The regression results share an equation Y = -248519109 + 23997860 X. The value of R2 shows a value of 0.7590. This value shows the relationship between the depth and abundance of zooxanthellae classified as strong

1.3. Primary productivity

The presence of zooxanthellae in corals is capable of producing or fixing carbon. The more carbon fixated to eat the higher the primary productivity produced.

a. **Branching coral group**

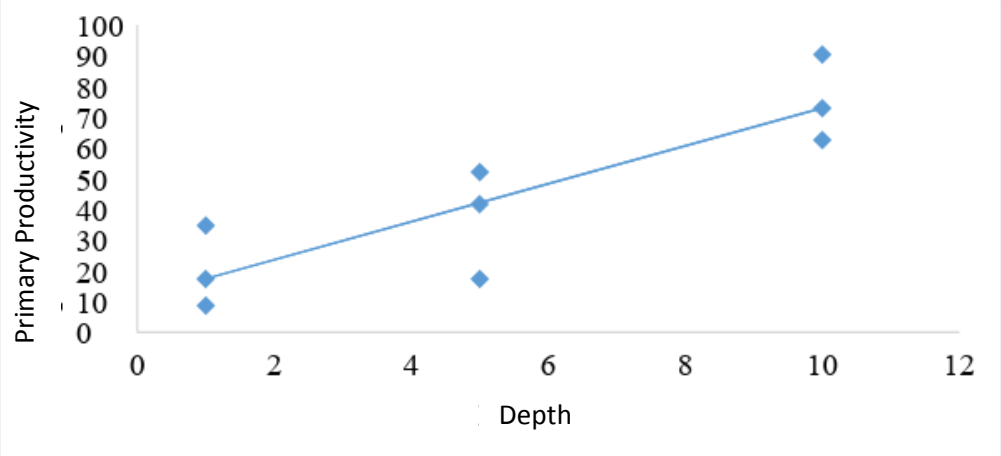
The results of primary productivity on branching corals in Baluran National Park are as shown in Table 4.

Table 4. Primary Productivity of Branching Corals

Depth	location 1	location 2	location 3
1	5.21	41.67	10.42
	10.42	20.83	31.25
	10.42	41.67	10.42
Average	8.68	34.72	17.36
5	20.83	52.08	52.08
	10.42	31.25	62.5
	20.83	41.67	41.67
Average	17.36	41.67	52.08
10	83.33	62.5	125
	52.08	72.92	52.08
	52.08	83.33	93.75
Average	62.50	72.92	90.27

The table of primary productivity results above with the highest average value at location 3 at a depth of 10 meters with an average of 90.27. The lowest average value is at a depth of 1 meter at location 1 which is 8.68. The results of the research have been obtained and then processed further with variation analysis to determine the effect between location and depth, on primary productivity using SPSS19 software.

Depth has a significant effect on primary productivity (α <0.05) by 0,000. Location and depth are very influential on primary productivity because the process of photosynthesis is influenced by sunlight so depth is very influential on primary productivity. The results of the analysis, followed by a test of primary productivity response with depth. The test results are as shown in Figure 4.



Gambar 4. The graph showing correlation between depth and primary productivity on branching coral

The regression results show the equation Y = 11,263 + 6,1709 X. The value of R square shows 0, 7563, it can be said that depth contributes to primary productivity.

b. **Massive coral group**

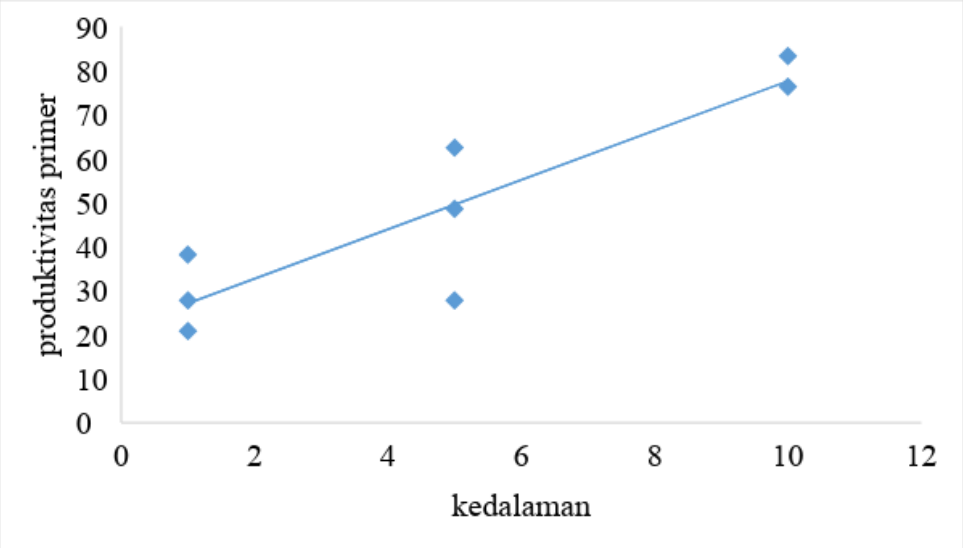
The results of primary productivity on massive corals in Baluran National Park are as shown in Table 5.

Table 5. Primary Productivity of massive corals

Depth	location 1	location 2	location 3
1	52.08	31.25	10.42
	20.83	41.67	20.83
	10.41	41.67	31.25
Average	22.78	38.20	20.83
5	62.5	31.25	52.08
	31.25	20.83	62.5
	52.08	31.25	72.91
Average	48.61	27.78	62.50
10	62.5	114.58	144.83
	125	41.67	20.83
	41.67	93.75	104.17
Average	78.93	83.33	89.94

The table of results of primary productivity above informs that the highest average value is found at location 3 at a depth of 10 meters with an average of 89.94. The lowest average value is at a depth of 1 meter in location 3 with an average of 20.83. The results of the research were followed by variation analysis to determine the effect between location and depth on primary productivity using SPSS 19 software.

Depth has a significant effect on primary productivity ($\alpha < 0.05$) which is 0.004. referring to the results of the analysis, then the primary productivity response test towards the depth was performed. The test results are as shown in Figure 5.



Gambar 5. The graph of correlation between depth and primary productivity on massive coral

Based on the results of the regression analysis, it can be concluded that there is no significant relationship which also means that the regression model shows the relationship between depth and primary productivity is classified as good. The regression results have an equation Y = 21,491 + 5,618 X (α <0.05) and R of 0,9093. This value can be interpreted that the relationship between depth and primary productivity is classified as strong. The value of R square shows 0.7856 so it can be said that depth contributes to primary productivity

2. Discussion

Based on Table 1, the average abundance of zooxanthellae at the research location with the highest value was found at a depth of 10 meters. based on the form of branching coral growth, the abundance of zooxanthellae in location 3 was highest reaching 22 x 107. Branching corals were able to live and develop at every level of depth. Branching corals are easy to grow and grow faster than other coral corals, but they are not separated from the role of symbiotic zooxanthellae. This can be seen from the morphology of the branching coral which has branches allowing space for zooxanthellae to develop more and more (Asmiati, 2017). Zooxanthellae live in endodermal cells and are spread throughout the coral animal colonies (Reid, 2011). According to Syarifuddin (2011), branching corals produce the highest carbonate production.

Based on Table 6, of all research site, at location 3 at a depth of 10 meters, the abundance of zooxanthellae on massive corals showed higher values than other locations. The abundance of zooxanthellae on massive corals reaches 33 x 107. This is reinforced by Fahrurrozie's statement (2012) that zooxanthellae abundance is more than 1 million cells / cm2. Massive corals are categorized as corals that are resistant to

environmental changes because they have thick tissue (Asmiati 2017).

Based on observations and the data obtained, the abundance of zooxanthellae on branching and massive corals at a depth of 1-10 meters has a significant difference. The results of the two way ANOVA test show that the significance value is smaller (0.05) than the confidence level (0.05). Fujise (2014) states that the thing that triggers the most or the least amount of zooxanthellae is temperature, light intensity and salinity. The incoming light causes the size of coral polyps to be small so that the abundance of zooxanthellae can be exposed to maximum, especially in areas with high light intensity.

Based on the results of the measurements, the working value of primary productivity in massive and branching coral reefs is located at location 3 at 10 meter depths. The depth has an influence on primary productivity. This is because zooxanthellae that live in symbiosis with coral polyps and its ability of zooxanthellae to fix carbon dioxide in the water. As Supriharyono (2017) states that high and low primary productivity on coral reefs is influenced by various other sources such as phytoplankton, seagrass and microalgae. This is reinforced by Elahi & Edmunds (2007) where corals provide shelter for zooxanthellae, also helps zooxanthellae in photosynthesis by providing CO2, nitrogen and inorganic compounds

The value of primary productivity of the two types of coral at 3 different depth values in Baluran National Park has a significant difference. This is due to the influence of zooxanthellae that live symbiosis in coral polyps and the ability of zooxathellae to fix carbon dioxide in the water. Hocheberg (2008) states that the measurement of primary productivity depends on the condition of the physical environment. Primary productivity in coral reefs is higher than in sandy areas and coral fragments. The value of primary productivity on each reef varies by type, depending on the efficiency of the use of light on different coral reefs causing the primary productivity value to be different. According to Atkinson (2003), the deeper the value of primary productivity, the lower, but depends on how corals use light intensity to do respiration. In addition, the low incubation duration can cause low primary productivity values.

CONCLUSION

Depth affects the abundance of zooxanthellae and primary productivity. The highest abundance of zooxanthellae as well as primary productivity is found at a depth of 10 m. Depth has a relationship with zooxanthellae abundance and coral primary productivity with a value of $\alpha < 0.05$.

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