The abundance and size of giant sea anemones at different depths in the waters of Teluk Tamiang village, south Kalimantan, Indonesia

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Abstract. The depth of waters has a close correlation with intensity of sunlight and waters' temperature. The deeper the waters from the surface, the less light intensity be received. As a result, temperature also decreases at the deeper layer. This certainly gives effect on the abundance and the body size of giant sea anemones. The purpose of this study is to find out the relationship of the depth of waters to the distribution of abundance and body size of the giant sea anemones in the waters of Teluk Tamiang village, south Kalimantan, Indonesia. Study sites were divided into five stations: three stations in the western part of the waters and two stations in the eastern part of the waters of Teluk Tamiang. Each station was subdivided into three depths: 0-2 m, > 2-4 m, and > 4-6 m. Data of relative abundance and body size of giant sea anemones at different depths were analyzed using Kruskal Wallis test. Distribution of abundance and body size of giant sea anemones based on depths was analyzed using Correspondence Analysis. The results showed that there were three species of giant sea anemones found, namely *Stichodactyla gigantea, Entacmaea quadricolor* and *Heteractis crispa*. The abundance and body size of *S. gigantea* were higher than those of *E. quadricolor* and *H. crispa.* However, the distribution of abundance and body size anemones had no significant difference among the depths of waters.
Key Words: depth of waters, *Stichodactyla gigantea, Entacmaea quadricolor* and *Heteractis crispa,* abundance, size of sea anemones.

Introduction. The depth of water affects the life and growth of tropical marine biota including giant sea anemones. Effect of the waters' depth usually associates with other environmental factors such as light, water movement, temperature, and salinity. The deeper the waters from the surface, the lower intensity of sunlight and temperature are there in the waters. According to Zepp et al (2007), exposure to the sun's ultraviolet radiation can reduce productivity, affect reproduction, and increase the mutation rate in the phytoplankton, eggs, fish larvae, macro algae, and other aquatic animals. The decline in productivity will give a negative impact on ecosystem stability, species diversity, and trophic interactions. Anemones will lose its zooxanthellae algae when environmental stresses occur, such as increased water temperature or low salinity. This will result in bleaching which can increase the risk of mortality of sea anemones (Engebretson & Martin 1994; Hoegh-Guldberg 1999). Several other studies showed the effect of increased environmental temperature on the sea anemones, such as weight loss and increased respiration rates (Chomsky et al 2004); temperature increase may cause bleaching of coral animals (Jokiel & Coles 1990; Douglas 2003; Goreau & Hayes 2005), effects of low temperature stress (4°C) and dark light for four days have caused around 99% of algae of zooxanthellae left the sea anemones (Steen & Muscatine 1987). Increase of zooxanthellae cell division was a response to temperature fluctuations (Gates & Brown 1985). Low temperature and dark light affected the speed of cell division of zooxanthellae from *Anemonia pulchella* (Steen & Muscatine 1987). Sea anemones and anemone fishes are highly vulnerable to over-exploitation. This has a relationship with the fact that the sea anemones have a high economic value in national and international markets, particularly for aquarium ornaments so that they are mostly hunted by aquarists

(Edwards & Shepherd 1992; Fautin & Allen 1997a; Wabnitz et al 2003; Shuman et al 2005; Olivotto et al 2011). In the Philippines the price of anemones at fishermen level could reach 13 times higher than the price of anemone fishes (Shuman et al 2005). In addition to economic value, anemones colonies rarely move that they are easily captured by collectors. Besides, anemones are classified as slow-growing and long life organisms while anemone fishes have limited ability to spread, but the two groups of organisms are dependent on each other (Fautin & Allen 1997b; Wilkerson 1998; Jones et al 2005; Shuman et al 2005; Almany et al 2007; Frisch & Hobbs 2009).

Teluk Tamiang is one of fishery villages that becomes a destination of tourists for snorkeling and diving. The village is in the district of Kotabaru, South Kalimantan, Indonesia. The village has characteristics of territorial waters, such as a Cape and Gulf that directly face the Java Sea with waters' depth ranging from 0 to 8 m. The village has diverse marine ecosystems, such as coral reefs, mangroves and reef fish and sea anemones (Anhar 2014). Three species of anemones were identified: *Stichodactyla gigantea*, *Heteractis crispa*, and *Entacmaea quadricolor* (Anhar 2014). Information related to the abundance and body size of sea anemones in waters still unidentified. This study aims to find out the distribution of abundance and body size of sea anemones at various depths in the waters of Teluk Tamiang.

Material and Method

Study sites. Surveys about abundance of giant sea anemones at different depths were conducted at five stations; three stations in the western and two stations in the eastern part of the waters of Teluk Tamiang village, Pulau Laut Tanjung Selayar subdistrict, Kotabaru district, South Kalimantan Province (Figure 1). The surveys started from 1 April to 27 November 2015. Each station was subdivided into three locations: 0-2 m,> 2-4 m, > 4-6 m in depth of waters. The west and east waters directly face the Java Sea. Coordinate positions and general overviews of the five stations are shown in Table 1.

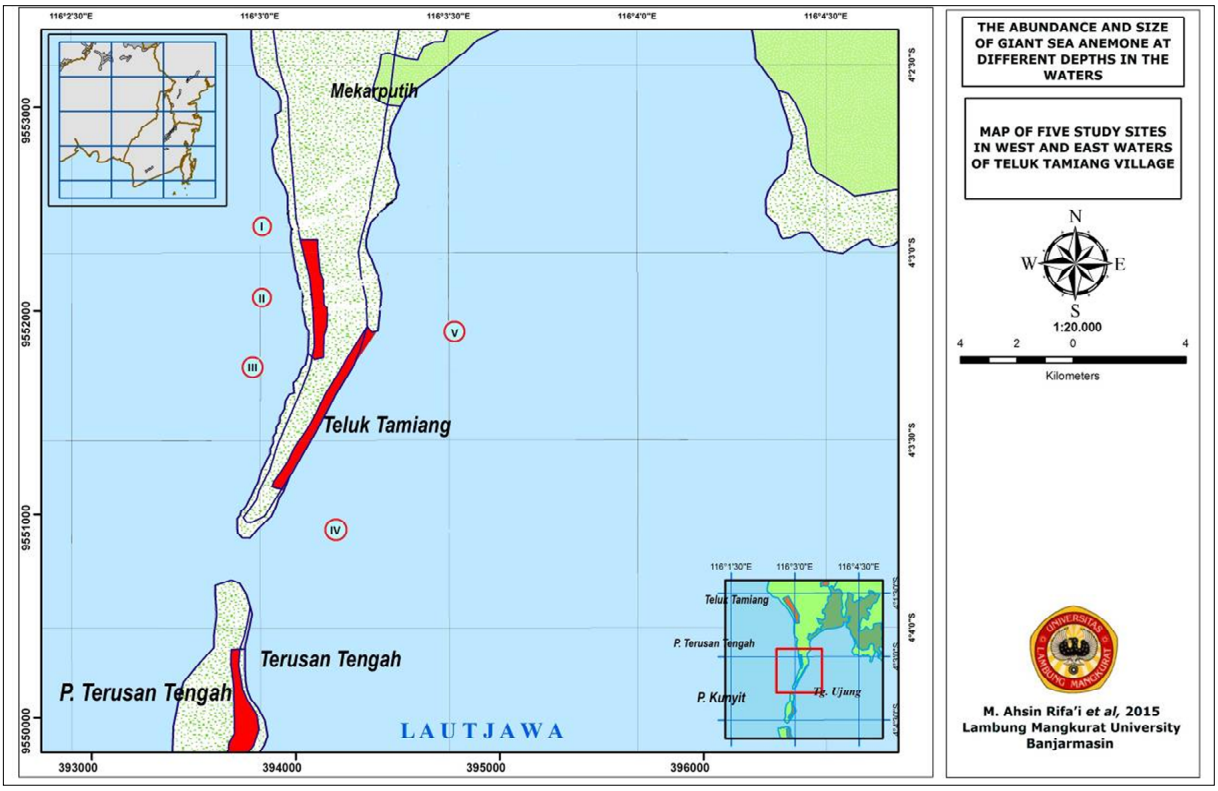
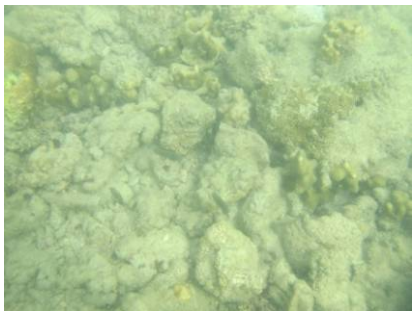
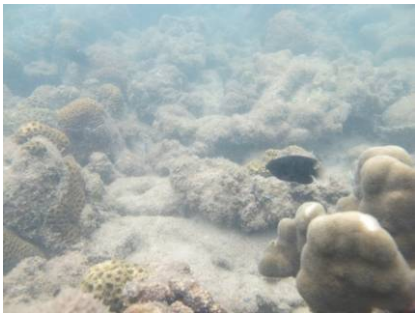
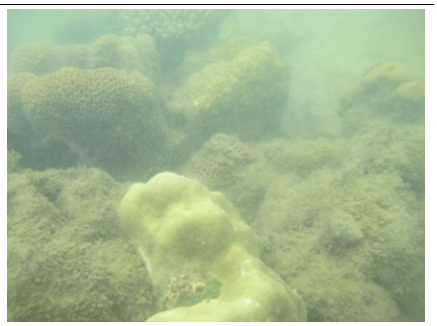


Figure 1. Map of five study sites in the West and East Waters of Teluk Tamiang Village. The red round lines indicate the study sites. Scale bar 1: 20.000.

Table 1

The coordinate positions and general description of stations

Study sites	*General overview of study site*	*Coral reefs condition*
Station I S 4°2'58.60" E 116°2'59.20"		
Station II S 4°3'9.70" E 116°2'58.90"		
Station III S 4°3'21.50" E 116°2'55.40"		
Station IV S 4°3'43.60" E 116°2'58.30"		
Station V S 4°3'14.80" E 116°3'25.20"		

Data collection. To find out anemones, SCUBA divers swam along a transect line using the Line Intercept Transect (LIT) (English et al 1997). The transect line was parallel to the coastline along 50 m and 2 m wide. At each station, SCUBA divers swam to the deep

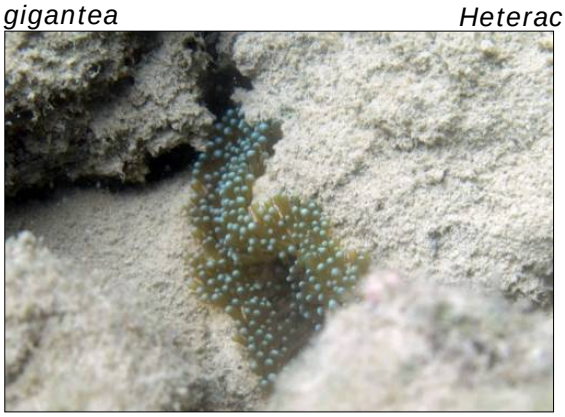
waters and searched for all giant sea anemones living among reef crevices and holes along the transect line. For the accuracy of data, free collection was also done at locations still included in the study area. Information collected for each anemone discovered was the species and size of anemones. Anemone species were identified according to the Fautin & Allen (1997b), while body size of anemones was measured using the method of Porat & Chadwick-Furman (2004) which measured the diameter of the tentacle crown = the distance from the tentacle tip to another one when fully expanding. Anemones that did not expand or contracted during the initial observation were marked with plastic flags, and they would be observed again when their tentacles expanding with measuring the tentacle crown diameter (Chadwick & Arvedlund 2005). The depth of waters was measured in situ (in the field) using a plumb and roll meter, and recorded its positions using GPS. The plumb was fallen down vertically into waters until reached the bottom of waters. Then the waters' level was measured with a roll meter. The depth measurements were conducted to analyze the effect of different depths on abundance and body size of sea anemones at study sites. The depth measurements were classified into three levels of depth as described above.

Data analysis. Data of relative abundance (%) and anemone body size (diameter = cm) at different depths were analyzed using Kruskal Wallis test. Distribution of abundance and body size of anemones was analyzed with Correspondence Analysis using statistical Biplot program. Before being analyzed, data of the relationship of both factors were firstly tested with Chi-square analysis. If there was a relationship, and then they were further analyzed with the correspondent factorial analysis. This analysis was for examining the waters' depth level influencing the relative abundance and or the body size of anemones.

Results. Based on the results of collecting and identifying of the sea anemones in the waters of Teluk Tamiang village at 45 observation sites in five 5 stations), it was found three species of sea anemones, that is *S. gigantea*, *H. crispa*, and *E. quadricolor* (Figure 2).

Stichodactyla gigantea

Heteractis crispa



Entacmaea quadricolor

Figure 2. The species of sea anemones founded in the study sites.

Total number of individuals found in the waters of Teluk Tamiang village was 42 individuals consisting of 26 individuals of *S. gigantea* (around 0-15 ind/15 observation sites), 6 individuals of *H. crispa* (around 0-1 ind/15 observation sites) and 10 individuals of *E. quadricolor* (range 0-2 ind/15 observation sites). Relative abundance among anemones has a significant difference (Asymp Sig = 0:03, $p < 0.05$) (Figures 3 and 4). The highest relative abundance was found in *S. gigantea*, that is 61.90%±4.30% with a density of 0.0052±0.0018 ind per 1000 m^2 area of observation, followed by *E. quadricolor*, that is 23.81%±1.42% with a density of 0.002±0.0006 ind per 1000 m^2 area observation, and the lowest one was *H. crispa*, that is 14.29%±1.17% with a density of 0.0012±0.0005 ind per 1000 m^2 area of observation. Relative abundance has no difference among stations (Asymp Sig = 0.052, $p > 0.05$) (Figure 3) and among depths (Asymp Sig = 0518, $p > 0.05$) (Figure 4).

Size of body diameter among anemones has also no difference (ranging from 0.00 to33.10 cm, N = 45 ind, Asymp Sig = 0.010, $p < 0.05$) (Figures 5 and 6). The highest size of body diameter found in *S. gigantea*, that is 30.17±1.31 cm, followed by *E. quadricolor*, that is 29.96±1.08 cm, and the lowest one was *H. crispa*, that is 19.87±1.14 cm. Yet, diameter of the body does not have any difference among stations (Asymp Sig = 0.068, $p > 0.05$) (Figure 5) and among depths (Asymp Sig = 0782, $p > 0.05$) and (Figure 6).

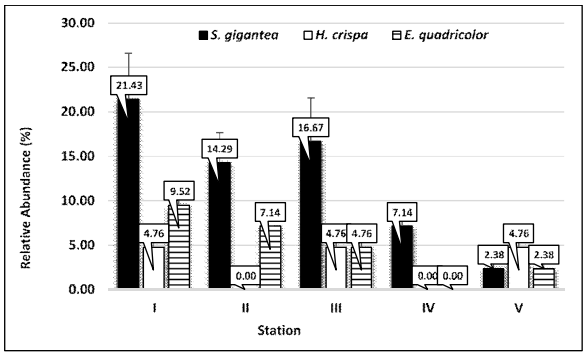


Figure 3. Average relative abundance (%) giant sea anemones based on station in waters of Teluk Tamiang Village (N = 45, Range = 0.00%-21.43%, $\bar{x}$ = 6.67%±1.6%).

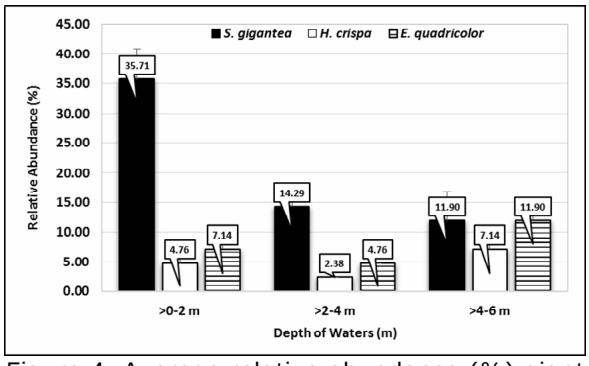


Figure 4. Average relative abundance (%) giant sea anemones based on depth in waters of Teluk Tamiang Village (N = 45, Range = 2.38%-35.71%, $\bar{x}$ = 11.117%±1.5%).

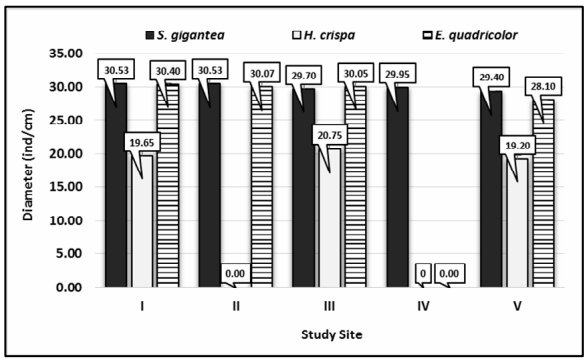


Figure 5. Average size of body diameter (ind/cm) giant sea anemones based on station in waters of Teluk Tamiang Village (N = 45, Range = 0.00-30.53 cm, $\bar{x}$ = 23.45±0.16 cm).

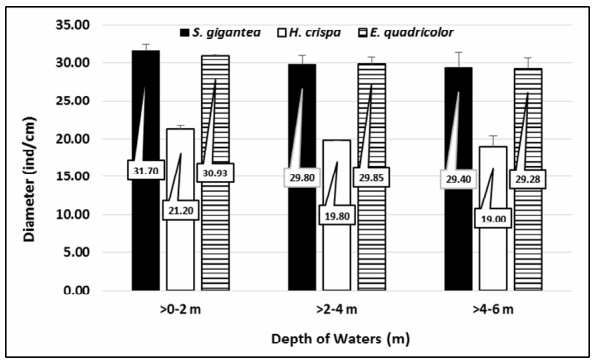


Figure 6. Average size of body diameter (ind/cm) giant sea anemones based on depth in waters of Teluk Tamiang Village (N = 45, Range = 0.00-30.53 cm, $\bar{x}$ = 26.77±0.39 cm).

Discussion. Number of individuals and relative abundance of sea anemone of *S. gigantea* were higher than those of *E. quadricolor* and *H. crispa*. Abundances of *S. gigantea* in these waters are caused by better morphologies of body and sturdy. According to Dunn (1981), morphologies of basel disks of *S. gigantea* are large and sturdy that they can clutch the bottom substrate of the waters. This enables them to withstand any current changes and strong waves. Furthermore, according to Fautin et al

(2009), genus of *Stichodactyla* has morphologies: basel disks that are well developed, columns wider than tall, oral disc is flat or corrugated, and tentacles are hollow. Such morphologies of *S. gigantea* make it more adaptive in waters; thus more able to live and grow than the other two species. Another factor is the low economic value of anemone *S. gigantea* compared to *E. quadricolor* and *H. crispa*. The demand for domestic and overseas markets of *S. gigantea* species is the lowest among other genera of *Stichodactylidae*, so that the capture intensity of fishermen for the species is low. This condition causes the *S. gigantea* found abundantly in these waters and in some other waters in Indonesia such as in the waters of Pulau Seribu (Dunn 1981), in the Bay of Jakarta (Fautin et al 2009), and in the waters of Pulau Barrang Lompo (Rifa'i 2011; Rifa'i et al 2013).

The body of sea anemone of *S. gigantea* has the biggest size among *E. quadricolor*, and *H. crispa*. The biggest size of *S. gigantean*'s body in these waters has a correlation with its abundance that is commonly found in the waters of Indonesia, such as Jakarta Bay (Dunn 1981), waters of Barrang Lompo, South Sulawesi (Rifa'i 2009), waters of Angsana, South Kalimantan (Rifa'I 2011), waters of North Maluku (Rifa'i et al 2014). Abundance of this anemone species shows that Indonesian waters are very suitable for the anemone of *S. gigantea* to live and grow.

Distribution of relative abundance (%) and body size (cm) of giant sea anemones based on depth of waters (m) is shown in Figure 7.

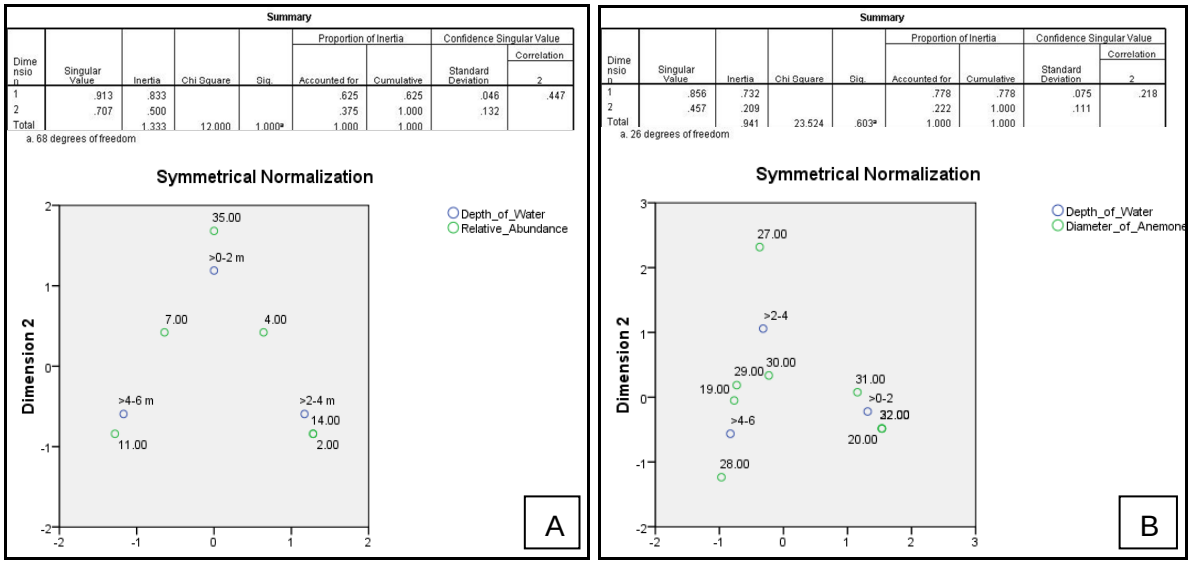


Figure 7. Map of waters' depth (m) and relative abundance (%) of sea anemones (A). Map of waters' depth (m) and diameter (cm) of body size of sea anemones (B).

Distribution of abundance of anemones and waters' depth (Figure 7A) has no clear pattern. At the depths of > 0-2 m, it was found relatively high abundance of 35%, but also found relatively low abundances of 7% and 4%. At the depth of > 2-4 m, it was found relatively moderate abundances of 14% and 7%, but also found low abundance of 2%. At the depth of > 4-6 m, it was found relatively moderate abundance of 14% and low abundances of 2% and 4%. Therefore, relative abundances of anemones based on waters' depth did not have significant differences, or did not have specific pattern. This was based on the K-Independent analysis using Kruskal Wallis test showing that there was no significant difference between both abundances of and waters' depth (Asymp Sig = 0518, p > 0.05). The non-significant different distribution of relative abundances among depths was related to the intensity of sunlight. The study showed that all research locations in all depths of waters had similar intensity of sunlight because sunlight was able to reach the bottom of waters up to 6 m. Sunlight is closely related to water temperature. The higher intensity of sunlight penetrating the waters, the higher temperature will be. Waters' temperature at all locations of depths was ranging from 28.5 to 30.3°C. According to Shick (1991) and Chomsky et al (2004), waters' temperature

affects rate of respiration. Temperature is an important factor that limits the geographic distribution of sea anemones. *Actinia equina* in the eastern part of the Mediterranean Sea was not found in the southern part, from Israel to the Egyptian coast. This was probably caused by the high temperature of sea water that exceeded the limits of their physiological tolerance. Individuals of this species were able to better adapt to low water temperature (Griffiths 1977). Furthermore, Chomsky et al (2004) suggested there is a possibility that the annual growth cycle of the sea anemone of *A. equina* was strongly related to temperature cycle in the Eastern Mediterranean Sea through the effect of temperature on respiration rates. Some individuals of anemone *Metridium senile* also provided a response to suitable latitude temperature (Sassaman & Mangum 1970; Walsh & Somero 1981). Influence of temperature on body size also occurred in the sea anemone *Anthopleura elegantissima*. According to Sebens (1980), body size of population of sea anemone *A. elegantissima* decreased with increasing temperature. This is possible due to the effect of temperature on respiration. Thus, considering water temperature is almost the same among depths, the respiration rate was also not significantly different. That condition causes all anemones can grow and develop well at all study sites, thus abundance did not differ among depths. Distribution between diameter of anemone's body and depth of waters (Figure 7B) has also no a clear pattern. In the depth of > 0–2 m, diameter of body was found high i.e. 31 cm and 32 cm, but was also found low i.e. 20 cm. In the depths of > 2–4 m, diameter of body was found high i.e. 27 cm, 29 cm and 30 cm, but also found low i.e. 19 cm. In the depth of > 4–6 m, diameter of body was found high i.e. 28 cm 29 cm and 30 cm, but also found low i.e. 19 cm. Thus, diameter of anemone's body based on depths is not able to show a significant difference or do not have a specific pattern. This was proved with analysis of K-Independent using Kruskal Wallis test which showed no difference between the body diameter and waters' depths (Asymp Sig = 0.449, $p > 0.05$).

The non-different distribution of body diameter of anemones among depths of waters, besides it was caused by the non-different temperature among waters' depths as mention above, it might also be affected by several other parameters of water quality supporting the life of sea anemones. The results of measurement of some parameters of water quality in all study sites showed that temperature ranged from 29.2 to 31.9°C and salinity ranged from 30.4 to 34‰. The ranges of temperature and salinity are optimum conditions for the life and growth of anemones. According to Rifa'i (2009), temperature and salinity of waters for life and growth of sea anemones in waters of South Sulawesi Island Barrang Lompo ranged from 27.7 to 32.5°C and from 32.9 to 34.7‰ respectively. According to Hoegh-Guldberg (1999), tropical corals and anemones can exist in a range of salinity of 32–40 ppt. Optimum temperature for growth of anemone *A. equina* is 18.7-19.9°C. The growth will decline at temperature above and below this range, possibly due to some feed digested inefficiently at extreme temperature (Ivleva 1964). In the population of sea anemone *A. elegantissima*, body size decreased with increasing temperature, this is probably due to thermal effects on respiratory (Sebens 1980). Bottom substrates of waters contribute in influencing the life and growth of anemones. The bottom substrate where the basel disks adhere to are similar. The study found that the bottom substrates in the three study sites are dead corals, crushed coral, and cracks or holes of coral. The three substrates are good for those three species of anemones to adhere (Dunn 1981; Fautin et al 2009; Rifa'i & Kudsiah 2007). Anemones will be settled properly if substrate where the basel disk of anemones are available and supportive (Rifa'i 2009, 2011).

Conclusions. It was found three species of giant sea anemones, namely *S. gigantea, E. quadricolor* and *H. crispa* in the waters of Teluk Tamiang village. Abundance and body size of anemone *S. gigantea* were higher than those of *E. quadricolor* and *H. crispa*. At different depths of waters, abundance and body size of anemones were relatively similar.

Acknowledgements. The author would like to thank the Directorate General of Strengthening for Research and Development, the Ministry of Research and Technology,

and Higher Education, Republic of Indonesia for the funding support through the National Strategic Research Scheme in 2015.

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Received: 13 April 2016. Accepted: 20 June 2016. Published online: 29 June 2016.
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How to cite this article:
Rifa'i M. A., 2016 The abundance and size of giant sea anemones at different depths in the waters of Teluk Tamiang village, south Kalimantan, Indonesia. AACL Bioflux 9(3):704-712.