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The Effect of Changes in Sea Surface Temperature on Linear Growth of *Porites* Coral in Ambon Bay

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Abstract. Coral is one of the most important organisms in the coral reef ecosystem. There are several factors affecting coral growth, one of them is changes in sea surface temperature (SST). The purpose of this research is to understand the influence of SST variability on the annual linear growth of *Porites* coral taken from Ambon Bay. The annual coral linear growth was calculated and compared to the annual SST from the Extended Reconstructed Sea Surface Temperature version 3b (ERSST v3b) model. Coral growth was calculated by using Coral X-radiograph Density System (CoralXDS) software. Coral sample X-radiographs were used as input data. Chronology was developed by calculating the coral's annual growth bands. A pair of high and low density banding patterns observed in the coral's X-radiograph represent one year of coral growth. The results of this study shows that *Porites* coral extents from 2001-2009 and had an average growth rate of 1.46 cm/year. Statistical analysis shows that the annual coral linear growth declined by 0.015 cm/year while the annual SST declined by 0.013^{o}C/year. SST and the annual linear growth of *Porites* coral in the Ambon Bay is insignificantly correlated with r=0.304 (n=9, p>0.05). This indicates that annual SST variability does not significantly influence the linear growth of *Porites* coral from Ambon Bay. It is suggested that sedimentation load, salinity, pH or other environmental factors may affect annual linear coral growth.

Keywords: *Porites coral, linear growth, SST, Ambon Bay.*

INTRODUCTION

Coral mainly grows in tropical regions as the main component in coral reef ecosystems. Recent studies show that there are several factors affecting coral growth rate such as ocean temperature [1, 2, 3, 4, 5], river runoff [6], turbidity [7], precipitation [8], and human activities or anthropogenic factor such as increasing of human population [9] and ocean pollution [10]. Coral grows by precipitating calcium carbonate ($CaCO_3$). The rate of coral calcification can be explained as the multiple of coral growth rate and coral density [11]. Due to the small variations in coral density, coral growth can be analyzed by using its growth rate only. In order to analyze coral growth rates, coral sample X-radiographs is used. There is a dark and light banding pattern in coral X-radiographs which represents low and high coral density. Previous studies stated that the pattern of a pair of high and low density banding represents one year of coral growth.

One of the most important natural factors that affects coral growth rate is SST. The variability of the SST affects the coral's metabolic rate, reproduction, and the rate of outer skeleton formation. There are many opinions about optimum ocean temperature for coral growth. The ocean temperatures which are suitable for coral growth are >18^{o}C with the optimum at either 23 – 35 ^{o}C (Bengen, 2002) or 25 – 29 ^{o}C (Wells, 1957) [12]. Coral is very sensitive to the changes of temperature and extreme changes of about 4 – 6 ^{o}C higher or lower than their ambient temperature decreases coral growth or causes death [13]. Changes in SST of about 1 – 3 ^{o}C may affect coral metabolism. An

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increasing 1 ^{o}C higher than annual maximum SST for 10 weeks or more can cause coral bleaching, when their symbiotic algae that provide food to the corals desert them [13].

Ambon Bay is one area that experienced extreme variation of seasonal SST. Average SST in Ambon Bay is ±27.5^{o}C in May, ±25^{o}C in August (Southeast monsoon), and ±28.3^{o}C in November (Northwest monsoon) [14]. However, the annual SST variability and its impact on coral linear growth in Ambon Bay have not been investigated. Thus, the aim of this study is to understand the effect of annual SST variability to the annual growth of *Porites* coral in Ambon Bay.

DATA AND METHODS

Porites coral sample were taken from the coast off Galala City (**FIGURE 1**) in Ambon Bay (about 3m depth) in October 2009. First, the coral core was cut into slab ~0.5 cm thickness. Then, the coral slab is cleaned using high-pressure air to remove dust and sediment. After that, coral slab was cleaned in an ultrasonic bath and dried in the oven at 50 ^{o}C for 24 hours. Then, the coral slab was scanned using an X-ray scanner at St. Borromeus Hospital Bandung to obtain coral X-radiograph. Coral X-radiograph (in *.bmp* format) was used as input data to calculate the linear growth of the *Porites* coral sample. The linear coral growth analysis use Coral*XDS*, a Windows-based program that freely downloaded at http://www.nova.edu/ocean/coralxds/. Three times transect in coral growth axis were applied in order to improve the accuracy and measure the standard deviation due to error choosing of coral growth axis lines.

SST data from ERSST v3b [15] was used to understand the influence of SST on the linear growth of *Porites* coral. The ERSST data has a 2^{o}x2^{o} horizontal grid resolution and monthly time resolution. Monthly SST data for the periods 2001 – 2009 located at 4^{o}S and 128^{o}E (**FIGURE 1**) were used to represent the SST variability of Ambon Bay. The accuracies of ERSST data was evaluated by comparing it with in situ SST data obtained from Balai Konservasi Biota Laut, Indonesian Institute of Science (LIPI) in Ambon from May to November 2008 [16]. However, this study is limited for annual scale analysis. Thus, to understand the impact of annual SST variability on the linear coral growth, monthly SST data from ERSST v3b were averaged for 12 months (one year) and compared to linear coral growth data.

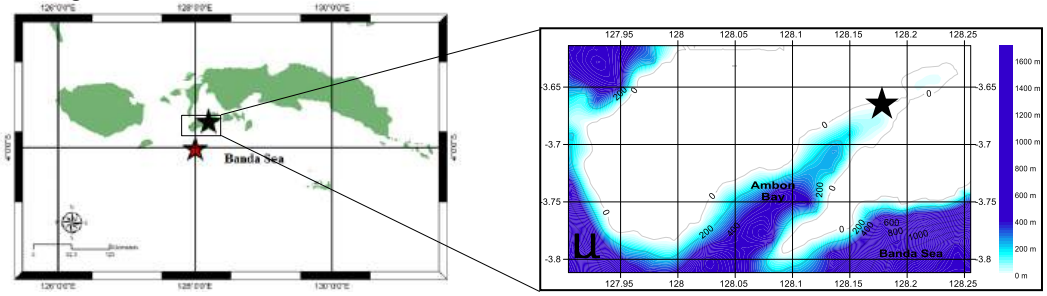

FIGURE 1. Location of *Porites* coral sample (black star) and ERSST data (red star).

RESULTS AND DISCUSSIONS

Based on the chronological development, *Porites* coral in Ambon Bay are extents from 2001 – 2009. The three times transect of coral X-radiograph results show the average of coral linear growth was 1.465±0.061 cm/year for the period 2001 – 2009. Annual linear coral growth fluctuated with a maximum of 2.317 cm in 2002 and minimum of 0.704 cm in 2006 (**FIGURE 2**). This fluctuation was then compared with ERSST data to understand the effect of annual SST variability on the annual *Porites* coral growth in Ambon Bay.

Before comparing coral linear growth with SST data, the accuracy of ERSST data was evaluated. The evaluation between ERSST and in situ data from May to November 2008 yields SST differences of 0.45 to 2.06 ^{o}C. However, monthly ERSST and in situ data shows a similar pattern, with r= 0.805 (n=7, p=0.023 or p<0.05). This result convinces us that ERSST data represents the SST in Ambon Bay. Previous studies in Ambon Bay using ocean numerical model ERSST data concluded that SST variability is strongly affected by monsoonal variation and meteorological factors such as wind speed [17]. In monthly resolution, SST in the Ambon Bay reaches its minimum value during the Southeast monsoon and reaches its maximum value during the Northwest monsoon due to

upwelling and downwelling cycles. It is also known that climatic phenomena such as the El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) did not significantly affect SST variability in Ambon Bay [17].

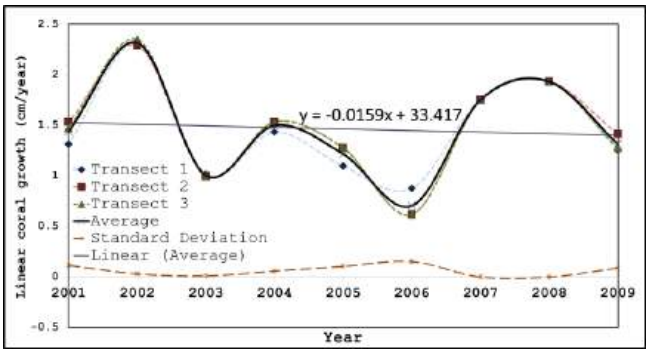

FIGURE 2. Coral linear growth of *Porites* coral sample in the Ambon Bay

Coral linear growth in Ambon Bay was compared to the annual SST anomalies. SST anomalies are calculated by subtracting annual SST (average of 12 months SST data) to its mean value within the period from 2001-2009. The mean values of SST data in those period are 28.85 ^{o}C and the range of SST anomalies lies between -0.2 and +0.2 ^{o}C which can be seen in **FIGURE 3**. Generally SST data has been declining by -0.013 ^{o}C/year. The declining trend of the SST is followed by a declining trend of coral linear growth of about 0.0159 cm/year. This is similar to the situation at Wakatobi, Natuna, Maumere, and Biak over 20 years past from 2011, where seven out of ten coral samples also declined during that period [4]. However, in this study, the decreasing trend in coral linear growth in Ambon Bay is not caused by increasing SST anomalies as expected on the basis of many previous studies [1,3,5]. Statistical analysis results show SST data and coral linear growth in Ambon Bay is insignificantly correlated, with r= 0.304 (n=9, p> 0.05). Consequently, further studies are needed to understand the main factor that led to the decreasing trend of *Porites* coral linear growth in Ambon Bay.

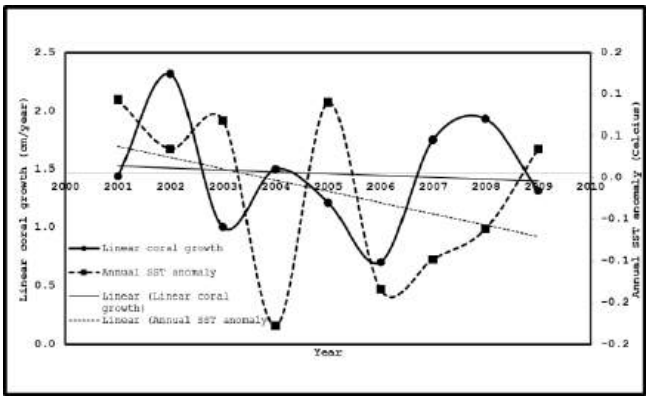

FIGURE 3. Decreasing trend of coral linear growth and annual SST anomaly in 2001 – 2009.

CONCLUSION

The decreasing trend of SST was followed by decreasing linear growth of *Porites* coral in Ambon Bay. However, the annual SST anomaly variation was insignificantly correlated to the coral linear growth. Correlation coefficient between the two series is r= 0.304 (n=9, p> 0.05). It is suggested that the variability of coral linear growth may be affected by the other processes such as the variability of salinity, pH condition, nutrients, sedimentation, or etc.

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