Annual growth band analysis of *Porites* corals: case study Seribu Islands corals, Indonesia

Sri Yudawati Cahyarini

ABSTRAK *Pertumbuhan koral bergantung pada beberapa faktor lingkungan, diantaranya yaitu suhu muka laut, salinitas, sedimentasi dan cahaya. Pada tulisan ini dibahas mengenai analisa parameter pertumbuhan tahunan koral (yaitu kecepatan kalsifikasi, densitas dan pertumbuhan linear) dari koral-koral yang diambil di wilayah Kepulauan Seribu. Hasil analisa beberapa parameter dari beberapa lokasi pengambilan koral di Kepulauan Seribu (yaitu Bidadari, Air dan Jukung) tersebut kemudian dibandingkan untuk lebih mengetahui pengaruh perubahan lingkungan di wilayah daratan terhadap koral di perairan terumbu koral Kepulauan Seribu. Metode Coral XDS digunakan untuk analisa parameter pertumbuhan tahunan koral. Hasil yang diperoleh menunjukkan bahwa koral dari Jukung (offshore) memperlihatkan kenaikan kecepatan kalsifikasi, sedangkan koral dari Air dan Bidadari menunjukkan penurunan kecepatan kalsifikasi selama periode 1985-2005. Walau begitu, penyebab penurunan atau kenaikan kecepatan kalsifikasi tersebut masih perlu diteliti lebih lanjut, terutama diperlukan kalibrasi antara parameter pertumbuhan tahunan koral dengan kondisi lingkungan (suhu, salinitas, sedimentasi dll) dimana koral tersebut diambil. Hal tersebut memerlukan monitoring dalam waktu yang lama.*

Kata kunci*: perlapisan pertumbuhan tahunan, kecepatan kalsifikasi, densitas, pertumbuhan linear*

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Sri Yudawati Cahyarini
Pusat Penelitian Geoteknologi, LIPI,
Jl. Sangkuriang Bandung 40135
Email: yuda@geotek.lipi.go.id

ABSTRACT Coral growth depends on certain environmental conditions, e.g. temperature, salinity, sedimentation, light, etc. In this paper, the coral core tops from Seribu Islands corals are analyzed for annual growth band parameters. The analyses include calcification rate, density and linear extension. The analysis is used to understand the impact of environmental parameters changes of coral reef waters to the corals growth band. We compare the results of three cores from different locations: Bidadari, Air and Jukung, which represent the inshore to offshore locations. This comparison is expected to picture the impact of anthropogenic (the development of Jakarta) to the coral reefs waters in the Seribu Islands. Coral XDS is used to analyze growth parameters. The result shows that the Jukung coral indicates increasing calcification, while the inshore Bidadari and offshore Air corals indicate decreasing calcification rates for period of 1985-2005. Whether that Bidadari and Air corals more disturbed by the anthropogenic than Jukung coral or not is still require further studies, through a long term monitoring to get the historical data timeseries for improving growth band analysis parameters calibration.

Keywords: annual growth band, calcification rate, density, linear extension

INTRODUCTION

Several coral studies have used annual growth band analysis to interpret environmental changes (eg. Lough and Barnes, 1997; Barnes & Lough, 1999; Bessat and Buigues, 2001; Lough et al., 2002). For instance, Bessat and Buigues (2001) analyzed the calcification rate of massive coral heads from Moorea, which is shown to correlate with air temperature. They stated that a rise of

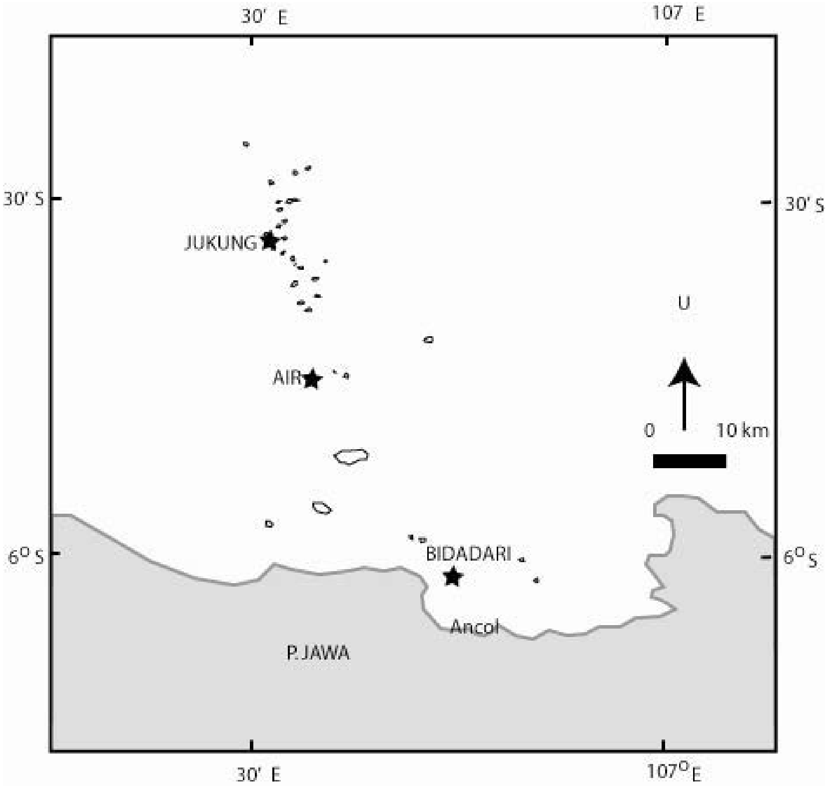

Figure 1. Location map of coral drilling (stars): Jukung, Air, Bidadari

1°C in sea surface temperature (SST) at this site is associated with an increase in the calcification rate by about 4.5%. Barnes & Lough (1999) showed that growth characteristics of the major reef-building *Porites* corals from Misima had changed in response to sudden and sustained increase in sedimentation. Annual variation in skeletal density was measured in 93 colonies and was clearly affected by sedimentation. Scoffin et al. (2006) conducted the first study on coral luminescence analysis for 5 year periods for the Seribu reef complex. Luminescence has shown to decrease from inshore to offshore corals, which suggets that inshore corals are more affected by river runoff than offshore corals. Since coral growth is influenced by water temperature, light intensity and salinities (Rodrigues and Grotoli, 2006), we presume that the analysis of coral growth parameters (e.g. calcification rate, density, linear extension) in combination with luminescence can be used to study the effect of SST and sedimentation changes across the Seribu reef complex. Due to their long live-time of several decades to hundreds of years, long-term environmental changes can be reconstructed from massive corals.

The Kepulauan Seribu (Seribu Islands) (Figure 1) is an archipelago well known for its maritime tourism and its unique position close to Jakarta, a city of over 10 million inhabitants. The Kepulauan Seribu lies at the westernmost extension of the centre of maximum marine benthic biodiversity within the Indo-Malayan region. Elsewhere, very few coral reefs are located close enough to metropolitan cities to

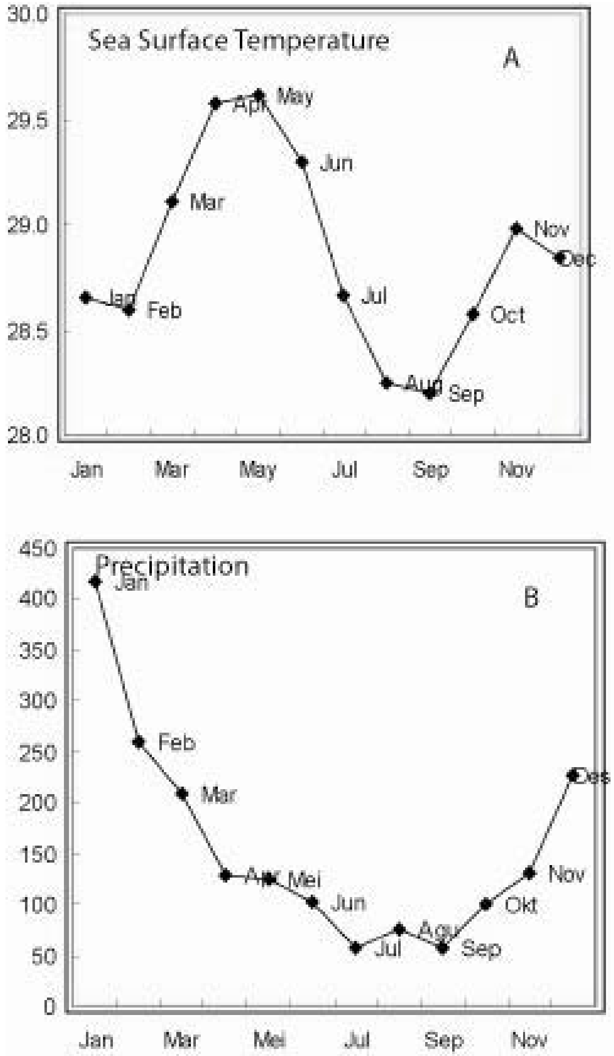

Figure 2. Monthly mean of sea surface temperature (A) and precipitation (B). SST data obtained from IGOSS from averaged SST of 5-6S, 106-107E coordinate. Observation precipitation data from Jakarta observation station is obtained from Royal Netherlands Meteorological Institute (www.knmi.nl)

study the influence of large urban populations on reef communities and coastal waters. Hence, the impact of a large-scale disturbance gradient (including surrounding countries) can be compared with local-scale disturbance (Indonesian urban centers) on coral health in the Jakarta Bay and Kepulauan Seribu reef complex of Jakarta, Indonesia. Therefore, the Seribu Islands is an interesting site to study the annual growth band analysis, which represents the health of corals, and its correlation to the large or local disturbance.

In this paper, we analyzed annual growth band for three core top of coral from inshore location (Bidadari and Air) and offshore (Jukung) (Figure 1). The annual changes in coral growth parameters is calculated using the coral XDS software (Helmle et al., 2002). We will report time series of changes in calcification rate, density and linear extension and compare these parameters with sea surface temperature (SST) and precipitation (rainfall) to understand the influence of temperature and rainfall on coral growth.

CLIMATE AND OCEANOGRAPHIC SETTING OF SERIBU ISLANDS

Natural factors such as the Asian monsoon and El Niño-Southern Oscillation (ENSO) influence marine biodiversity of Jakarta Bay (Seribu Islands waters). These seasonal movements of freshwater due to the monsoonal phenomena control seasonal changes of sea surface temperature (SST) and salinity in the Seribu Island waters. During the wet monsoon season, intensive rainfall feeds freshwater runoff into Jakarta Bay (Gordon et al., 2004). The prevailing monsoon winds distribute the freshwater plume within Jakarta Bay affecting the Seribu Islands reef complex with varying intensity. In addition, El Nino events bring drought and high sea surface temperatures in several locations across the Seribu islands (Brown and Suharsono, 1990; Suharsono, 1998). The mortality of corals increases due to such natural causes (Suharsono, 1998). In combination, natural and anthropogenic influences (increased river runoff, pollution) put high pressure on coral reef biota (Suharsono, 1998) and fishery resources. Based on climatology data, the monthly mean average at Seribu region has two maximum peaks of SST (in May and November) and two minimum in February and August. Based on Jakarta observation rainfall station, the maximum rainfall is in January and the minimum is in July (Figure 2).

MATERIAL AND METHOD

Coral cores were cut in two half, sectioned and the slabs were subsequently smoothed to a thickness of 3 mm. The slabs were cleaned in an ultrasonic bath for 20 minutes and subsequently dried at 50 ˚C overnight. The slabs were X-rayed to perform clear annual density band. Coral densytometer approach is used to analysis the annual growth band parameters (Helmle et al., 2002; Carricart-ganivert et al., 2007). The Coral XDS software developed by Helmle et al. (2002) is used for the calculation of linear extension, calcification rate and coral density in core tops (Figure 3).

The x-rayed of coral slabs are scanned to obtain a digital bitmap file as a data input for coral XDS software. In this study, we analyzed the core tops of 3 cores: Bidadari, Air and Jukung. These cores represent the inshore and offshore coring sites. For comparison with rainfall data, we used an average of rainfall data measured at 4 station for period 1989-2004 obtained from the Jakarta Meteorological & Geophysical Office Station (Cileduk station, Cengkareng station, Tanjung Priok station). We computed annual means for the rainfall data averaged between January and December. Sea surface temperature (SST) data were obtained from the IGOSS database for SST averaged in coordinate 5^o-6^oS, 106^o-107^oE. Similarly with rainfall, the annual means SST was computed between January and December.

RESULT AND DISCUSSION

We analyzed the core tops of Jukung, Air and Bidadari cores. Based on the annual density

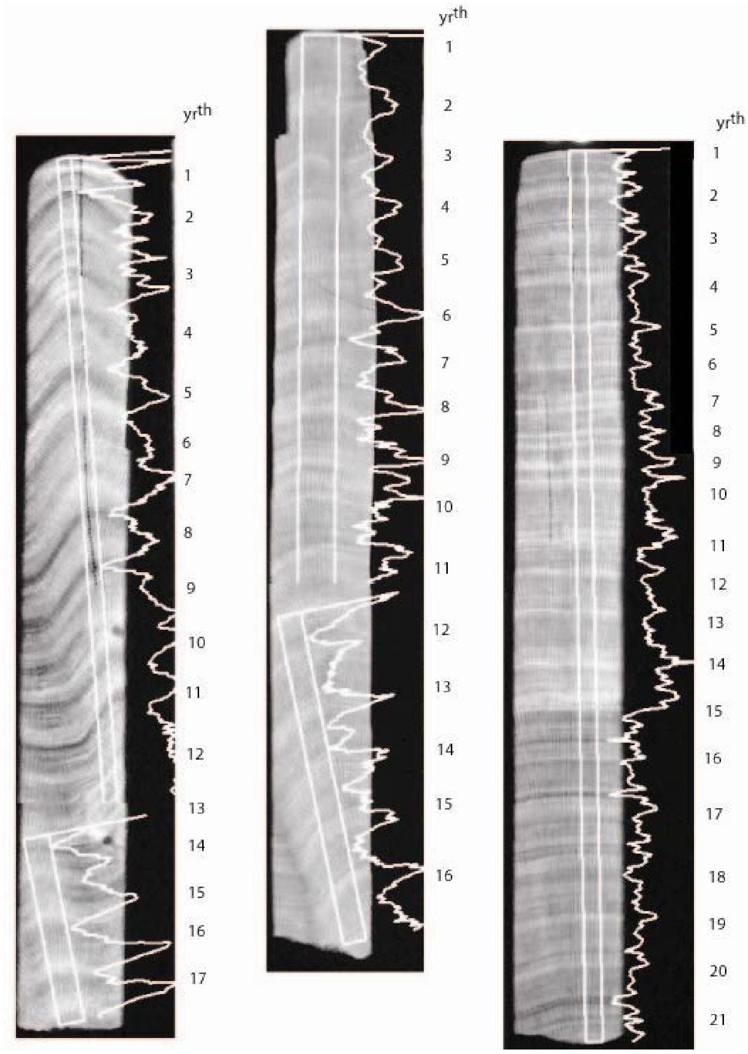

Figure 3. Linear extension transect superimposed on the X-Ray's of the coral slabs from Bidadari (left), Air (middle) and Jukung (right) corals.

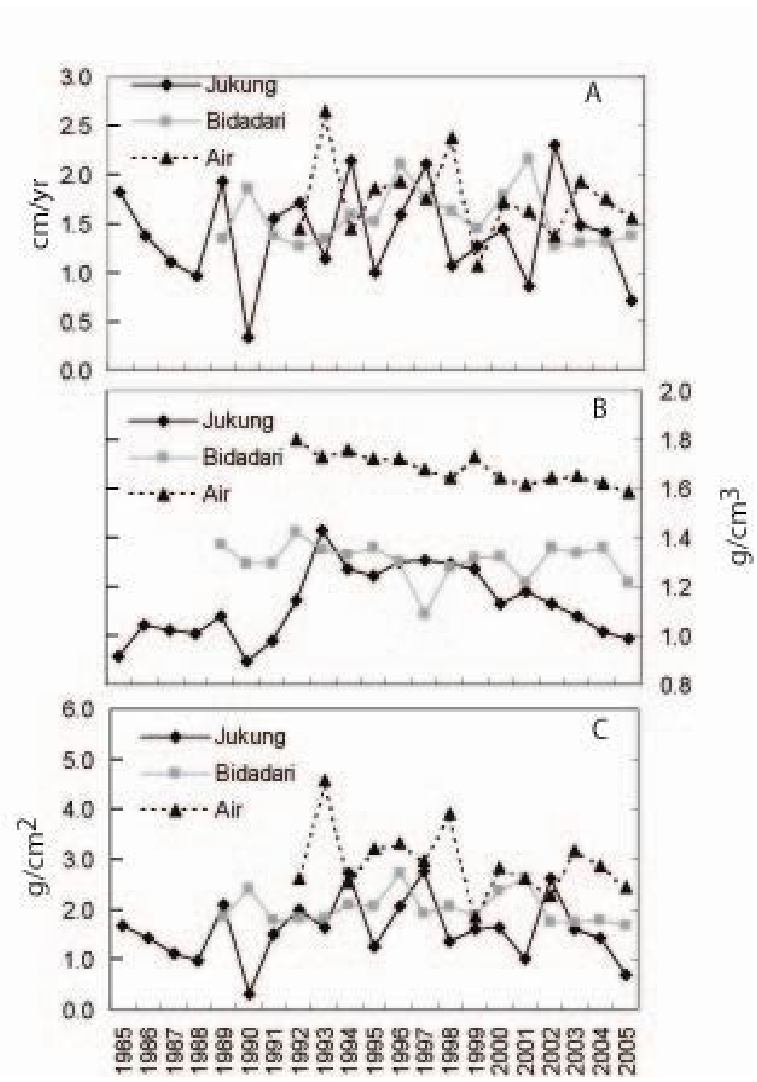

Figure 4. (A) Linear extension, (B) density, and (C) calcification rate from Bidadari, Air and Jukung corals. See text for discussion.

Table 1. Averaged value of extension, density and calcification (the period of available data and the period of 1992-2005 to get the same length of data)

Coral site from Inshore to offshore	Extension (cm/yr)	Density (gr/cm^3)	Calcification (gr/cm^2)
Bidadari (1989-05 /1992-05)	1.56/1.56	1.30/1.30	2.02/2.02
Air (1992-07 /1992-05)	1.78/1.75	1.67/1.68	2.96/2.94
Jukung (1985-05 /1992-05)	1.4/1.45	1.13/1.20	1.59/1.74

Note: x/y = period of x value/period of y value

couplets observed in the X-Ray's we constructed an initial age model for the three cores: Jukung = 21 years (1985-2005), Air = 16 years (1992-2007) and Bidadari = 17 years (1989-2005) (Figure 3). The linear extension rates are: Jukung: 0.34-2.31 cm/yr, average value of 1.4 cm/yr; Air: 1.07-2.65 cm/yr, average value of 1.78 cm/yr and Bidadari: 1.27-2.17 cm/yr, average value of 1.56. Table 1 shows the extension, density and calcification rate averages for the three cores. Figure 4 shows a comparison of growth rate analysis of the three cores (Bidadari, Air and Jukung). The average growth rate over the 15-year period 1990-2005 is highest for the Air's coral followed by Bidadari and Jukung. However, compared to the Bidadari's coral, the Air coral shows better growth than Bidadari for the ~ 15 year period, with the difference of calcification rate is 0.92 gr/cm^2 (Table 1). This is what we had expected since Bidadari is located closer to the land than Air. It is also suggested that Bidadari's coral is disturbed more by the anthropogenic activities than Air corals. Table 2 shows the statistical description of the annual growth parameter from Seribu Corals.

The calcification rates in both the Bidadari and the Air corals show decreasing trends over the last 15 years. The Air coral shows a steeper trend of decreasing calcification rate compared to the Bidadari coral (Figure 5). The Jukung coral shows an increase in calcification rate during the last 15 years. This indicates that the environmental conditions at Jukung were better compared to Bidadari and Air. The cause of the regional differences can only be assessed by local water quality experiments, which could help to improve the calibration and to validate the coral geochemical data. However, longer periods need to be analyzed to bring the observed changes in growth parameters into a long-term context. Thus, it is required to continue the geochemical analysis for the longer cores.

We compared calcification rates with SST since coral growth is expected to be influenced by temperature. Correlation between calcification and SST for the 15 year periods is low for all three cores. Similarly, the correlation between calcification and precipitation is low. However, there is a correlation between coral

Table 2. Statistical description of the annual growth parameters

	Bidadari			Air			Jukung		
	Ex	Den	Cal	Ex	Den	Cal	Ex	Den	Cal
Mean	1.57	1.31	2.02	1.78	1.67	2.96	1.40	1.13	1.60
Standard Deviation	0.29	0.08	0.32	0.40	0.07	0.67	0.50	0.15	0.63
Minimum	1.27	1.08	1.67	1.07	1.53	1.85	0.34	0.89	0.31
Maximum	2.12	1.42	2.72	2.65	1.79	4.57	2.31	1.43	2.76
Conf. Level (95.0%)	0.16	0.04	0.17	0.22	0.04	0.36	0.23	0.07	0.28

Note: Ex= linear extension, Den= Density, Cal= Calcification rate

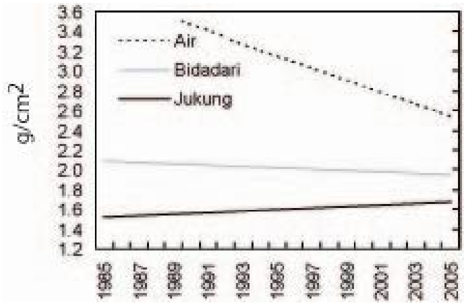

Figure 5. Trends in calcification rate from Bidadari (grey line), Air (dashed line) and Jukung (bold line) corals.

skeletal density and precipitation (R= 0.52 for the Bidadari core, R=0.42 for the Air core, and R= 0.31 for the Jukung core) (Figure 6). We suggest that density is dominantly influenced by precipitation in this region and less by SST. However, both SST and precipitation do not influence calcification and linear extension.

SUMMARY

Fifteen years periods in Seribu corals are analyzed for annual calcification rate, linear extension and density. Based on calcification rate analysis, the Jukung coral shows increasing calcification, while the inshore Bidadari and offshore Air corals indicate decreasing calcification rates. There is no correlation between calcification rate, density and extension rate with sea surface temperature at the three locations: Bidadari, Air and Jukung.

A correlation is observed between density and precipitation for all corals. Further analysis is required to cover longer time period to obtain statistically significant data for the reconstruction of past environmental change. Coral luminescence must be compared to the annual growth band analysis based on coral XDS and to the geochemical proxy records (e.g. SST, sedimentation, salinity) to better understand the role of environmental changes.

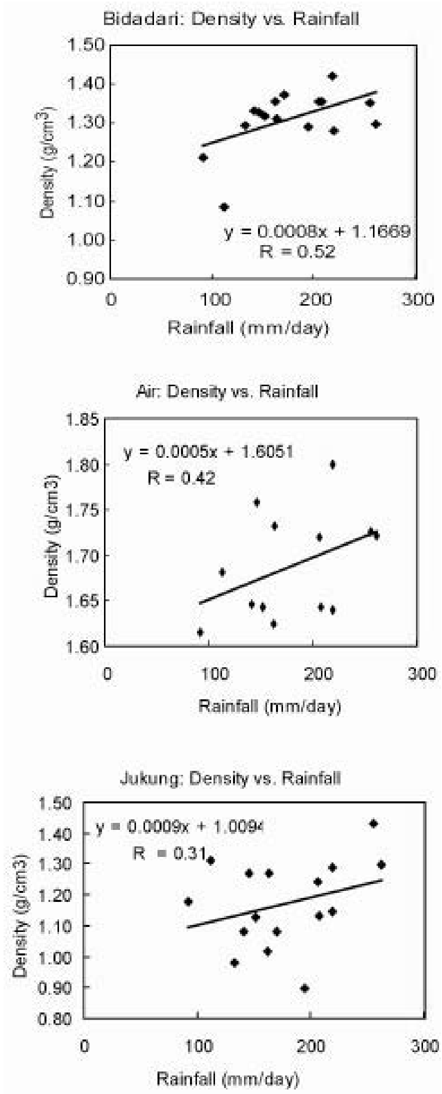

Figure 6. Linear regression of density vs. rainfall of Bidadari (upper), Air (middle) and Jukung (bottom).

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