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SKELETAL BANDING PATTERN AND GROWTH RATES OF THE MASSIVE CORAL *Porites lutea* EDWARDS & HAIME ON THE NORTH COAST OF CENTRAL JAVA, INDONESIA

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ABSTRACT

Growth rates (linear skeletal extension) and the timing of skeletal band formation were measured in 15 specimens of the massive coral Porites lutea *at three locations on the north coast of Central Java. The results of skeletal X-rayed indicate that the timing of the high density (HD) and low density (LD) bands is synchronous at the three locations. A one year growth is characterized by three HD bands, one of which is usually wider.*

Comparasions of the skeletal extension rates (X-ray radiography) indicate that the growth rates of P. lutea *are statistically lower at the Menjangan Kecil Island when compared to Bandengan Bay ($p < 0.01$) and Panjang Island ($p < 0.05$).*

Keywords : Coral Growth Rate

I. INTRODUCTION

Porites lutea is one of the most common scleractinian coral species on Indonesian reefs. Hudson *et al* (1982) have suggested that *P. lutea* is tolerant to high sedimentation rates associated with anthropogenic activities. High sedimentation tolerance may explain the success of this species in colonizing diverse coral reef environments found around the Island of Java (Lachmudin, 1983; Supriharyono, 1986; 1987).

Comparisons between growth forms and those of environmental variables suggest that variation in coral morphology (e.g. growth form) within species may be related to a number of environmental factors, e.i. sedimetation, temperature, illumination and food availability (Chappell, 1980). For example, many massive scleractinian corals, such as *P. lutea*, growing in turbid coastal waters off Jepara (Central Java, Indonesia) exhibit nodular growth form (Supriharyono, 1986).

The skeletons of massive corals have been used by several workers (Dodge and Vaisnys, 1977; Highsmith, 1979; Hudson *et al*, 1982; Supriharyono, 1986; Supriharyono, 1987) as tools for measuring environmental changes over their growth history.

Accretion of calcium carbonate by reef building corals depends on a number of environmental factors (i.e. such as sun hour, light transparancy, and temperature). These environmental factors affect the accretion of high and low density bands within the skeletal matrix of coral colonies. The high density (HD) and low density (LD) bands are revealed by X-ray radiographic techniques (Dodge and Vaisnys, 1977; Highsmith, 1979; Hudson *et al*, 1982). Generally one year growth consist of two density bands, one HD band and one LD band. However, some corals may have more than two high density bands during a one year growth period. Similar results were reported for the massive coral *Porites lutea* from Ko Phuket, Thailand (Charuchinda and Chansang, 1985; Brown *et al*, 1986), and Bandengan Bay, Indonesia (Supriharyono, 1986).

The study reports on the growth characteristics of *Porites lutea* on the north coast of Central Java.

II. MATERIALS AND METHODS

2.1. Site Description

The study sites were located at Jepara waters, the north coast of Central Java. Reefs on the north coast of Java are characterized by poorly developed fringing reefs. The coastal waters receive heavy sediment loads from terrigenous run-off, especialy during the wet monsoon season. The fringing reefs are also directly and/or indirectly affected by a number of anthropogenic activities (e.g. coral mining, coral collection, blasting). These anthropogenic activities have been recently intensified.

The study sites chosen were Bandengan Bay and Panjang Island, Jepara, and Menjangan Kecil Island, Karimun Jawa Islands (Figure 1).

2.2. Coral Collection and Analysis

Five colonies of *Porites lutea* were collected from the each reef flat at Bandengan Bay, Panjang Island and Menjangan Kecil Island, in September/ October 1987. Coral specimens were taken from a depth of 2.0-2.5 m (Bandengan Bay), 1.0-1.5 m (Panjang Island), and 3.5-5.0 m (Menjangan Kecil Island). After being air dried, each coral head was then cut (with a hack saw) parallel to the major growth axis to produce a slab 10 mm thick. Scoffin (1986) suggested that X-radiographs may revealed indistinct yearly bands, which were difficult to interpret. Several factors (e.g. thickness of slab, misjudged axis of growth, and length of X-ray exposure) are responsible for the quality of the X-radiographs. In the present study the coral slabs were X-rayed on a medical X-ray machine unit, MISONO CM-12 (THOSIBA), Model MX 12 No. 70722506 (1981) using Fuji film at the Karyadi Hospital, Semarang, Central Java. Exposures were made at 40 kv, 50 mA for 1.6 sec with a source to film distance of 90 cm. X-ray negatives were contact printed on to photographic paper and the positives were used for analysis of annual bands.

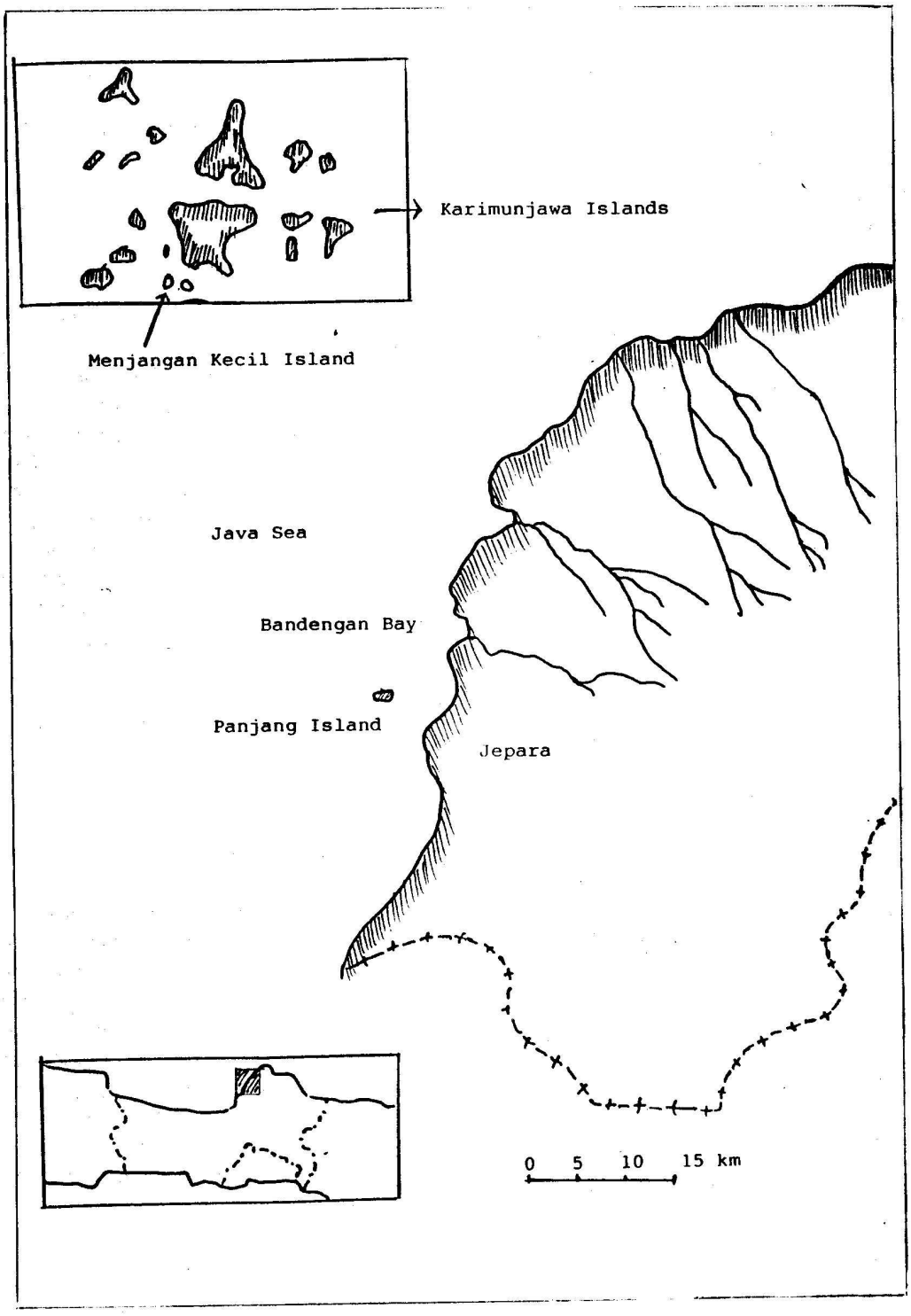

Figure 1.

Map of the study sites

2.3. Environmental Assessment

Meteorological data were collected from the nearest meteorological station located 5-10 km from the study sites (Panjang Island and Bandengan Bay). Since there were no available meteorological data from Karimun Jawa Islands, the cilamatological information was obtained from Jepara and Semarang which are approximately 45 mil and 60 mil from Karimun Jawa Islands, respectively.

III. RESULTS

3.1. Climatological Information

The sites are under the influence of a tropical monsoon climate (Supriharyono, 1986). Generally, the northwest monsoon lasts from about December to February and the southeast monsoon from June to August. The rest of the year consists of two transition periods, from the northwest to the southeast monsoon (March - May), and from the southeast to the northwest monsoon (September - November).

The northwest monsoon is also called the wet monsoon, since the wind, blowing from the northwest to southeast,brings heavy rainfall. Conversely, the southeast monsoon is characterized by dry conditions and is called the dry monsoon, with the wind blowing from southeast to northwest.

Two distinct seasons were recorded at the sites; 1) wet season between October and March; and 2) dry season between April and September. In general, the highest rainfall (e.g. up to 600 mm) occurs in December, while the lowest amount of rainfall is usually recorded in August (Figure 2).

Figure 2 also showed that the number of sun hours per day fluctuate throughout the year. Generally the number of sun hours are high during the dry season (June to August) and low during the wet season (December to February). The number of sun hours is about 6.7 hours/8 hours a day and 4.4 hours/8 hours a day during the dry and wet seasons respectively (recorded from 08.00 - 16.00). Sun hours monitoring at the present study resulted that no significantly different was found between the number of sun hours either at Semarang, Jepara, or Karimunjawa ($p > 0.05$).

3.2. Banding Pattern

X-ray radiography revealed distinct density banding patterns in a number of specimen of the massive coral *Porites lutea* (Figure 3). High and low density increments, in the coral skeletal matrix, appear as dark and light bands on the black and white positive prints of X-radiographs. The dark band is considered as the high density band, while the light band is considered the low density band.

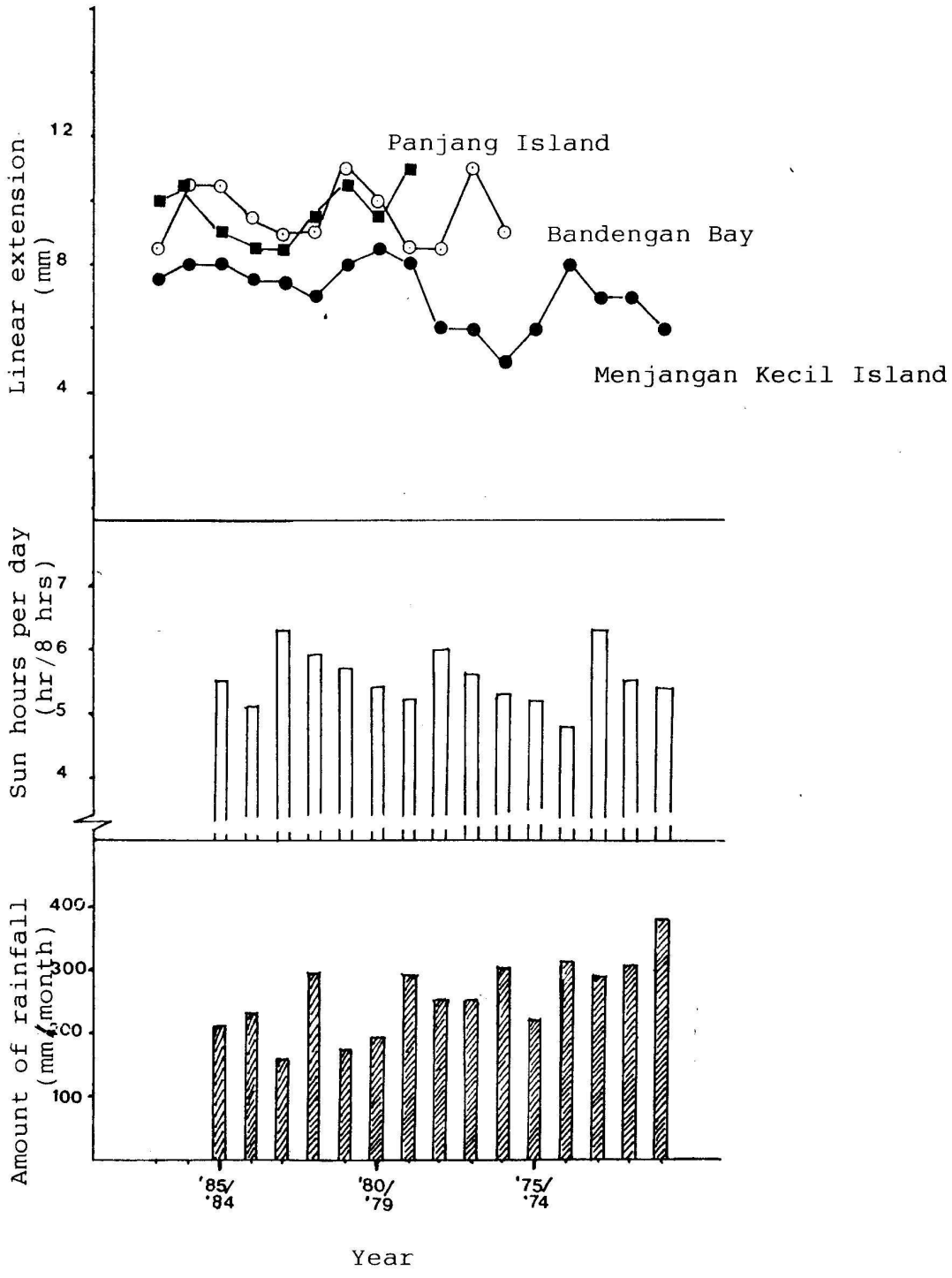

Figure 2.

Environmental variables at the site over the year

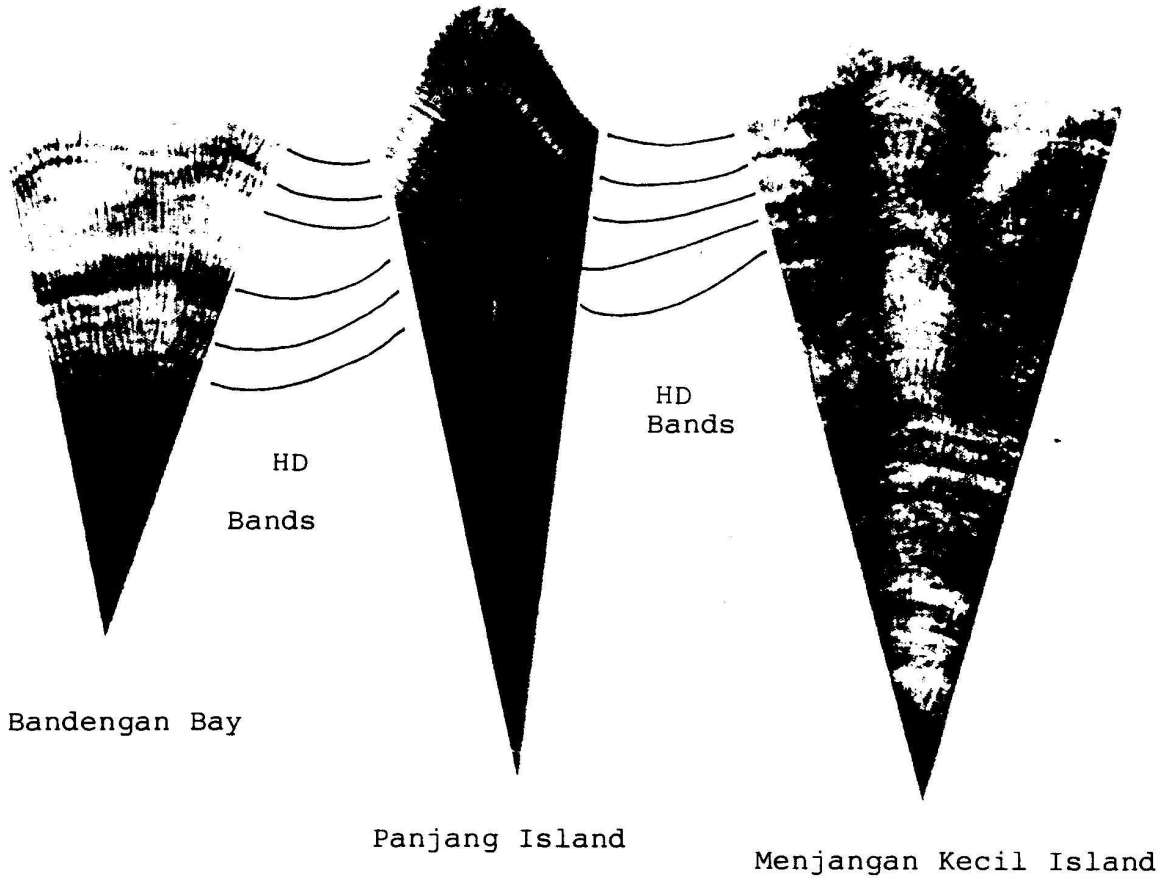

Figure 3. Coral density banding patterns revealed by X-ray radiography.

Supriharyono (1986) suggested that high density bands were deposited during the wet season (probably between November and March) when the amount of rainfall and sedimentation were very high and the number of sun hours low. Low density bands were probably deposited between April and October, since the amount of rainfall and sedimentation were very low and the number of sun hours low. *Porites lutea* also produced high density bands in the dry season as well as in the wet season. In addition, using Alizarin stains as reference method (Supriharyono, 1986) it was showed that *P. lutea*, in the present study, accreted three high density bands (one band wider than the others) and three low density bands. The dominant wider high density band is considered as the wet season band, while the other two HD bands are considered as stress bands (transition seasons production).

The present study suggests that the patterns of skeletal density banding in *P. lutea*, collected from three different areas, are similar.

3.3. Coral Growth Rate

Growth rates of *Porites lutea* in the present study were recorded back to more than 15 years ago. The annual growth rate was not significantly different ($p < 0.05$) between coral specimens from Panjang Island and Bandengan Bay. While these were significanly higher ($p < 0.05$ to Panjang Island; $p < 0.01$ to Bandengan Bay) when compared with coral specimens from Menjangan Kecil Island.

3.3.1. Bandengan Bay

Linear skeletal extension rates of all coral specimens showed high variability. Figure 4 presents yearly average skeletal extension rates of *P. lutea* at Bandengan Bay. Annual linear extension rates ranged from a minimum of 8.5 mm/year to a maximum of 11.0 mm/year.

3.3.2. Panjang Island

The population of *Porites lutea* at Panjang Island consisted mostly of small head corals. Coral colony size of *P. lutea* is smaller when compared to the other sites. Most of the specimens collected were about eight years old.

Growth rates of the coral specimens from Panjang Island ranged from a minimum of 8.5 mm/year to a maximum of 11 mm/year (Figure 4). The highest growth rates occured during early stage of growth between 1978/ 1979, while the lowest growth rates occured during of 1983 and 1984.

3.3.3. Menjangan Kecil Island

Qualitative observation suggest that coral colonies at the Menjangan Kecil Island tend to be bigger when compared to the two other sites. Coral specimens from Menjangan Kecil Island were about 17 years old. However coral growth rates at this site may have been affected by water depth. Since the depth at Menjangan Kecil Island is slightly deeper (i.e. 3.5-5.0 m) than at the other sites (i.e. 1.0-2.5 m), coral growth rates may be correspondingly lower.

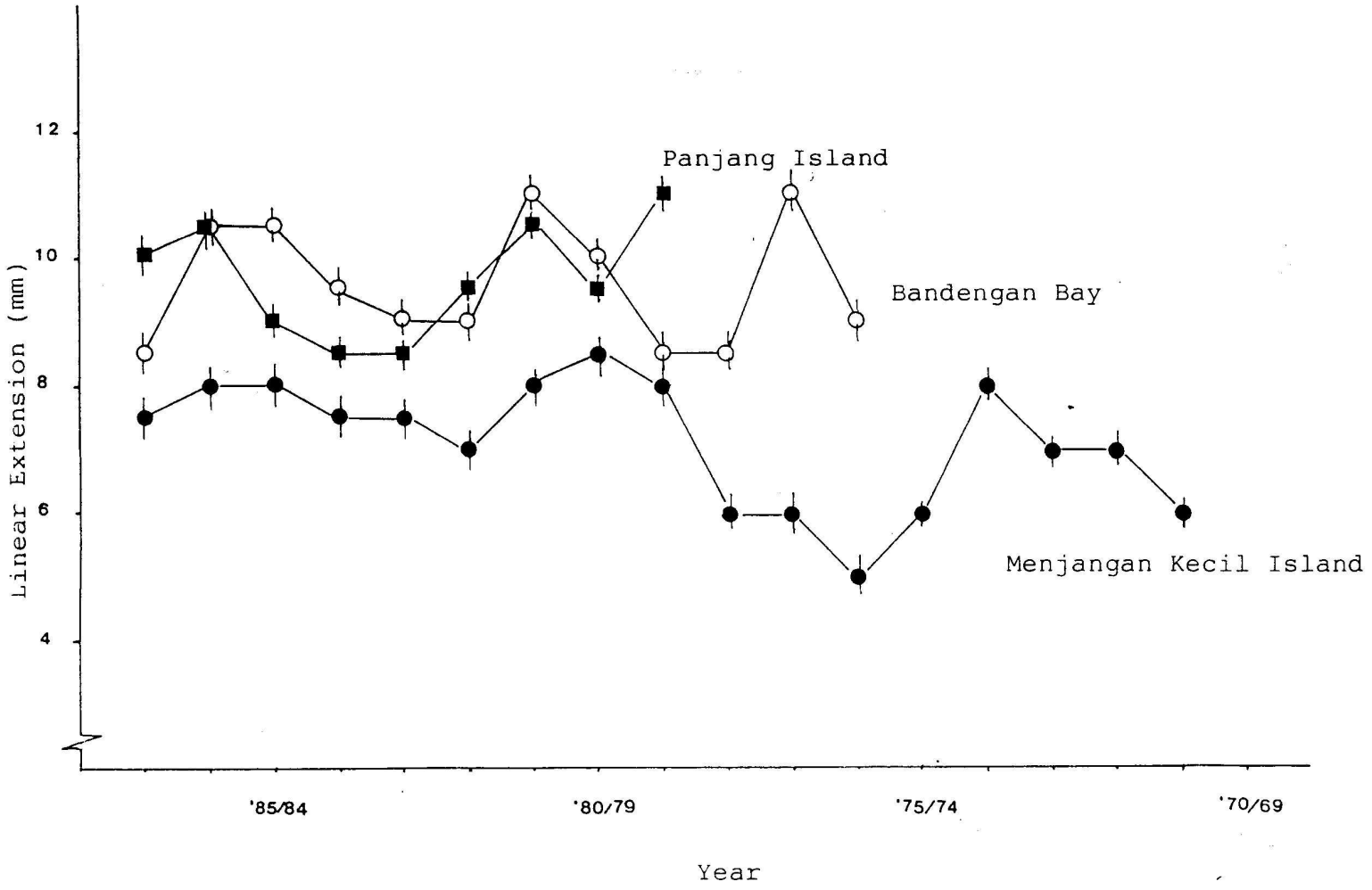

Figure 4. Annual linear extension rate of coral colonies, Porites lutea from the study sites. Vertical bar Indicates standart error.

Annual linear extension of coral specimens ranged from a minimum of 5 mm to a maximum of 8.5 mm. Low growth rates occured during 1970/1971, which corresponds to a period of high rainfall and low sun hours. However, no significant correlation ($p > 0.05$) was found between coral growth rates and either the amount of rainfall ($r = -0.28$) or sun hours ($r = 0.16$). The results suggest that annual growth rates were not affected by either the amount of rainfall or the number of sun hours, hoever these factors may affect the timing of skeletal band formation (i.e. accretion of high or low density bands).

IV. DISCUSSION

It is well known that variations in environmental factors affects the deposition of high density (HD) and low density (LD) bands in the coral matrix (Dodge and Thomson, 1974; Hudson *et al*, 1976). In general, HD bands are accreted during the wet season when rainfall is heavy and water temperatures are low (Buddemeier, 1974; Budemeier *et al*, 1974; Dodge and Thomson, 1974; Hudson *et al*, 1976; Highsmith, 1979), although some workers (Macintyre and Smith, 1974; Weber *et al*, 1975a; Weber *et al*, 1975b) have found that HD bands are also produced during the dry season when water temperatures are high.

Highsmith (1979) discussed the relationship between density banding and light availability, and surface water temperature. He concluded that on the whole the evidence suggests that HD bands are formed during periods of either relatively high or low temperature. The HD bands may be associated also with either high or low light availability. The LD bands are generally formed at moderate temperatures between 24 and 29 C. In addition, he concluded that HD bands may be produced in response to a variety of environmental factors, but LD bands are only produced during priods of high light availability and a narrow range of temperatures. In contrast to Highsmith (1979), Wellington and Glynn (1983), who worked in the Eastern Pacific (Panama), found that variation in light was more important to changes in skeletal density than fluctuations in temperature. Wellington and Glynn (1983) concluded that formation of the HD bands corresponded to lower light levels.

In the present study HD bands were acrreted during the wet season. However, not all HD bands were produced during the wet season, since most coral specimens exhibited more than one HD band. Similar results were reported by Charuchinda and Chansang (1985) and Brown *et al* (1986) from Ko Phuket (Thailand), and Supriharyono (1986) from a reef flat in Bandengan Bay, Jepara (Indonesia). It was suggested that acrretion of HD bands coincided with periods of low light availability and/or increased sedimentation. Supriharyono (1986) reported that in Bandengan Bay, this condition usually occur during the wet season (December-February) as well as at the transition periods (March-May and September-November). In addition, Supriharyono (1986) reported that sedimentation rates was significantly correlated ($r = 0.78$; $p < 0.01$) to the amount of rainfall. If the HD bands correspond to sedimentation rates than the one HD band may be accreted during the wet season (December-February), and the other two HD bands during the transi-

tion periods, which are characterized by short periods of heavy rainfall. The HD band which was acrreted during the wet season is considered as a seasonal band, while the other two HD bands are considered as "stress" bands (Hudson *et al*, 1976).

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