CHAPTER 3

RESULTS

1. Meteorological condition

1.1 Wind speed and direction

During November to January, the northwest monsoon will be the most influencing wind. Southwest monsoon wind although can attain maximum wind from the south, southwest and west to 15 - 16 knots as presented in Table 1, is obstructed by Kang Kao Island, thus has less effect.

1.2 Precipitation

The southwest monsoon wind can induce the precipitation which is frequently found in September and the average to being about 9.54 ± 22.67 mm in this month (Table 1).

1.3 Air temperature

As in Table 2, the air temperature in each month does not shown significant difference. The temperature range is about 26.0 - 29.8 ^{o}C with the maximum in May and minimum in January. Furthermore, the difference between maximum and minimum temperature (Max. - Min.) in January (winter month) iis 7.8 ^{o}C while in May (summer month) is 4.4 ^{o}C (Table 2).

Table 1 Meteorological data in study period at Si Chang Island.

Month	Precipitation (mm)		Wind Direction	Wind Speed		
	Frequency	Mean±S.D.		Beaufort	Knot	km
July '85	16	4.11 ± 9.05	SW	5	15.03 ± 6.32	27.84 ± 11.74
August '85	9	2.93 ± 7.83	WSW	4	15.71 ± 5.86	29.52 ± 13.54
September '85	19	9.54 ± 22.67	SSW	4-5	15.93 ± 5.99	29.47 ± 11.23
October '85	18	5.13 ± 10.40	various	3-5	13.81 ± 3.92	25.55 ± 7.18
November '85	12	4.24 ± 8.45	W -> NE	3-5	12.97 ± 2.62	23.83 ± 4.88
December '85	-	-	NE	3-5	13.64 + 3.27	25.64 + 6.05
January '86	-	-	NW - NE	4-5	14.29 + 5.32	26.48 + 9.87
February '86	2	0.08 ± 0.31	SSE	3-5	12.18 ± 2.61	22.68 ± 4.77
March '86	1	0.08	WSW	4-5	14.10 + 4.30	26.13 + 8.03
April '86	4	2.83 ± 19.94	S	3-5	12.87 ± 2.43	23.80 ± 4.59
May '86	7	9.15 ± 19.45	SSW	3-5	15.45 ± 4.70	28.81 ± 8.29
June '86	7	2.96 ± 7.08	WSW	5	16.17 ± 6.50	31.97 ± 16.04
July '86	13	2.60 ± 5.64	WSW	3-5	15.71 ± 7.70	29.00 ± 14.27

Source : Department of Meteorology

Table 2 Air temperature at the study area (^{o}C)

Month	Average Max.	Average Min.	Max - Min	Average
Sep. '85	30.5	25.0	5.5	27.8
Oct. '85	30.2	24.4	5.8	27.6
Nov. '85	30.5	24.5	6.0	27.5
Dec. '85	29.4	23.5	5.9	26.4
Jan. '86	28.9	21.1	7.8	25.0.
Feb. '86	30.4	23.6	6.8	27.0
Mar. '86	31.3	25.2	6.1	28.3
Apr. '86	32.3	26.8	5.4	29.5
May '86	32.0	27.6	4.4	29.8
Jun. '86	31.9	27.0	4.9	29.4
Jul. '86	31.3	26.3	5.0	28.8

Source : Department of Meteorology.

2. Oceanographic condition

2.1 Wave; The study site generally has not been effected by strong wave as it is an inlet area and its position is located on the north-south direction. But in the winter season, this area is effected by the northeast monsoon as aforementioned. Thus, the wind driven-wave is generated by this prevailling wind during November to January which directly affects the study site. Moreover, the wave is usually generated during the lowest and highest tidal period.

2.2 Tide; The predicted water level at Sichang Island during the field investigation was used.The Mean Sea Level (MSL), Mean Low Water (MLW) and Mean High Water (MHW) are 24.60, 22.48 and 23.69 dm above datum respectively (Table 3). In addition, the maximum tidal range is about 16 dm during March to April. On contrary, the minumum tidal range is 13.43 dm in June. Also, the type of tide is determined and its range was 0.9639 - 1.4197 which could be analysed as mixed tide (tend to be semi-diurnal tide). Besides, the tide table of Department of Hydrology and field observation revealted that during May to July the lowest tide usually occur in daytime for 4-6 hours per day. Thus, it causes shallow zone exposure during this periods.

2.3 Current; The Kang Kao coral community is in shallow water area not deeper than 7 metres at MHW. Once current is generated by wave energy which has rushed to the shallow

Table 3   Analysis of predicted tidal data at Si Chang Island

Month 'Year	MMSL (dm)	MHW (dm)	MLW (dm)	Range (dm)	DHQ	DLQ	Type of Tide
July '85	24.69	31.68	18.10	13.58	2.48	7.16	1.4197
August '85	24.59	32.36	17.12	15.24	3.16	5.96	1.1962
September '85	24.53	32.16	17.29	14.87	2.92	5.29	1.1042
October '85	24.46	32.60	18.72	13.88	1.42	6.96	1.2082
November '85	24.54	32.28	18.00	14.28	1.48	7.88	1.3109
December '85	24.58	32.34	17.98	14.36	1.98	8.16	1.4130
January '86	24.62	32.91	17.82	15.08	2.09	7.22	1.2341
February '86	24.62	32.26	16.79	15.47	3.20	5.68	1.1480
March '86	24.69	32.94	16.88	16.06	2.12	5.62	0.9639
April '86	24.68	33.38	17.38	16.00	1.68	7.34	1.1275
May '86	24.66	32.90	17.65	15.25	1.36	7.02	1.0990
June '86	24.62	31.97	18.54	13.43	2.30	7.14	1.4058
July '86	24.53	31.77	17.72	14.05	2.87	6.35	1.3126
Average	24.60	32.43	17.69	14.73			

Remark : Data from "Tide tables Thai waters", Hydrographic Department, Royal Thai Navy.

MMSL = Monthly mean sea level
MHW = Mean high water
MLW = Mean low water
DHQ = The diurnal high water inequality
DLQ = The diurnal low water inequality

zone of coral reef particular in winter season. Then it immediately became to perpendicular currents and flowed away. Another current have generated parallelly along the shore line at the outer of coral reef. This current was induced by lowest and highest tidal period particular in estuarine environment as study site (field observation).

3. Coral reef condition

Profile as shown in Figure 6 illustrated that the coral reef substrate and topography of the study area at the upper most part is rocky shore which consists of rock and pebbles. The next area is abundantly inhabited by several species of oysters; Crassostrea spp. The shallow zone is mostly dead coral and microatoll due to the combination effect of long exposure particularly in summer season which the lowest tide occurred during the day time and the role of grazing by Diadema setosum. However, in other seasons, this zone is always submerged. Thus, there are substrates available for boring organisms, various algae succession particularly filamentous and coralline algae. The coverage area is shown in Figure 7. In subzone AB approximately 80 % was dead coral. In subzone CD, the live corals were restricted to areas shallower than 3 metre depth. The consist of Porites lutea (Edwards and Haime), Pavona frondifera (Lamark), Platygyra daedalea (Ellis and Solander), Montipora sp. and Pocillopora darmicornis (Linneaus). Next in deep zone, live corals were about approximately 40-63 %. Particularly, Porites lutea was the

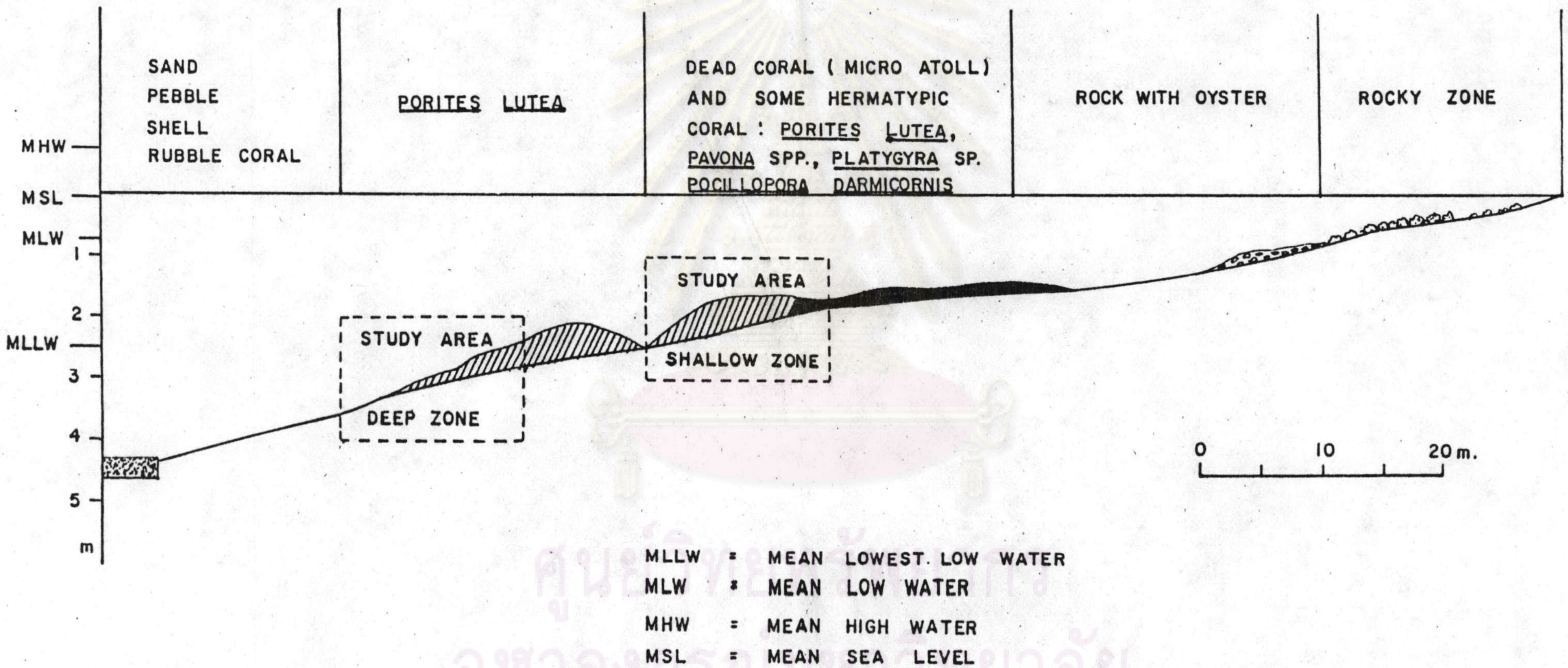


Figure 6 Profile of coral community in study area.

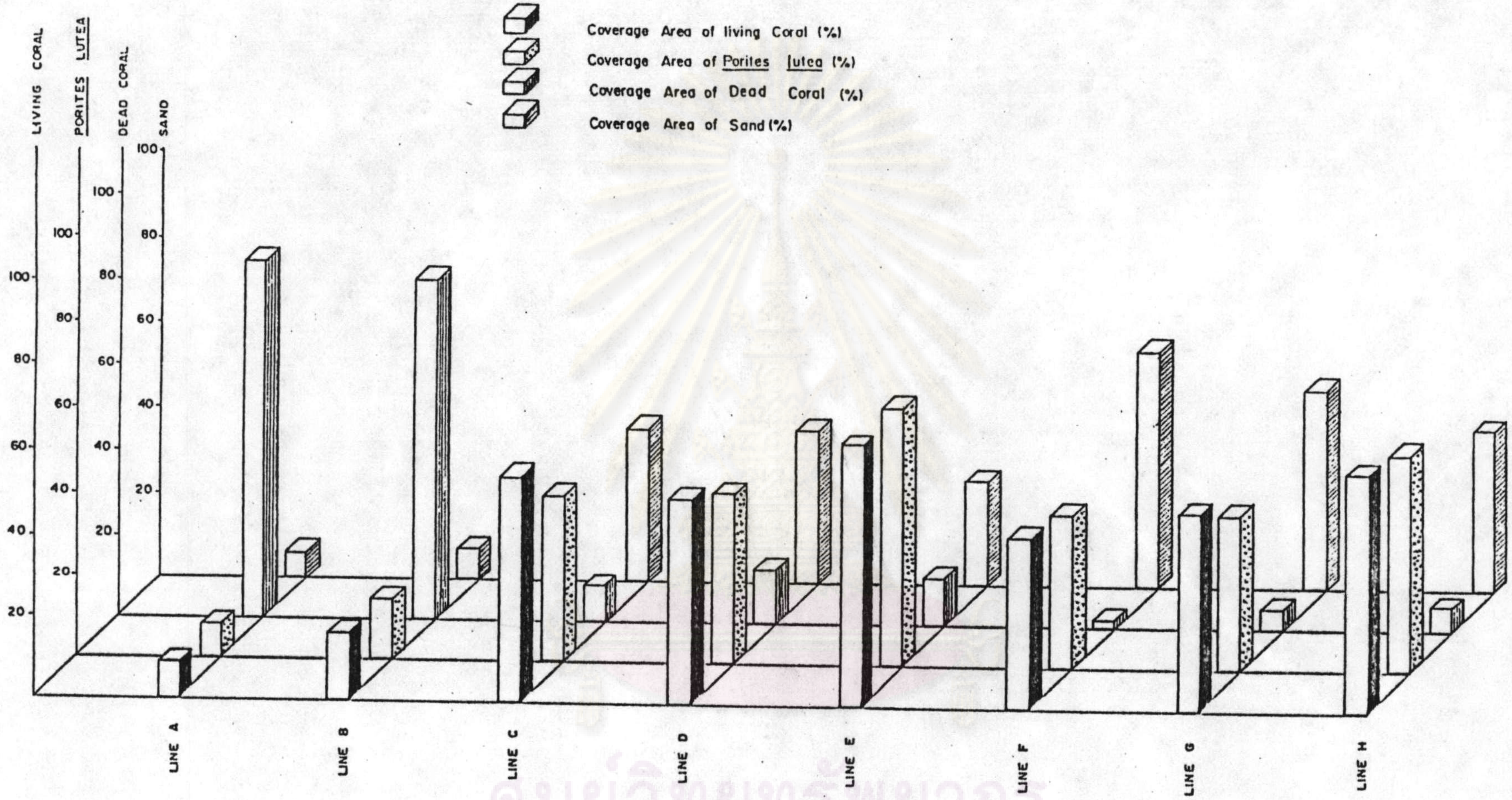


Figure 7 Comparison of coverage area of various substrates in each transect line.

most abundant species and had widest vertical range. It amounted to 82-98 % of live corals in this zone. Furthermore, it was found that <u>Porites lutea</u> grew rapidly in vertical axis and usually found overlying each other or dispersing on sandy substratum due to breaking off.

4. Environmental factors

4.1 Salinity and temperature

The results in Table 4 showed minimum salinity in September at 16.3 ± 0.3 ppt which was likely due to high precipitation as in Table 1 and freshwater run off from Chao Phraya and Bang Pakong rivers. In contrary, maximum salinity occurred during March-May being 31-32 ppt.

The maximum average temperature was 29.8 ± 0.0 ^{o}C in July and minumum average temperature was 26.0 ± 0.0 ^{o}C in January.

4.2 Light intensity

The results in Table 4 showed that the percentage relative light of penetration was minimum in January as 18 %, 12 %, 8 % at surface, mid depth and bottom respectively. Then, they increased to the maximum in July as 45 %, 37 %, 25 %. This phenomenon was caused by the initial light intensity before penetrating into seawater and some light reflection, scattering and absorbsion properties of seawater such as quantity of suspended solids.

Table 4 Physical environmental factors in study area.

Date	Sampling level	Suspended solids (mg/litre)	% of relative light penetration	Temperature (°C) Mean ± S.D.	Salinity (ppt) Mean ± S.D.
September '85	Surface	-	26		
	Mid depth	-	20	29.3 ± 0.3	16.3 ± 0.3
	Bottom	-	15		
November '85	Surface	7.5	38		
	Mid depth	-	31	29.0 ± 0.0	22.3 ± 1.7
	Bottom	-	24		
January '86	Surface	8.2	18		
	Mid depth	-	12	26.0 ± 0.0	22.8 ± 0.3
	Bottom	-	8		
March '86	Surface	5.6	28		
	Mid depth	-	25	27.1 ± 0.1	32.0 ± 0.0
	Bottom	-	21		
May '86	Surface	7.8	42		
	Mid depth	-	34	28.0 ± 0.0	31.0 ± 0.0
	Bottom	-	23		
July '86	Surface	6.4	45		
	Mid depth	-	37	29.8 ± 0.0	25.0 ± 0.0
	Bottom	-	25		

4.3 Suspended solids

The results revealed that the minimum suspended solids was 5.6 mg/l in March and maximum suspended solids was 8.20 mg/l in January due to previalling wind. Nevertheless, the suspended solids seemed to be consistent throughout the field experimental period as in Table 4.

4.4 Sedimentation rate

Table 5 showed the maximum sedimentation rate during November-January period which was 167.48 ± 71.95 $mg/cm^2/day$ in shallow zone and 58 ± 30.38 $mg/cm^2/day$ in deep zone. However, the minimum sedimentation rate appeared during March-May period which was 15.91 ± 6.20 $mg/cm^2/day$ in shallow zone and 3.22 ± 0.72 $mg/cm^2/day$ in deep zone. In the shallow zone sedimentation rates were higher than in deeper areas in all. this trend incline from line A to H except for line G.

Figure 8 illustrated comparison of sediment rate at different sediment fraction which were classified into > 63 μm and < 63 μm size range. The sediment larger than 63 μm was resuspended in water column in shallow water and tended to decrease with depth especially during November to January. On the other hand, silt clay fraction of sediments which is less than 63 μm in diameter were regularly found in each period. The minimum sedimentation rate was found during March-May.

Table 5 Sedimentation rate at each line and zone.

zones	Study line	Sedimentation rate ($mg/cm^2/day$)				
		Sep. - Nov.	Nov. - Jan.	Jan. - Mar.	Mar. - May	May - Jun.
Shallow	A	37.82 ± 23.07	268.65 ± 20.16	18.51 ± 7.02	23.22 ± 18.75	32.07 ± 13.83
	B	22.77 ± 6.01	167.82 ± 66.28	22.62 ± 6.97	18.27 ± 18.97	76.76 ± 15.95
	C	14.68 ± 1.68	108.23 ± 16.52	25.26 ± 7.90	13.23 ± 5.94	84.90 ± 33.34
	D	9.78 ± 2.43	125.24 ± 95.33	13.55 ± 4.30	8.91 ± 7.96	64.53 ± 9.91
	Mean ± S.D.	21.26 ± 12.27	167.48 ± 71.95	19.98 ± 5.11	15.91 ± 6.20	64.56 ± 23.22
	Range	9.78 - 37.82	108.23 - 268.65	13.55 - 25.26	8.91 - 23.22	32.07 - 84.90
Deep	E	7.27 ± 1.63	83.16 ± 50.16	11.38 ± 1.50	3.54 ± 0.69	35.28 ± 2.60
	F	6.81 ± 2.80	64.93 ± 4.10	14.66 ± 4.66	2.58 ± 1.11	35.36 ± 4.49
	G	4.53 ± 1.00	36.43 ± 20.95	11.44 ± 3.26	2.66 ± 0.41	30.36 ± 7.39
	H	4.97 ± 0.60	47.99 ± 28.84	16.10 ± 7.40	4.08 ± 1.89	34.78 ± 16.96
	Mean ± S.D.	5.90 ± 1.35	58.13 ± 20.38	13.40 ± 2.37	3.22 ± 0.72	33.94 ± 2.40
	Range	4.53 - 7.27	36.43 - 83.16	11.38 - 16.10	2.58 - 4.08	30.36 - 35.36

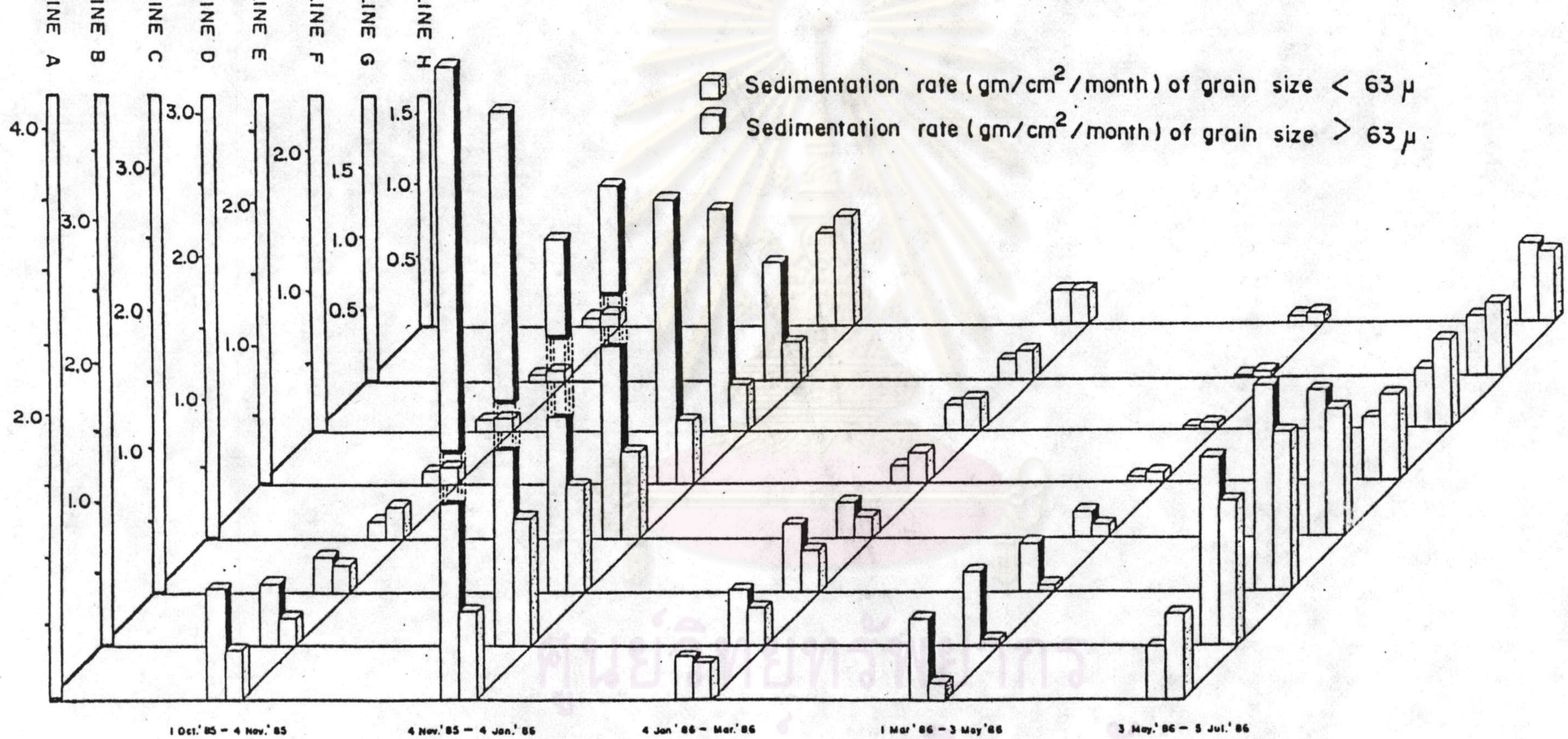


Figure 8 Comparison of the sedimentation rate in each line and period.

4.5 Primary productivity

Figure 9 illustrated the net primary production (NNP) since November 1985 to July 1986 in both zones. The NNP was generally higher in deep zone than in shallow zone . In shallow zone, NNP was maximum in November while the NNP in deep zone was maximum in July. The result presented that the maximum in shallow and deep zones were 1,849 mg C/m^2/day and 3,150 mg C/m^2/day respectively. In July the minimum NNP was 592 mg C/m^2/day. But in shallow zone, the minimum NNP in March was 157 mg C/m^2/day.

5. Comparison of boring organisms on coral substrates

5.1 Composition of boring organisms on living coral (Porites lutea).

Figure 10 showed the cumulative species curve of borers from 25 Porites lutea coral heads randomly collected from each zone. This showed the adequate samples in both zones. Thus the composition of infaunal animals were sufficiently represented by 25 collected coral heads in both shallow and deep zones. These animals were divided into 3 main groups, consisted of 22 families as in Figure 11. These infaunal animals were 3 families of boring sipunculids, 11 families of polychaetes, particularly which three families were borers, and 8 families of Molluscs which was 1 family of gastropods and 7 families of bivalves, only 2 families of boring bivalves (Figure 12).

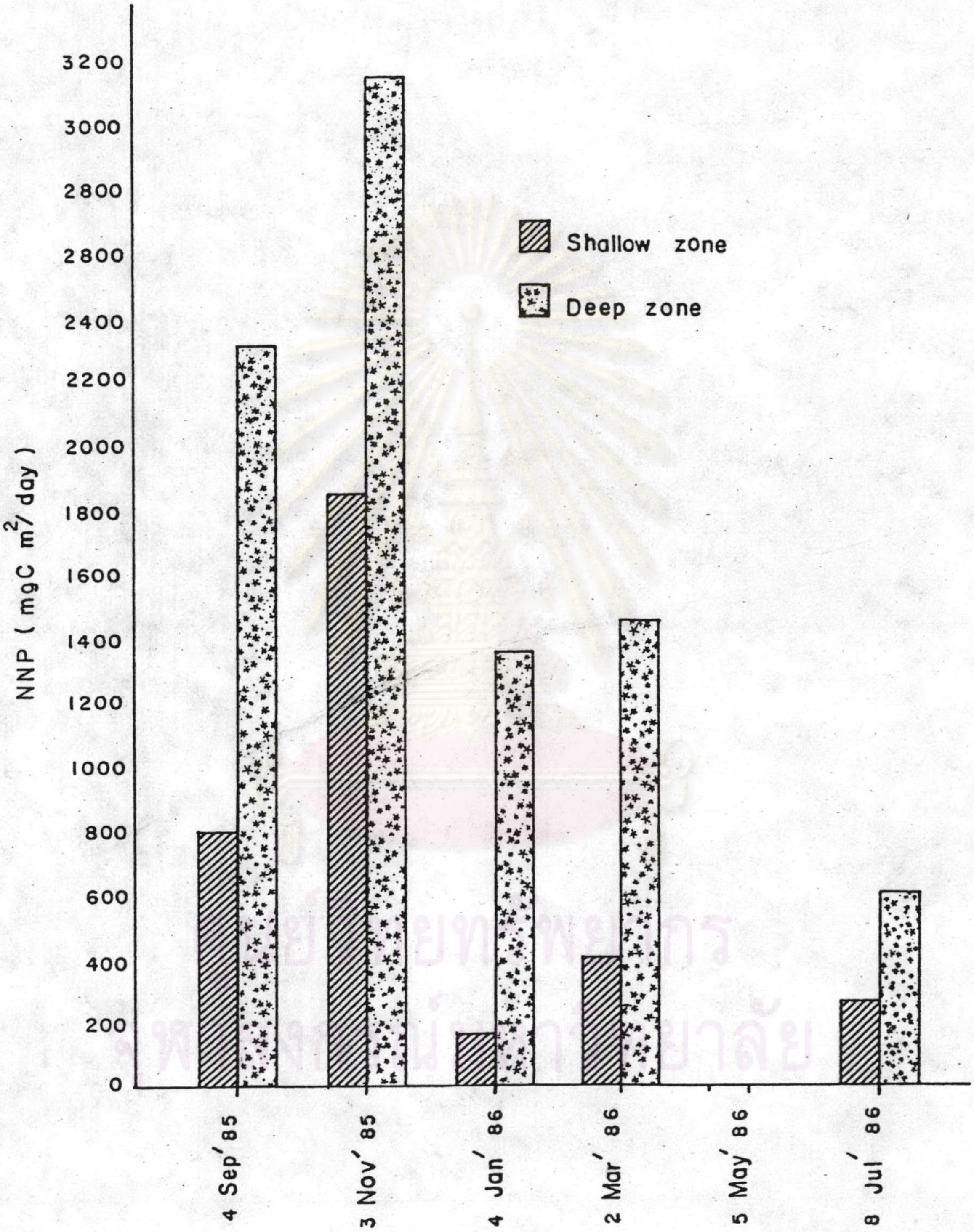


Figure 9 Comparison of primary productivity in each zone at different period.

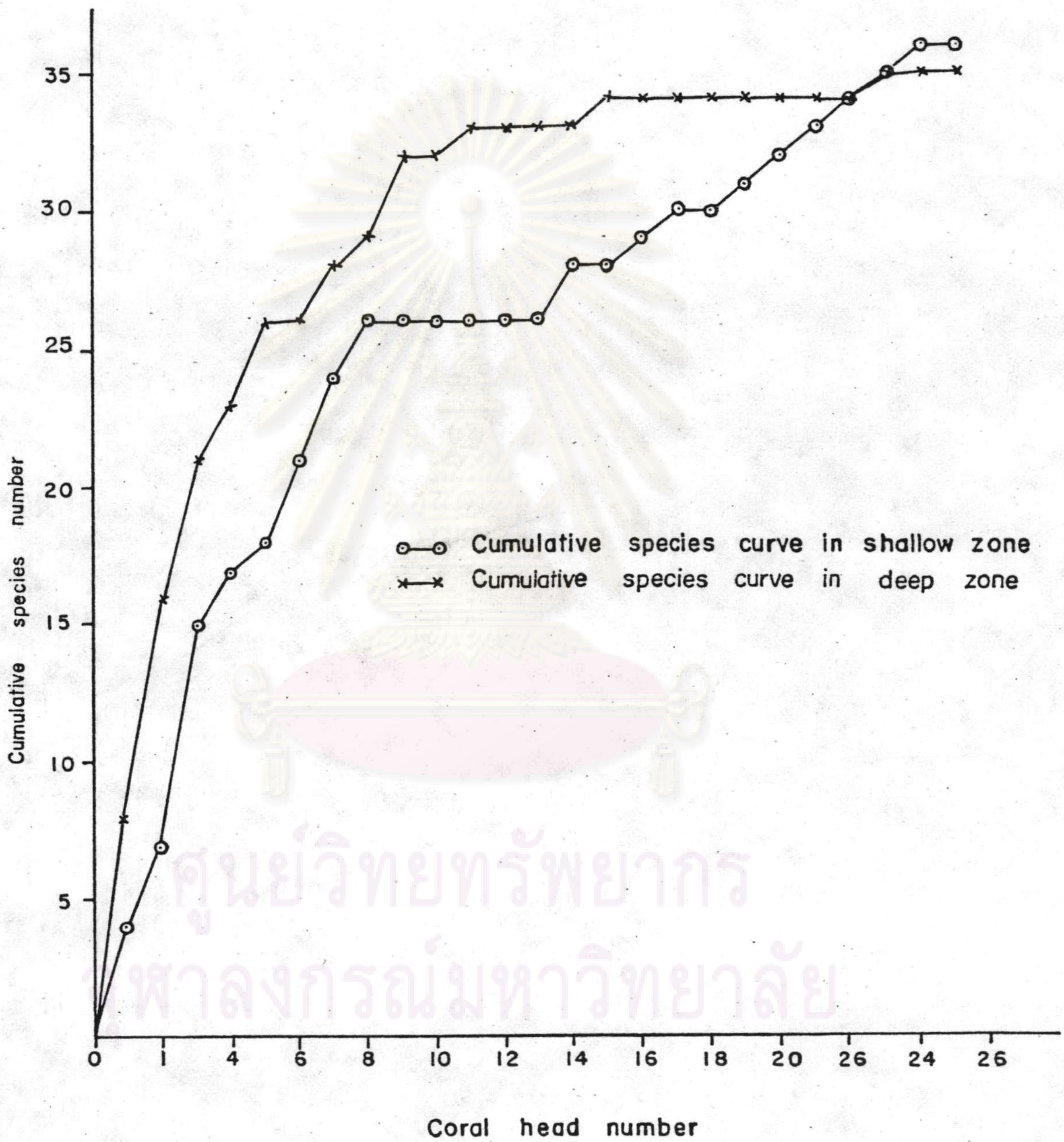


Figure 10 Cumulative species curves of infaunal animals in each zone.

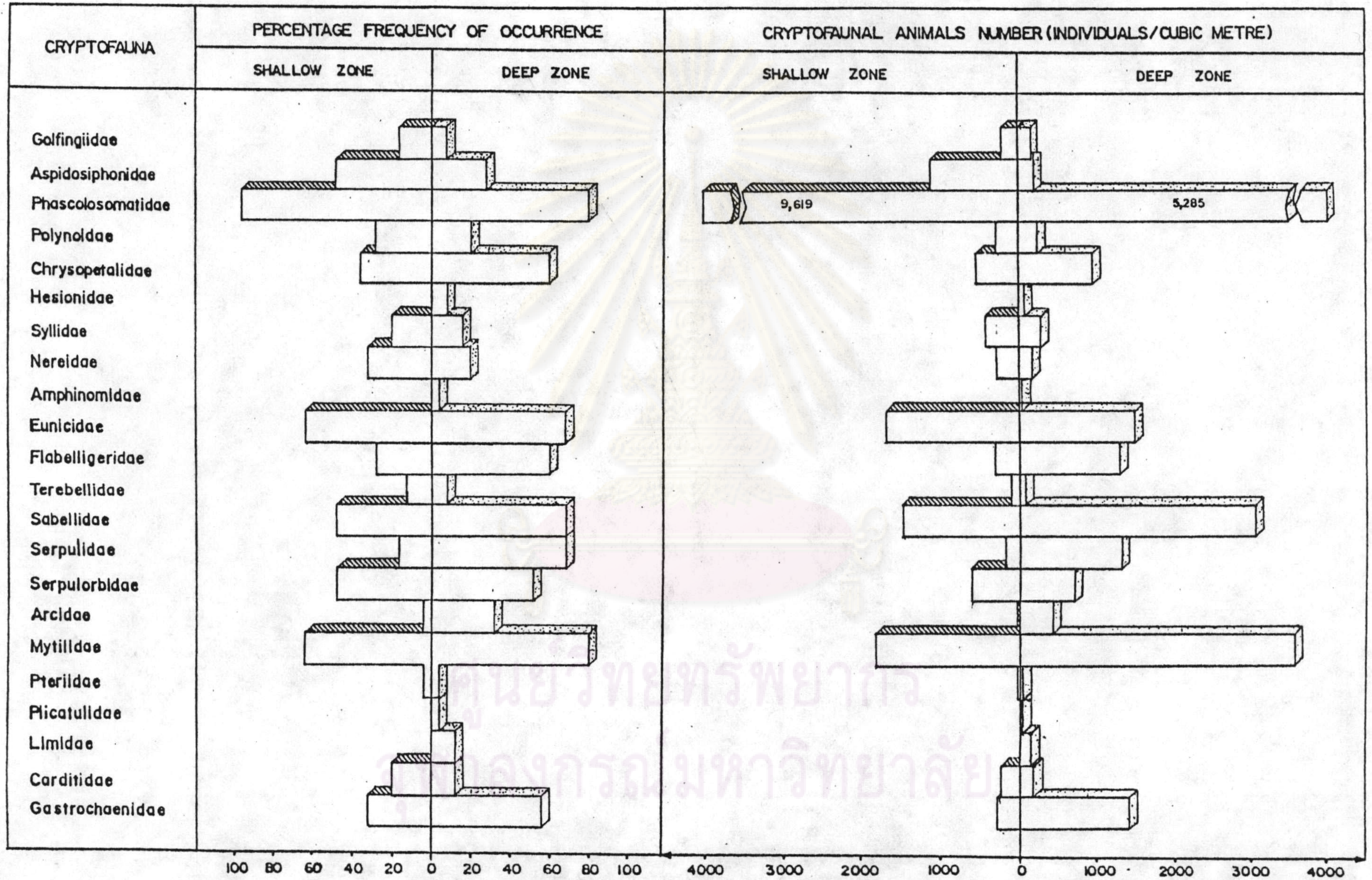


Figure 11 Comparison of cryptofauna percentage frequency of occurrence and number which were found in Porites lutea in each zone.

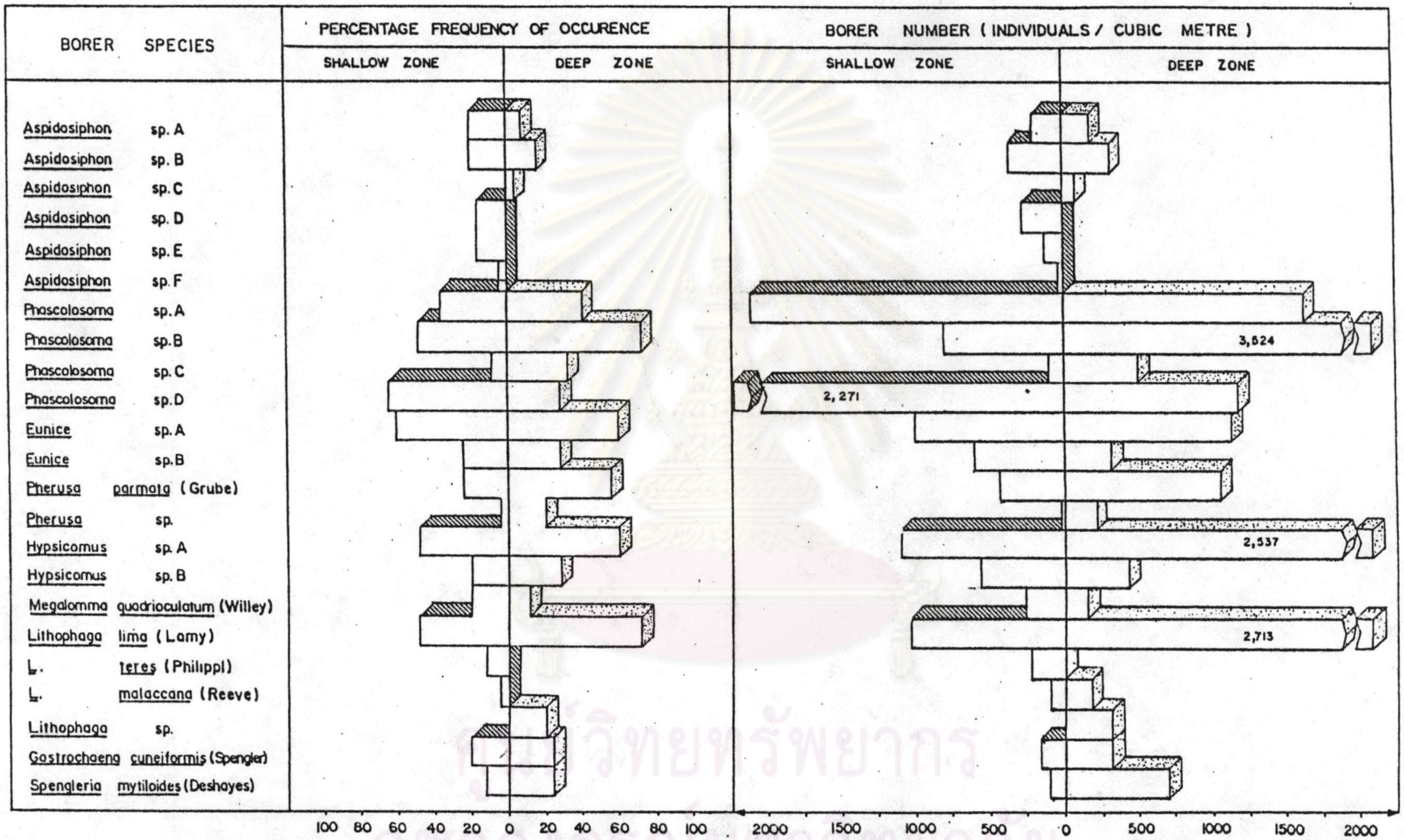


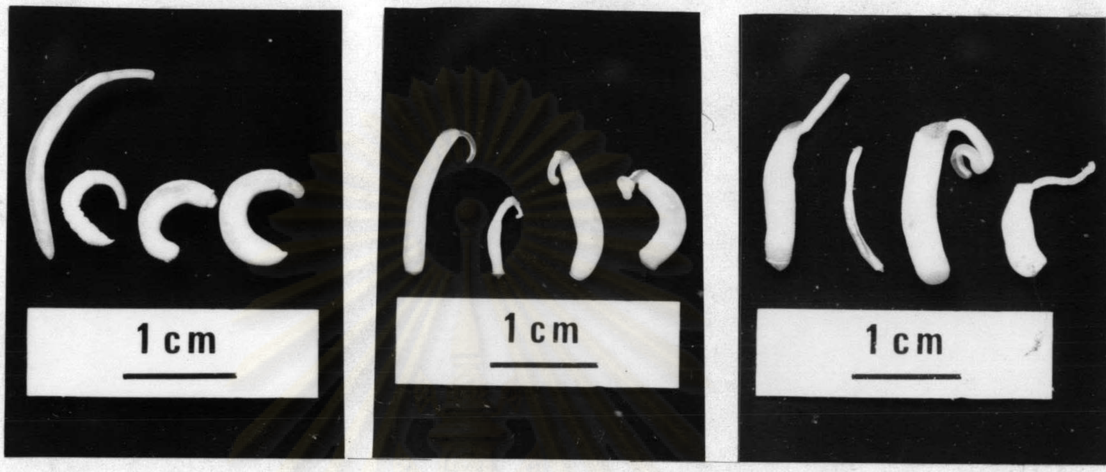
Figure 12 Comparison of borer species percentage frequency of occurrence and number which were found in Porites lutea in each zone.

The sipunculids consisted of family Phascolosomatidae which was the most frequent and abundant in both shallow and deep zones. Their total numbers were 9,619 indiv./m^3 in shallow zone. In addition, Family Aspidosiphonidae also found as boring sipunculids in Porites lutea.

The boring polychaetes Families Eunicidae, Flabelligeridae and particularly Sabellidae were the most abundant in deep zone. In contrary, Eunidae was the most abundant in shallow zone.

The boring bivalves found were of the Families Mytilidae and Gastrochaenidae which frequently and abundantly occurred in deep zone.

The three main animal groups mentioned above were subsequently identified as to genera and species. The results were found the boring sipunculids comprised of 6 species wach of Aspidosiphon and Phascolosoma as shown in Figure 13. The most abundant species, however, were Phascolosoma sp.B, in shallow zone, and Phascolosoma sp.D, in deep zone. The photographs of sipunculids were also displayed in Figure 13. For polychaetes, 7 species could be identified as in Figure 14. The most common were Hypsicomus sp., Pherusa parmata (Grube) and Eunice spp.. Hypsicomus sp. was found more abundant in deep zone than in shallow zone. The boring bivalves found were as follows Lithophaga lima Lamy, L. teres (Philippi), L. malaccana (Reeve), Gastrochaena cuneiformis Spengler and Spengleria mytiloides (Deshayes) (as in Figure 15). The excavated boreholes of



a b c

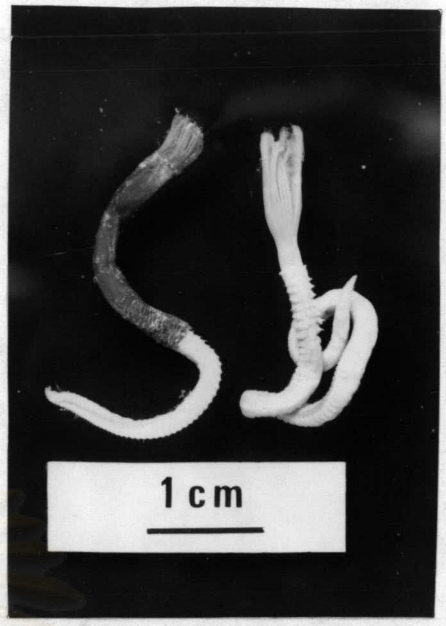
Figure 13 The sipunculid borers penetrated in Porites lutea

a) Family Phascolosomatidae(from left to right) ;
1) Phascolosoma sp. A, 2) Phascolosoma sp.B,
3) Phascolosoma sp. C, 4) Phascolosoma sp.D

b) Family Aspidosiphonidae (from left to right) ;
1) Aspidosiphon sp. A, 2) Aspidosiphon sp.B,
3) Aspidosiphon sp. C, 4) Aspidosiphon sp.D

c) Family Aspidosiphonidae (from left to right) ;
1) Aspidosiphon sp. E, 2) Aspidosiphon sp.F,
3) Aspidosiphon sp. G, 4) Aspidosiphon sp.H

a



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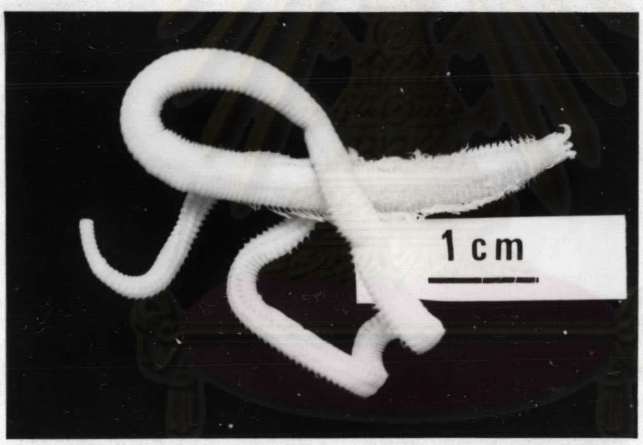


c

Figure 14 The polychaete borers penetrated in Porites lutes

a) Family Flabelligeridae; Pherusa parmata the arrow indicate sand shield which is the specific character of this species.
b) Family Sabellidae: Hypsicomus sp.
c) Family Eunicidae: Eunice sp.

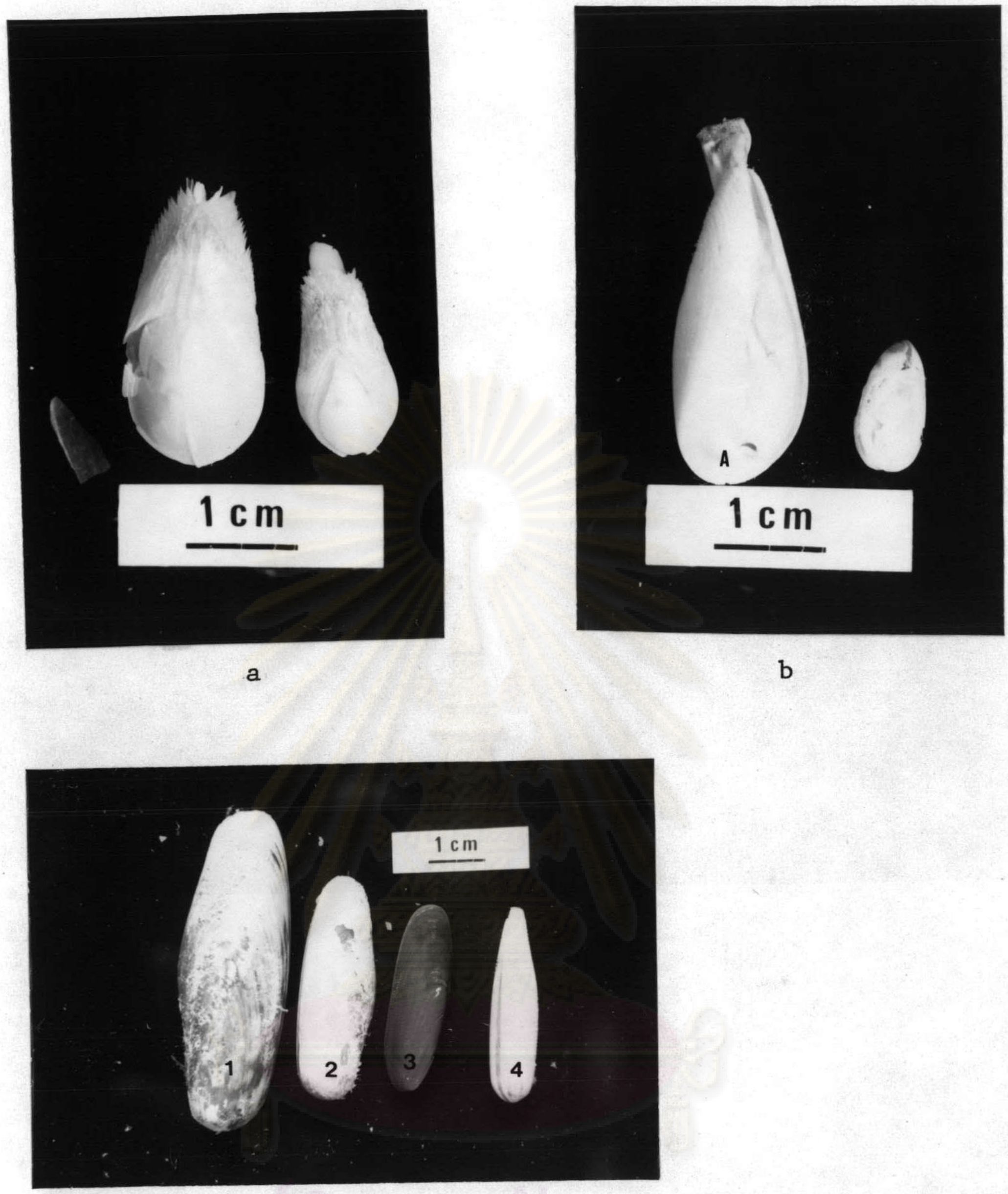


Figure 15 The boring bivalves bored in Porites lutea

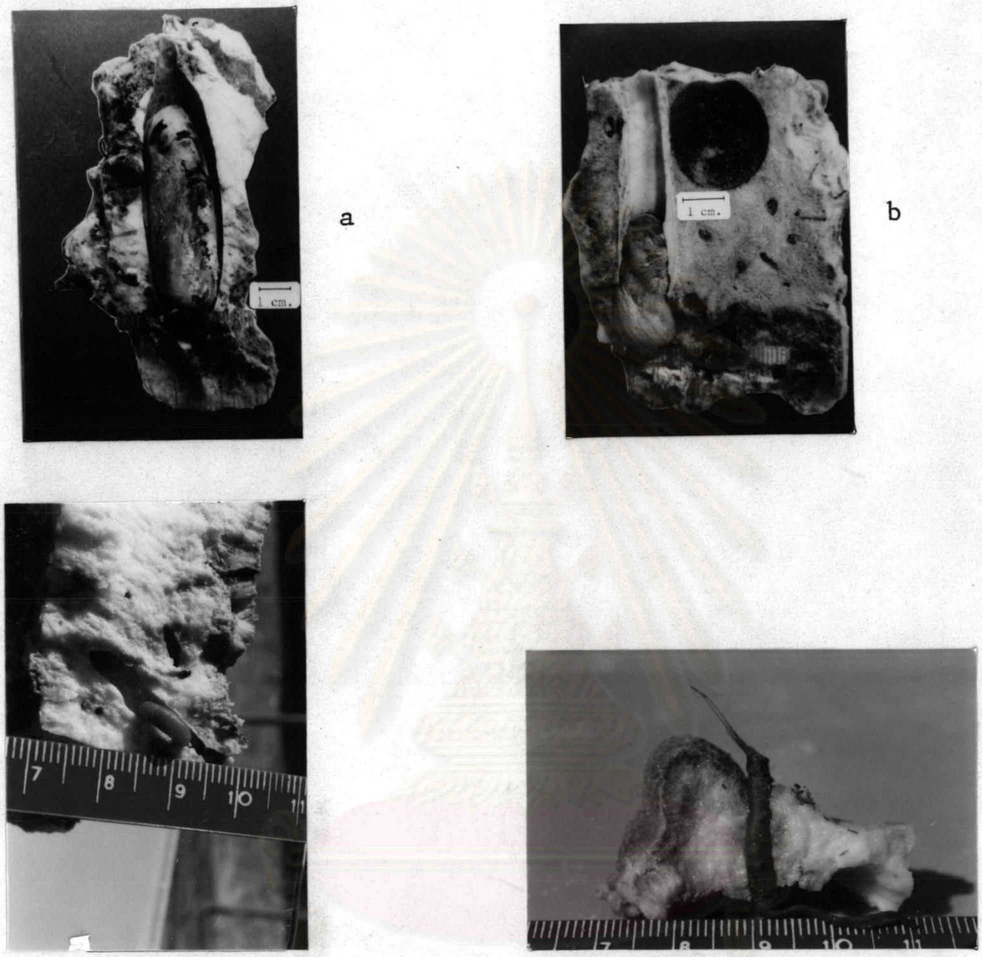
a) Family Gastrochaenidae; Spengleria mytiloides
b) Family Gastrochaenidae; Gastrochaena cuneiformis (A)
c) Family Mytilidae; 1) Lithophaga sp., 2) L. lima, 3) L. teres, 4) L. malaccana.

such predominant borers in Porites lutea were illustrated in figure 16. In additional, their aperture boreholes were also shown in Figure 17.

These borer compositions were analysed for Biological Index to determine out the most predominant species. The results obviously showed the predominant borers in shallow zone namely Phascolosoma sp.D, Eunice sp., Phascolosoma sp.B, Lithophaga lima, Hypsicomus sp.A, Phascolosoma sp.A, Eunice sp.B and Pherusa parmata respectively (as in Table 6). In deep zone, the predominant borers were ranked as follow; Phascolosoma sp.B, Lithophaga lima, Hypsicomus sp.A, Eunice sp.A, Pherusa parmata and Phascolosoma sp.A as shown in Table 7.

In addition, the dispersion pattern of these predominant borer species were determined by using Poisson's method as in Table 8,9. The ratio obviously exhibited that almost all of predominant borer species displayed clumped dispersion pattern. But for Phascolosoma sp.B in shallow zone and Pherusa parmata in deep zone, they acted as randomly dispersion pattern.

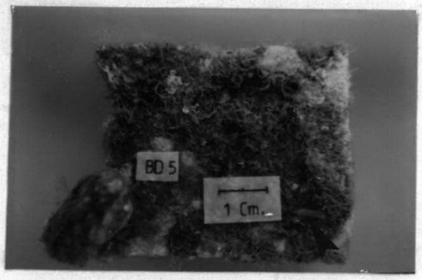
The coefficient of association (c) of 6 predominant borers were determined. The outcomes showed that Phascolosoma sp.D associated with the occurrence of Phascolosoma sp.B. On the other hand, it showed negative associations with Lithophaga lima, Hypsicomus sp.A and Phascolosoma sp.A. These are the result in shallow zone as in Table 10. Table 11 presented the results in deep zone



a b c d

Figure 16 The excavated boreholes bored by various boring organisms.

a) Illustration of coral exoskeleton which is bored by Lithophaga lima
b) The coral exoskeleton section, showing the pattern of penetration and borehole of Spengleria mytiloides.
c) Illustration of the sipunculid borer; Phascolosoma sp. in coral exoskeleton.
d) Pherusa parmata in Porites lutea exoskeleton.



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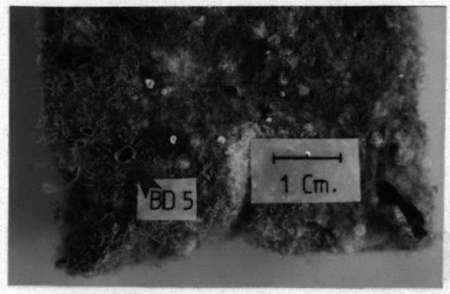


b

c

Figure 17 Aperture of boreholes due to various borers.

The arrows indicate

a) Introvert of Phascolosoma sp. which bore in coral blocks.

b) Aperture boreholes of Megalomma guadrioculatum on 10 months coral blocks.

c) "Dumbel shape or figure of eight", these illustrate apertures of siphonated boring bivalves at the dead part of Porites lutea colonies.

Table 6 Dominant boring organisms from the living coral (Porites lutea) in shallow zone, ranked according to their Biological Index values

Boring organisms	Individuals/cubic metre		Frequency	Frequency*	Biological
	x̄	S.D.	(25 colonies)		**Index
Phascolosoma sp.D	276.60	380.8	16	16	314
Eunice sp.A	114.8	152.0	15	12	273
Phascolosoma sp.B	99.6	140.8	12	10	237
Lithophaga lima	106.0	216.4	12	11	222
Hypsicomus sp.A	105.4	168.0	12	8	218
Phascolosoma sp.A	202.2	401.8	9	8	174
Eunice sp.B	59.0	210.4	6	4	110
Pherusa parmata	23.0	46.6	6	4	108
Hypsicomus sp.B	58.8	119.4	5	3	90
Megalomma quadrioculatum	44.12	121.6	5	3	89
Aspidosiphon sp.B	49.2	147.2	5	2	88
Aspidosiphon sp.A	19.8	44.4	5	2	87
Gastrochaena cuneiformis	22.2	46.8	5	3	87
Aspidosiphon sp.D	44.4	161.2	4	3	73
Aspidosiphon sp.E	17.2	57.8	4	2	70
Lithophaga teres	26.6	84.8	3	1	51
Spengleria mytiloides	16.8	48.8	3	0	47
Phascolosoma sp.C	5.8	20.8	2	2	38
Lithophaga malaccana	10.6	53.4	1	1	19
Pherusa sp.A	8.0	40.0	1	0	17
Aspidosiphon sp.F	4.8	23.6	1	0	17

Remark * as one of three most common borers
** 20-0 scale

Table 7 Dominant boring organisms from the living coral (Porites lutea) in deep zone, ranked according to their Biological Index values.

Boring organism	Individuals/cubic metre		Frequency	Frequency*	Biological
	$\bar{x}$	S.D.	(25 colonies)		**Index
Phascolosoma sp.B	411.0	423.6	18	17	346
Lithophaga lima	445.2	741.0	18	13	333
Hypsicomus sp.A	260.2	386.6	15	9	275
Eunice sp.A	137.4	191.4	15	11	271
Pherusa parmata	149.8	178.4	14	11	257
Phascolosoma sp.A	142.8	234.4	10	8	185
Phascolosoma sp.C	34.8	62.4	8	3	139
Hypsicomus sp.B	38.8	74.0	7	4	126
Unidentified Gastrochaenida	48.6	114.6	7	2	119
Eunice sp.B	38.8	74.2	7	2	118
Phascolosoma sp.D	69.7	138.8	6	5	111
Spengleria mytiloides	67.6	67.8	6	4	111
Gastrochaena cuneiformis	30.8	77.0	6	3	100
Lithophaga sp.A	42.6	105;6	5	3	86
L. malaccana	22.2	55.8	5	2	85
Pherusa sp.A	20.81	81.2	5	2	84
Aspidosiphon sp.B	27.80	105.2	4	2	71
Megalomma quadrioculatum	28.0	77.6	3	1	52
Aspidosiphon sp.A	11.6	47.4	2	2	38
Aspidosiphon sp.C	6.4	32.6	1	1	19

Remark * as one of three most common borers
** 20-0 scale

Table 8 Dispersion pattern of 7 predominant borers in <u>Porites lutea</u> in shallow zone by poisson method.

Boring organisms	Mean ($\bar{x}$)	Variance (s^2)	S^2: $\bar{X}$ ratio	T-test
Phascolosoma sp.A	2.52	28.01	11.12	34.90*
Phascolosoma sp.B	1.00	1.26	1.59	2.03
Phascolosoma sp.D	2.72	3.21	3.79	9.62*
Eunice sp.A	1.20	1.44	1.73	2.51*
Hypsicomus sp.A	1.12	1.76	2.77	6.09*
Lithophaga lima	1.24	2.05	3.39	8.24*

Remark * T-test, degree of freedom = n-1, at significant level 97.5 %

Table 9 Dispersion pattern of 7 predominant borers in <u>Porites lutea</u> in deep zone by poisson method.

Boring organisms	Mean ($\bar{x}$)	Variance (s^2)	$S^2 : \bar{X}$ ratio	T-test
<u>Phascolosoma</u> sp.A	1.84	3.64	7.2	21.38*
<u>Phascolosoma</u> sp.B	4.04	45.37	11.23	35.28*
<u>Eunice</u> sp.A	1.28	2.38	1.87	2.95*
<u>Pherusa parmata</u>	1.20	1.67	1.39	1.34
<u>Hypsicomus</u> sp.A	2.88	20.03	6.95	20.53*
<u>Lithophaga lima</u>	3.28	18.79	5.73	16.31*

Table 10 Coefficient of association (c) and chi-square (x^2) of borers are found in Porites lutea in shallow zone.

	Phascolosoma sp. D	Eunice sp. A	Phascolosoma sp. B	Lithophaga lima	Hypsicomus sp. A	Phascolosoma sp. A
Phascolosoma sp. D	0.00	0.22	0.40*	-0.36*	-0.36*	-0.65*
Eunice sp. A		0.00	-0.04	0.10	0.10	0.06
Phascolosoma sp. B			0.00	0.04	-0.31*	-0.31
Lithophaga lima				0.00	0.04	0.35*
Hypsicomus sp. A					0.00	0.22
Phascolosoma sp. A						0.00

Phascolosoma sp. D	0.00	0.59	5.53*	3.31*	3.31*	13.68*
Eunice sp. A		0.00	0.33	0.06	0.06	0.01
Phascolosoma sp. B			0.00	0.04	3.28*	2.30
Lithophaga lima				0.00	0.04	3.31*
Hypsicomus sp. A					0.00	0.97
Phascolosoma sp. A						0.00

Remark :- * The values of coefficient of assciation and chi-square at significant level 95 %

Table 11 Coefficient of association (c) and chi-square (x^2) of borers are found in Porites lutea in deep zone

	Phascolosoma sp. B	Lithophaga lima	Hypsicomus sp. A	Eunice sp. A	Pherusa parmata	Phascolosoma sp. A
Phascolosoma sp. B	0.00	0.01	0.17	0.03	-0.03	-0.52*
Lithophaga lima		0.00	0.03	0.03	0.12	-0.28
Hypsicomus sp. A			0.00	0.00	-0.32	0.00
Eunice sp. A				0.00	0.09	0.00
Pherusa parmata					0.00	0.05
Phascolosoma sp. A						0.00

Phascolosoma sp. B	0.00	0.21	0.40	0.07	0.27	6.03*
Lithophaga lima		0.00	0.07	0.07	0.14	2.39
Hypsicomus sp. A			0.00	0.00	2.44	0.00
Eunice sp. A				0.00	0.01	0.00
Pherusa parmata					0.00	0.01
Phascolosoma sp. A						0.00

Remark : * The values of coefficient of association and chi-square at significant level 95 %

which showed that Phascolosoma sp.B was negatively associated with Phascolosoma sp.A, as in the shallow zone.

Furthermore, the correlation coefficient analysis revealted that the total number of polychaetes borers had positive correlation with sipunculids total number in shallow zone as $y = 0.67x + 5.04$ and $y = 0.30x + 3.66$ respectively.

The result also exhibited the comparison of species composition, densities and frequency of occurrence in each zone. As in Table 12, the Diversity Index indicated cryptofauna which found in deep zone were more diverse than shallow zone. But the Diversity Index of borers species in shallow and deep zone were almost equal.

5.2 Composition of boring organisms on coral blocks

Cryptofauna found in coral blocks after 10 months (Figure 18) could be identified into 13 families (Figure 19), 2 families of sipunculids, it families of polychaetes. Of which were 5 borer families namely Spionidae, Cirratilidae, Eunicidae, Dorvilleidae and Sabellidae. Consequently, the results also presented that the densities of Eunicidae, Cirratulidae were 30,556 and 22,700 indiv./m^3 res[ectively in shallow zone. In contrary, in deep zone, Sabellidae was the most abundant which showed the density of 45,299 indiv./m^3.

Subsequently, these animals were identified to genus (Figure 19) or species as well. The results exhibited that 2 genera (Figure 20) of sipunculids were Aspidosiphon spp.

Table 12 Diversity Index and Evenness of cryptofaunal animals in various substrates and zones.

Zones	Substrates	Diversity Index ($\bar{H}$)	Evenness (e)
Shallow	*Porites lutea*	0.8133	3.4818
	Coral blocks	0.7769	4.1074
Deep	*Porites lutea*	1.0190	4.4057
	Coral blocks	0.8923	4.6401

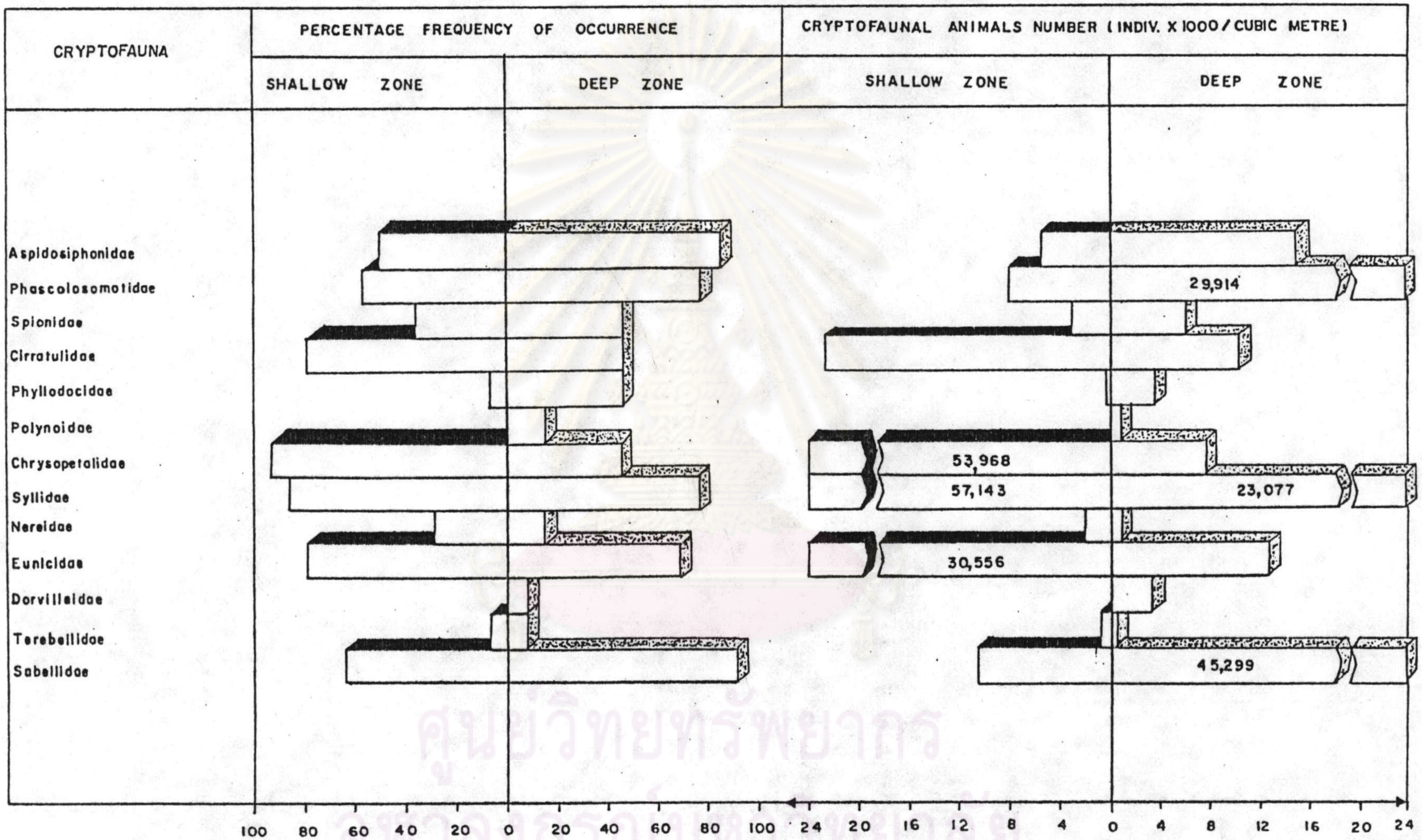


Figure 18 Comparison of borer species percentage frequency of occurrence and number which were found in each zone.

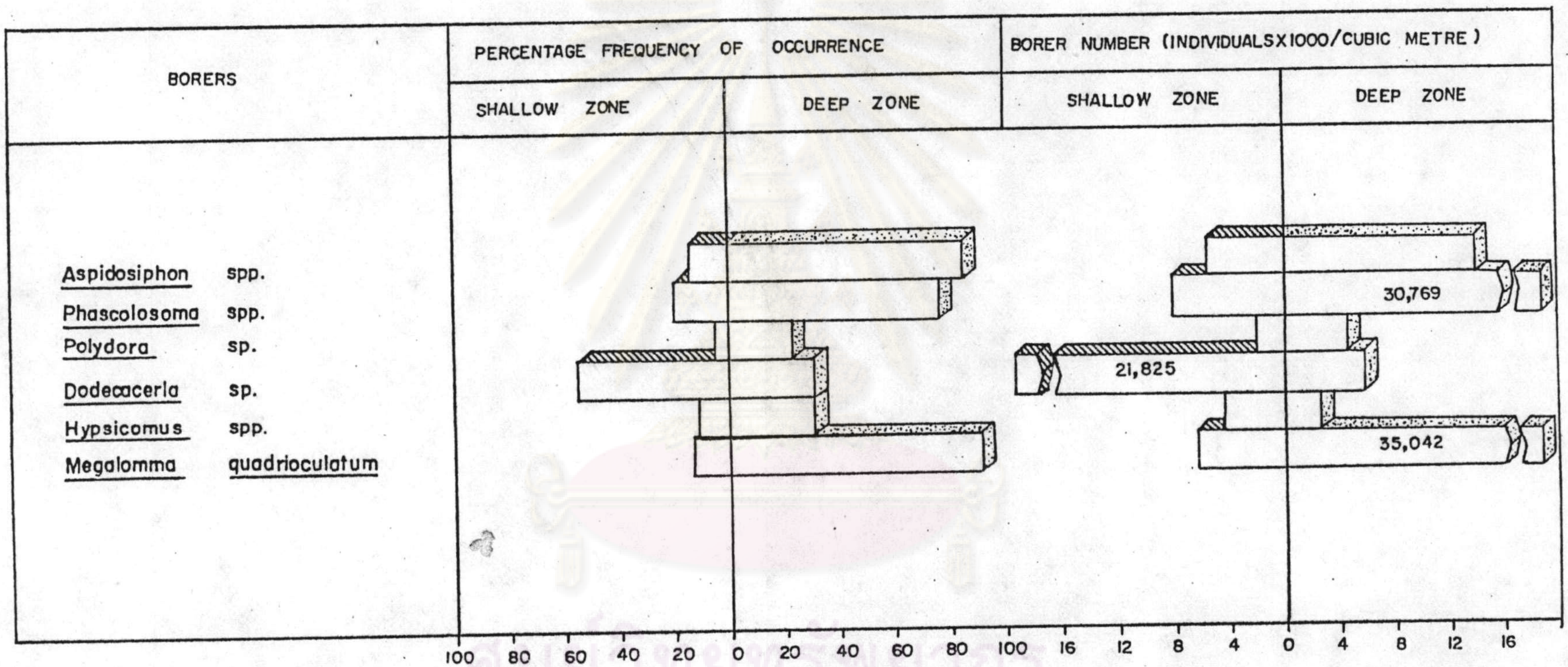


Figure 19 Compared the amount of various borer groups in each zone at different substrates.

and Phascolosoma spp., and 4 genera of boring polychaetes namely Polydora sp., Dodecaceria sp., Hypsicomus spp. and particularly Megalomma quadrioculatum which was the most abundant with densities 35,042 indiv./m^3 (as in Figure 19, 20, 21).

Furthermore, the predominant boring organisms found in coral blocks after 10 months in shallow zone in Dodecaceria sp. with density 21,325 indiv./m^3 and in deep zone, Megalomma quadrioculatum.

The 4 predominant borers were taken for Biological Index analysis as in Table 13. The outcomes were ranked as follow : Dodecaceria sp., Phascolosoma spp., Aspidosiphon spp., Megalomma quadrioculatum, respectively in shallow zone. The result in Table 14 also confirmed that 4 predominant borers in coral blocks were the same as in Porites lutea in shallow zone. Particularly, Dodecaceria sp. were abundantly found in shallow zone whilst in deep zone, Megalomma quadrioculatum was the most abundance. Their aperture boreholes were illustrated in Figure 17.

However, the boring sponges were rarely found in coral blocks with the exception of the coral blocks which were placed at line G in subzone GH as in Figure 22. This area had the minimum sedimentation rate as aforesaid.

Table 15 showed the dispersion patterns of the 4 predominant borers in coral blocks. They were found that all of boring organisms which penetrated in coral blocks were of clumped distribution.

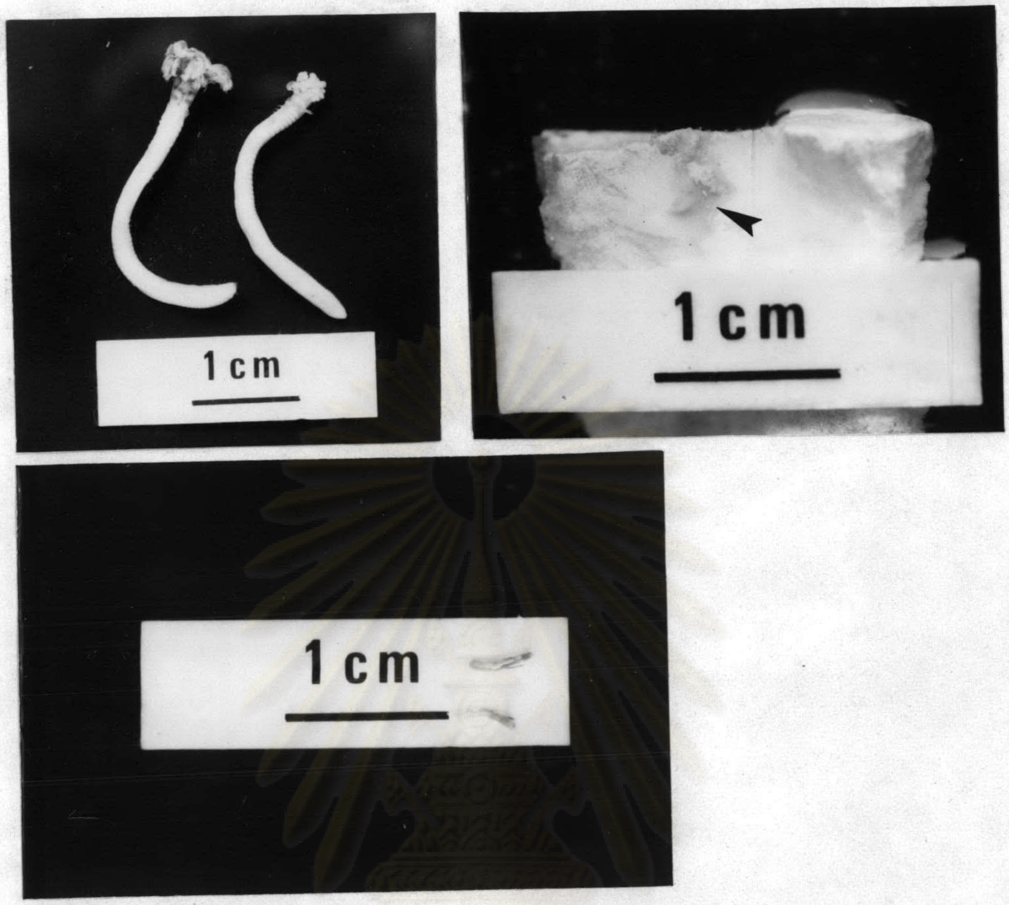
a

c b

Figure 20 The sipunculid borers in coral blocks after leaving in study area for 10 months

a) Family Phascolosomatidae; Phascolosoma spp.
b,c) Family Aspidosiphonidae; Aspidosiphon spp.

1 a 2 a



b

Figure 21 Predominant polychaetes borers and boring sponges chamber in coral blocks after leaving for 10 months.

a) The polychaete borers in coral blocks after being set in study area for 10 months as follows :-

1a) Polychaete borers which had been found predominantly on coral blocks in the deep zone; Megalomma quadrioculatum.

2a) Polychaete borers which had been found dominantly in the shallow zone; Dodecaceria sp.

b) Boring sponge which bored in coral blocks.

Table 13 Dominant boring organisms from the coral blocks in shallow zone,ranked according to their Biological Index values

Boring organisms	Individuals/cubic metre		Frequency	Frequency*	Biological
	$\overline{x}$	S.D.	(14 blocks)		**Index
Dodecaceria sp.	4,365.2	5,537.4	11	11	127
Phascolosoma spp.	1,587.4	1,614.0	8	8	88
Aspidosiphon spp.	1,111.4	1,509.8	7	4	73
Megalomma quadrioculatum	952.6	1,562.8	5	5	57
Unidentified sabellids	854.8	1,213.4	5	5	52
Polydora sp.	397.0	703.8	3	3	33
Unidentified cirratulids	79.4	297.2	1	1	10
Hypsicomus sp.B	79.4	297.2	1	1	10
Unidentified spionids	79.4	297.2	1	0	9

Remark * as one of three most common species

** 12-0 scale

Table 14 Dominant boring organisms from the coral blocks in deep zone, ranked according to their Biological Index values

Boring organisms	Individuals/cubic metre		Frequency	Frequency*	Biological
	$\overline{x}$	S.D.	(13 blocks)		**Index
Megalomma quadrioculatum	7,008.6	7,689.4	12	12	133
Phascolosoma spp.	6,666.0	6,530.4	10	9	113
Aspidosiphon spp.	2,820.6	2,340.2	11	9	112
Dodecaceria sp.	1,196.8	2,813.4	4	2	41
Hypsicomus sp.A	427.6	722.8	4	0	35
Unidentified spionids	256.6	487.6	4	0	33
Polydora sp.	940.4	2,753.4	3	1	29
Unidentified cirratulids	683.8	1,606.4	3	1	28
Unidentified sabellids	79.4	297.2	1	0	8

Remark * as one of three most common borers
** 12-0 scale

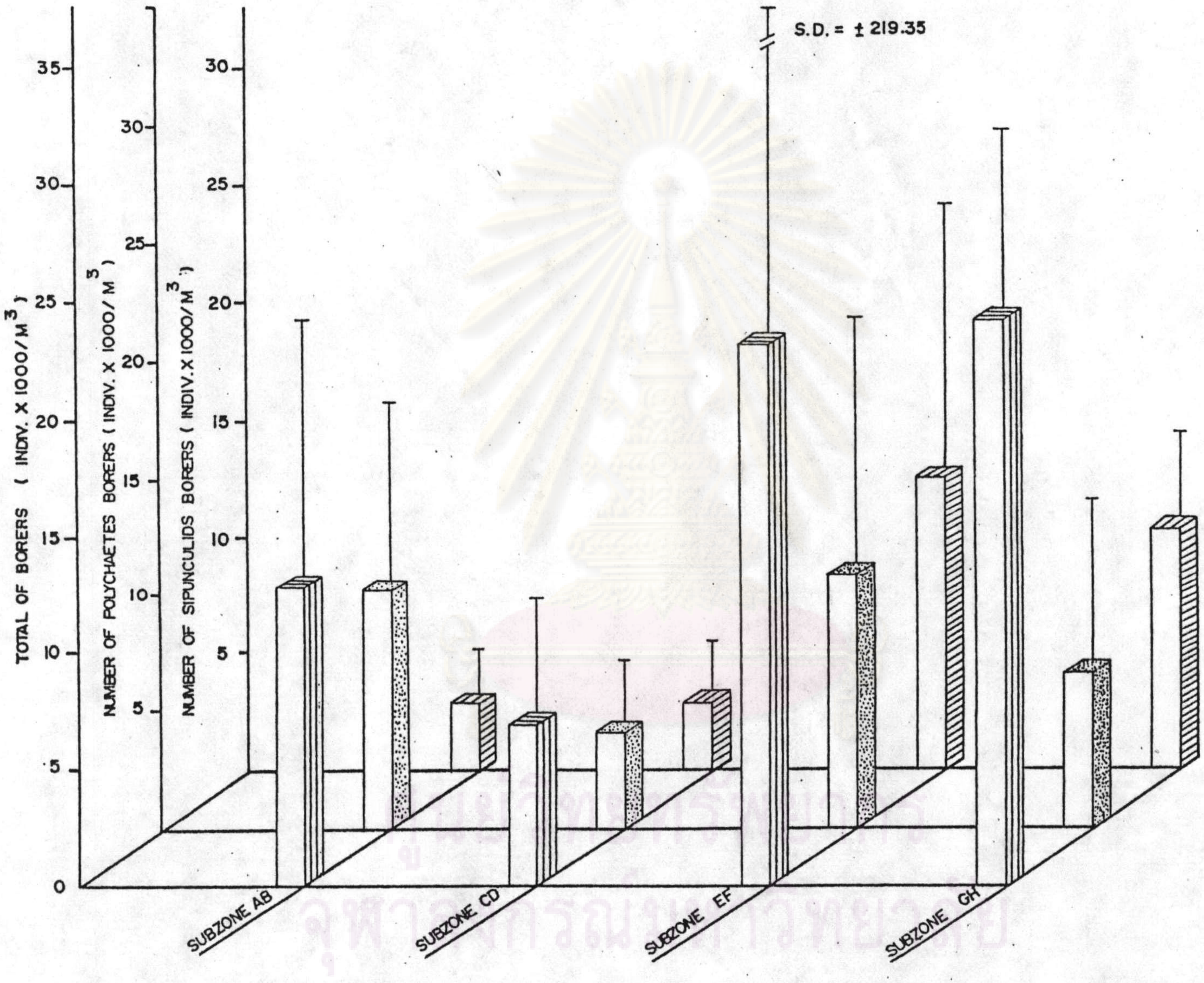


Figure 22 Comparison of total number of borer, polychaetes borers and sipunculids in each subzone.

Table 15 Dispersion pattern of 4 dominant borers in coral blocks after experiment for 10 months, by poisson method

Boring organisms	Mean ($\bar{x}$)	Variance (s^2)	$S^2 : \bar{X}$ ratio	T-test
<u>Dodecaceria</u> sp.	2.65	17.92	6.76	20.57*
<u>Megalomma</u> <u>quadrioculatum</u>	3.52	30.80	8.75	7.68*
<u>Phascolosoma</u> spp.	3.41	21.33	6.25	18.77*
<u>Aspidosiphon</u> spp.	1.74	3.58	2.06	3.78*

Remark * T-test degree of freedom = n-1, at significant level 99%

In addition, the densities of all borers, polychaetes and sipunculids, were also illustrated in Figure 23. Such a zone was divided into 2 subzones and found that the total number of borers indeep zone were higher than in shallow zone with the abundances of the polychaete borers and sipunculids.

Besides, coefficient of association (c) was also analysed and presented in Table 16, 17. The results as in Table 17 indicated that Megalomma quadrioculatum had absolutely negative association with Phascolosoma sp. and Aspidosiphon spp..

5.3 Comparison of the borers composition in each substrate

The species composition as aforementioned, showed that sipunculids found in both zones were in the same family but different species. Some families of boring polychaetes in Porites lutea and coral blocks were quite different as follows; Spionidae, Cirratulidae, Dorvilleidae were only found in coral blocks while in Porites lutea they were Eunicidae and particularly, Sabellidae; Hypsicomus spp. Sabellidae in coral blocks was Megalomma quadrioculatum. In addition, the boring bivalves were only found in Porites lutea.

Furthermore, the Diversity Index indicated that cryptofauna families as in Table 12 were similar except for Porites lutea in deep zone. Table 18 obviously exhibited that the diversity of borers species in coral blocks was

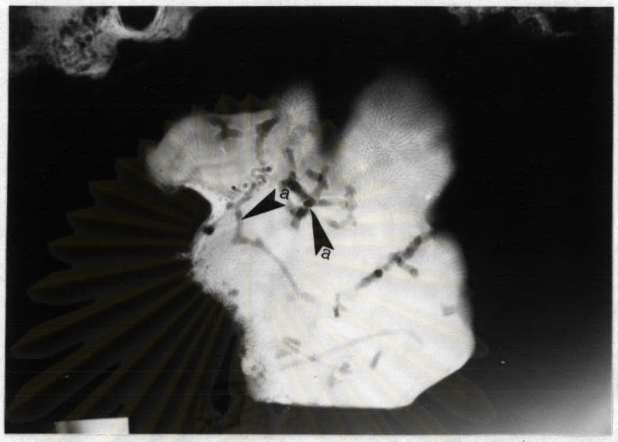


Figure 23 Slabbed coral after x-radiographic process which could be identified (indicated arrows)

a polychaetes boreholes.
b sipunculids boreholes.
c bivalves boreholes.
d sponges boreholes.

Table 16 Coefficient of association (c) and chi-square(x^2) of borers are found on coral blocks at deep zone.

(c)

	Megalomma quadrioculatum	*Phascolosoma* spp.	*Aspidosiphon* spp.
Megalomma quadrioculatum	0.00	-1.00*	-1.00*
Phascolosoma sp.		0.00	0.35
Aspidosiphon spp.			0.00

(x^2)

	Megalomma quadrioculatum	*Phascolosoma* spp.	*Aspidosiphon* spp.
Megalomma quadrioculatum	0.00	3.56*	3.49*
Phascolosoma sp.		0.00	0.00
Aspidosiphon spp.			0.00

Remark : * The values of coefficient of association and chi-square at significant level 95 %

Table 17 Coefficient of association (c) and chi-square (x^2) of borers are found in coral blocks at shallow zone.

(c)

	Dodecaceria sp.	*Phascolosoma* sp.	*Aspidosiphon* spp.	*Megalomma quadrioculatum*
Dodecaceria sp.	0.00	-0.22	0.27	0.01
Phascolosoma sp.		0.00	0.25	0.06
Aspidosiphon spp.			0.00	0.11
Megalomma quadrioculatum				0.00

(x^2)

	Dodecaceria sp.	*Phascolosoma* sp.	*Aspidosiphon* spp.	*Megalomma quadrioculatum*
Dodecaceria sp.	0.00	1.07	1.07	0.34
Phascolosoma sp.		0.00	0.29	0.16
Aspidosiphon spp.			0.00	0.00
Megalomma quadrioculatum				0.00

Remark : * The values of coefficient of association and chi-square at significant level 95 %

Table 18 Diversity Index and Evenness of boring organisms in various substrates and zones.

Zones	Substrates	Diversity Index ($\bar{H}$)	Evenness (e)
Shallow	*Porites lutea*	1.0749	4.3816
	Coral blocks	0.5599	2.6150
Deep	*Porites lutea*	1.0697	4.5362
	Coral blocks	0.6433	3.1967

less than in live corals. In addition, the result also presented that the borer density which was found in Porites lutea was significantly less than in coral blocks as in Table 19.

6. Estimation of bioerosion rate on coral substrates

6.1 Bioerosion on Porites lutea

The x-ray film as shown in Figure 23 were taken to determine the bioerosion and identify the bioeroders. Following (Table 20), the borers in shallow zone could destroy about 5.9 ± 4.0 cm^2 or 8.2 ± 6.9 % of total area. Meanwhile, the destruction indeep zone was 13.7 ± 6.4 cm^2 or 17.0 ± 9.1 % of total area. The results from x-ray film diagnosis were classified into 4 groups as follows : bivalves, polychaetes, sipunculids and sponges. However, the bivalves were the most efficient bioeroders in deep zone. This is due to that the boring bivalves abundantly inhibited in deep zone and they could bore by using at least two mechanisms. In addition, the boring polychaetes and boring sponges also played the significant effect in deep zone.

6.2 Bioerosion on coral blocks

The coral blocks were cut out from Porites lutea and taken to determine density as average 1.16 ± 0.06 gm/cm^3, range 1.12 - 1.21 gm/cm^3 and porosity 42.48 ± 1.94 %, range 41.10 - 43.83 %. The results obviously showed that all of coral blocks had the same properties. As shown in

Table 19 Comparison of various borer density in each zone in different substrates.

Substrates	Zone	Boring organisms (indiv./cubic metre)		
		Sipunculids	Polychaetes	Bivalves
<u>Porites lutea</u>	Shallow	917.8 ± 795.0	389.2 ± 515.2	180.2 ± 272.2
	Deep	863.6 ± 651.0	628.2 ± 520.6	657.0 ± 806.8
Coral blocks	Shallow	2,857.2 ± 2,252.6	6,825.4 ± 6,358.4	-
	Deep	11,453.0 ± 9,031.0	8,675.2 ± 9,018.8	-

Table 20 Destructed area on slabbed Porites lutea by X-ray method due to various borers in each zone.

Zone	Total destructed coral slab		Bivalves		Polychaetes		Sipunculids		Sponges	
	area (cm^2)	%	area (cm^2)	%	area (cm^2)	%	area (cm^2)	%	area (cm^2)	%
Shallow										
Mean ± S.D.	5.9 ± 4.0	8.2 ± 6.9	2.7 ± 2.9	3.6 ± 3.8	2.7 ± 3.6	4.5 ± 7.0	0.3 ± 0.2	-	0.1 ± 0.3	-
Range	0.8 - 10.6	0.0 - 16.5	0.0 - 6.8	0.0 - 9.1	0.1 - 8.7	0.0 - 16.5	0.1 - 0.5	-	0.0 - 0.6	-
Deep										
Mean ± S.D.	13.7 ± 6.4	17.0 ± 9.1	8.7 ± 6.6	11.8 ± 9.3	3.2 ± 2.5	3.7 ± 2.5	0.5 ± 0.4	0.2 ± 0.5	0.5 ± 1.3	1.3 ± 2.5
Range	7.7 - 22.0	7.7 - 30.7	0.0 - 25.9	0.0 - 25.9	0.9 - 7.4	1.6 - 7.7	0.0 - 1.0	0.0 - 1.3	0.3 - 5.6	0.0 - 6.2

Table 21 the net erosion in shallow and deep zone were 4.49 ± 0.85 and 4.86 ± 0.40 $kg/m^2/yr$. In addition, Net erosion rate between shallow and deep zones were not so different. The field observation and analysis on coral blocks revealed that net erosion was mostly due to grazing of Diadema setosum on coral substrates with fillamentous and coralline algae.

The average maximum bioerosion rate in shallow and deep zone, were 67.98 ± 48.09 $gm/m^2/yr$, 214.74 ± 157.83 $gm/m^2/yr$ respectively. The minimum bioerosion rate was 31.80 ± 3.42 $gm/m^2/yr$ and 85.74 ± 16.92 $gm/m^2/yr$ in shallow and deep zone respectively. However, the bioerosion rate due to borers was less than net erosion which affected mostly due to black urchins.

The comparison between Figure 22 and Figure 24 illustrated that the trend of bioerosion rate in each zone was correlated to borer numbers. Thus, the similarity and difference among the maximum and minimum bioerosion rate could indicated the borer generation numbers which had penetrated in these coral blocks.

6.3 Comparison of bioerosion in each coral substrate

Table 22 shows that the bioerosion on Porites lutea was 993.15 gm/m^2 and 2,306.18 gm/m^2 in shallow and deep zone respectively. The results in Figure 24 illustrated boring bivalves as the most effective bioeroders which could erode 454.49 gm/m^2 in shallow zone and 1,464.78 gm/m^2 in deep zone. Furthermore, the results as in Table 21 and 22

Table 21 Properties and erosion rate of coral blocks in each subzone.

Subzone	Density (gm/cm^3)	Porosity (%)	Net erostion ($kg/m^2/yr$)	Max. bioerosion rate ($gm/m^2/yr$)	Min. bioerosion rate ($gm/m^2/yr$)
Shallow AB	1.21 ± 0.05 1.12 - 1.26	41.11 ± 2.84 38.05 - 44.15	3.89 ± 1.64 1.70 - 5.27	99.87 ± 53.37 30.66 - 160.61	34.22 ± 24.13 14.70 - 64.43
Shallow CD	1.15 ± 0.03 1.11 - 1.17	43.21 ± 2.07 41.22 - 45.75	5.09 ± 1.63 3.28 - 7.03	36.10 ± 18.90 11.37 - 57.00	29.38 ± 31.54 0.77 - 74.43
Mean ± S.D. Range	1.18 ± 0.04 1.15 - 1.21	42.16 ± 1.48 41.11 - 43.21	4.49 ± 0.85 3.89 - 5.09	67.98 ± 45.09 36.10 - 99.87	31.80 ± 3.42 29.38 - 34.22
Deep EF	1.12 ± 0.06 1.05 - 1.18	41.10 ± 1.70 39.81 - 43.49	4.58 ± 3.73 0.27 - 8.84	103.13 ± 75.18 29.00 - 207.88	97.70 ± 71.23 28.54 - 17.68
Deep GH	1.21 ± 0.07 1.11 - 1.28	43.85 ± 3.69 40.41 - 48.91	5.14 ± 1.98 2.82 - 7.27	326.36 ± 508.70 29.66 - 1,086.30	73.77 ± 84.14 12.13 - 197.96
Mean ± S.D. S.D.	1.16 ± 0.06 1.12 - 1.21	42.48 ± 1.94 41.10 - 43.85	4.86 ± 0.40 4.58 - 5.14	214.74 ± 157.85 103.13 - 326.36	85.74 ± 16.92 73.77 - 97.70

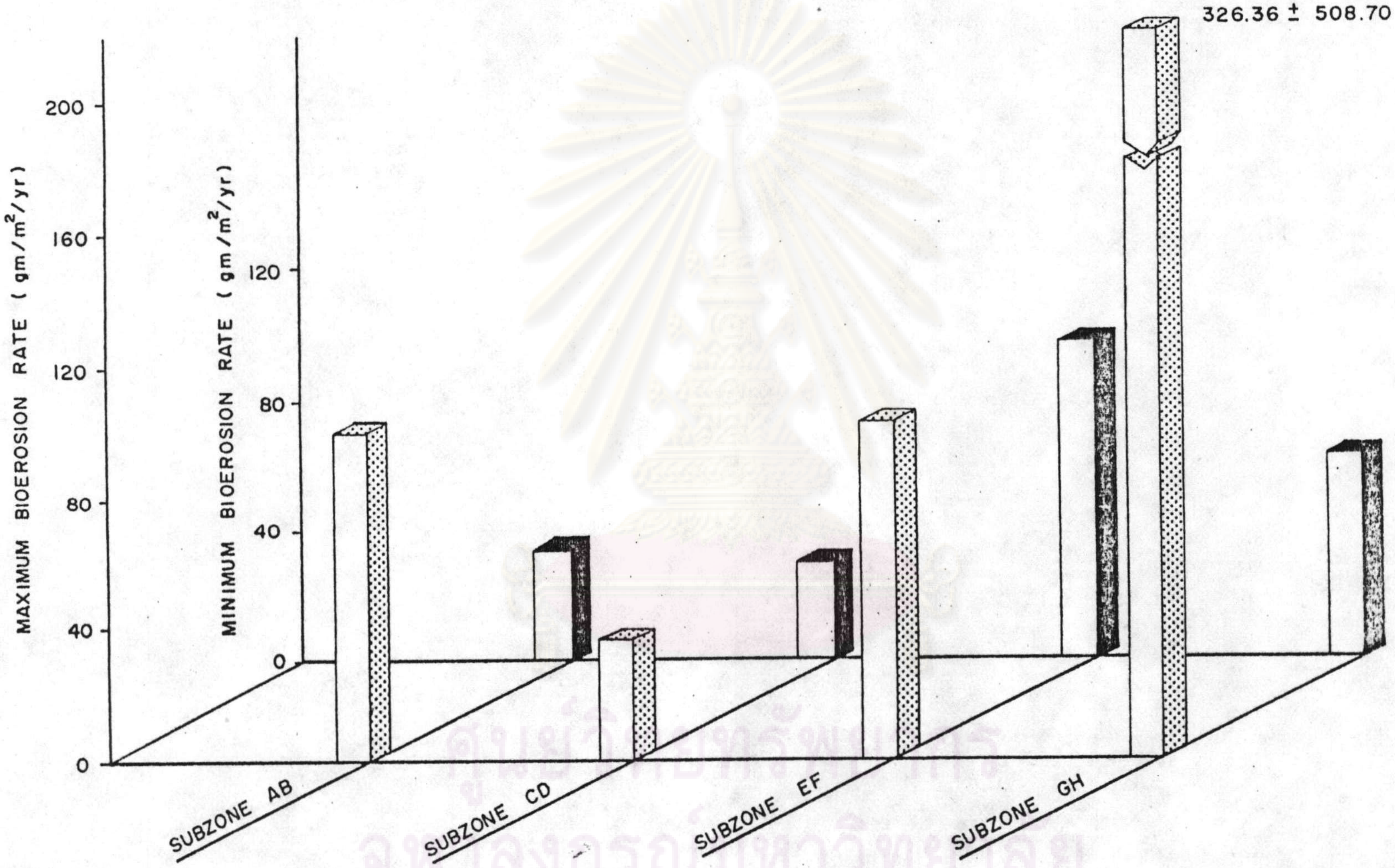


Figure 24 Comparison of maximum and minimum bioerosion rate in each subzone.

Table 22 Excavated calcium carbonate which was destroyed by various borer groups.

Zone	Total bioerosion gm/m^2	Bivalves gm/m^2	Polychaetes gm/m^2	Sipunculids gm/m^2	Sponges gm/m^2
<u>Porites</u> <u>lutea</u>					
Shallow	993.15	454.49	454.49	50.00	16.83
Deep	2,306.63	1,464.78	538.66	84.16	84.16

indicated that the bioerosion in Porites lutea was more severe than in coral blocks.

Moreover, the simple correlation coefficient also exhibited that the maximum bioerosion rate depended on the minimum bioerosion rate. This showed that the most effective boring in coral blocks,had occurred in the last period of field experiment (in May to July). There were also positive relationships between maximum and minimum bioerosion and borer number such as polychaetes, sipunculids. These showed that the boring animals abundance and diversity important and effective biological factors on bioerosion in coral blocks. In addition, the minimum bioerosion represented the erosion in last period of field experiment due to the borer succession in this period. This also might the most important period on bioerosion by these borers on natural coral substrates in this area.

7. Investigation on succession of borers on coral blocks

The successions of various cryptofaunal animals were illustrated in Figure 25. They were found that the recruitment had frequently succeeded at the underneath side of coral blocks. Meanwhile, the cryptofaunal succession had rarely appeared at the upper surface because of Diadema setosum grazing.

The borer organisms seemed to increase with exposure time as in Figure 25. Furthermore, Figure 26 showed that the coral blocks after leaving for 2 months were recruited

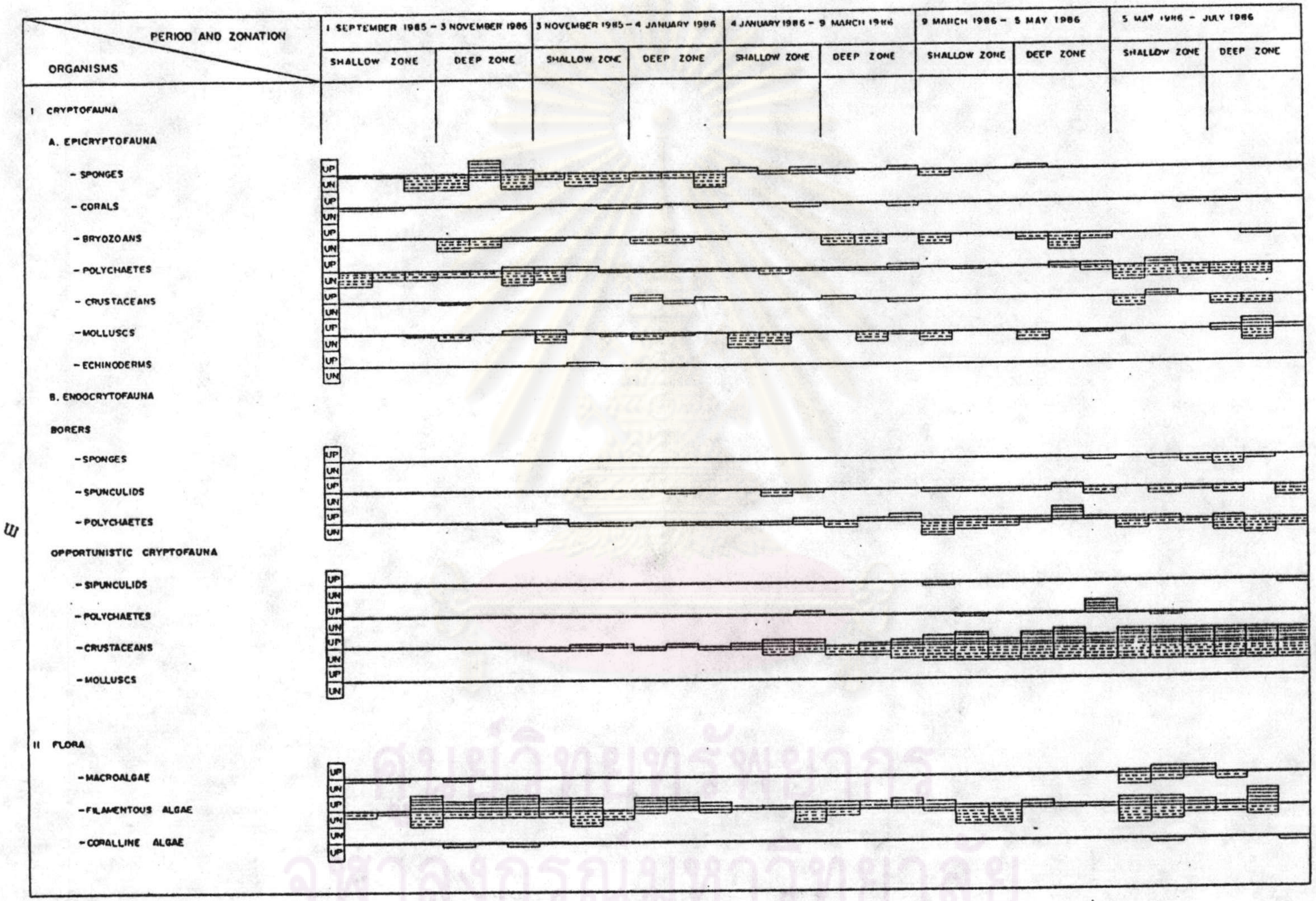


Figure 25 Comparison of the cryptofauna succession on coral blocks.

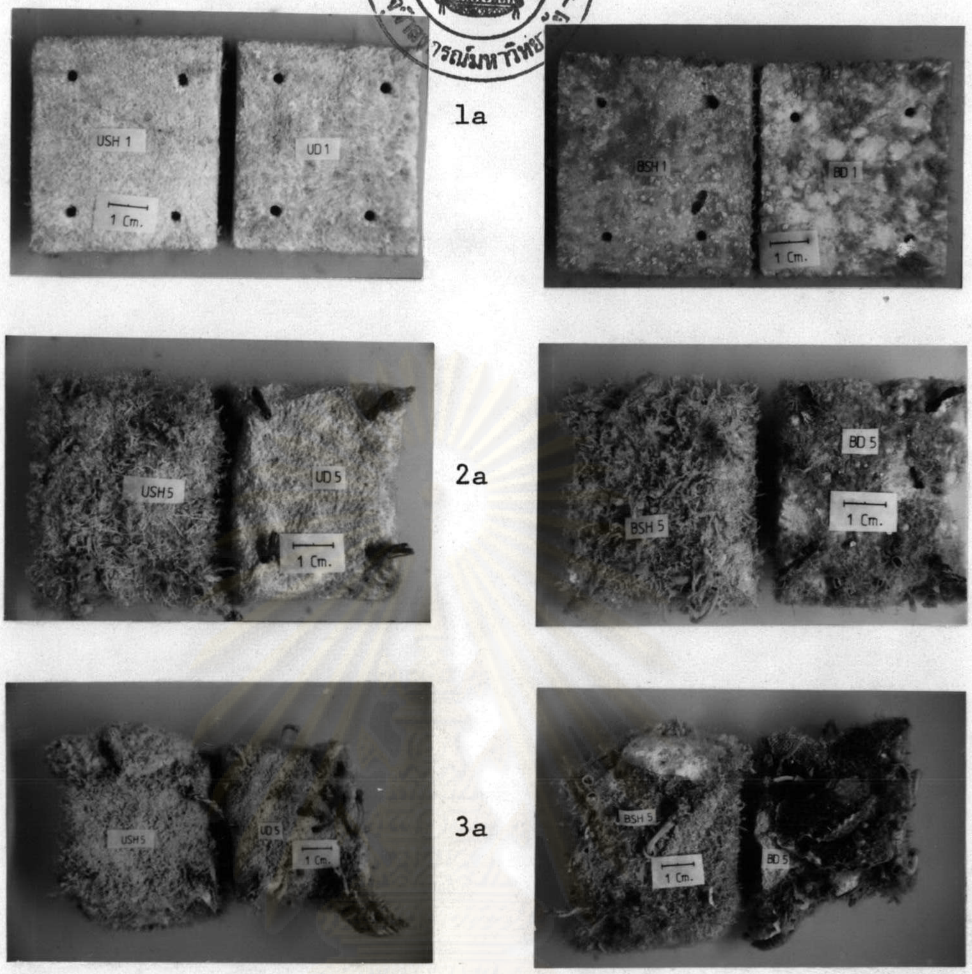


Figure 26 The succession of cryptofauna on coral blocks in various periods and zones as follows :-

1a, 1b) After leaving for 2 months.
2a, 2b) After leaving for 10 months.
3a, 3b) After leaving for 10 months.

USH = Upper surface of fixed coral blocks which had been set in the shallow zone.

BSH = Bottom surface of fixed coral blocks which had been set in the deep zone.

UD = Upper surface of fixed coral blocks which had been set in the deep zone.

BD = Bottom surface of fixed coral blocks which had been set in the deep zone.

by various algae, particularly filamentous algae and epifauna animals as bryozoa, calcareous tube polychaetes. However, after 10 months, these coral blocks were obviously indicated by the borers particularly boring polychaetes, Megalomma quadrioculatum and boring sipunculids. Moreover, the result also exhibited that M. quadrioculatum would widely distributed on most of coral blocks which were placed in both shallow and deep zones. In addition, their recruitment appeared on the surface of coral blocks as a whole even in the under neath of coral blocks. As the results in Table 23 could affirm the results as aforementioned. Particularly, Megalomma quadrioculatum obviously exhibited the most abundance during May-July period in deep zone whilst as the cirratulids; Dodecaceria sp. abundantly occurred in shallow zone. In Table 24 the Biological Index was analysed to investigate the borer communities dynamic in each period and to find out the dominant borers species changing thruout the experimental period.

The outcomes presented the borers communities not only changed in dominant species but also increased in total number as illustrated in Figure 27. The total number of polychaete and sipunculid borers were increased after 2 months during September to November until attained maximum during March to May in shallow zone and May to July in deep zone. Especially boring polychaetes displayed the same pattern tendency as well as the total number. On the other hand, the number of boring sipunculids seemed to be

Table 23 Occurence of boring organisms in coral blocks in various periods in shallow (SH) and deep (D) zones.

Boring organisms	Period									
	Nov. '85		Jan. '86		Mar. '86		May '86		Jul. '86	
	SH	D	SH	D	SH	D	SH	D	SH	D
Aspidosiphon spp.	-	-	-	-	+	+	++	++	++	++
Phascolosoma spp.	-	-	-	+	++	-	+++	++	+	++
Hypsicomus sp.	-	-	+	+	-	-	-	+	+	++
Spionidae	-	-	+	+	+	++	++	++	++	+
Cirratulidae	-	-	+	+	++	+	+	+	+	++
Dodecaceria sp.	-	-	-	-	-	+	+++	-	+++	++
Megalomma quadrioculatum	-	-	-	-	-	-	-	+	++	+++

Remark :
- \- = absent
- \+ = rare
- ++ = seldom
- +++ = frequency

Table 24 Dynamic of boring organisms in coral blocks, showing the Biological Index in each period with the ranking of 11-0 scale

Boring organisms \ Sampling period	Nov. '85	Jan. '86	Mar. '86	May '86	Jul. '86
Aspidosiphon spp.	0	0	21	40	38
Phascolosoma spp.	0	11	22*	47*	28
Hypsicomus sp.	0	22*	0	11	32
Megalomma quadrioculatum	0	0	0	11	50*
Polydora sp.	0	21	22*	39	28
Dodecaceria sp.	0	0	0	41	55*

Remark : * Dominant species at each period

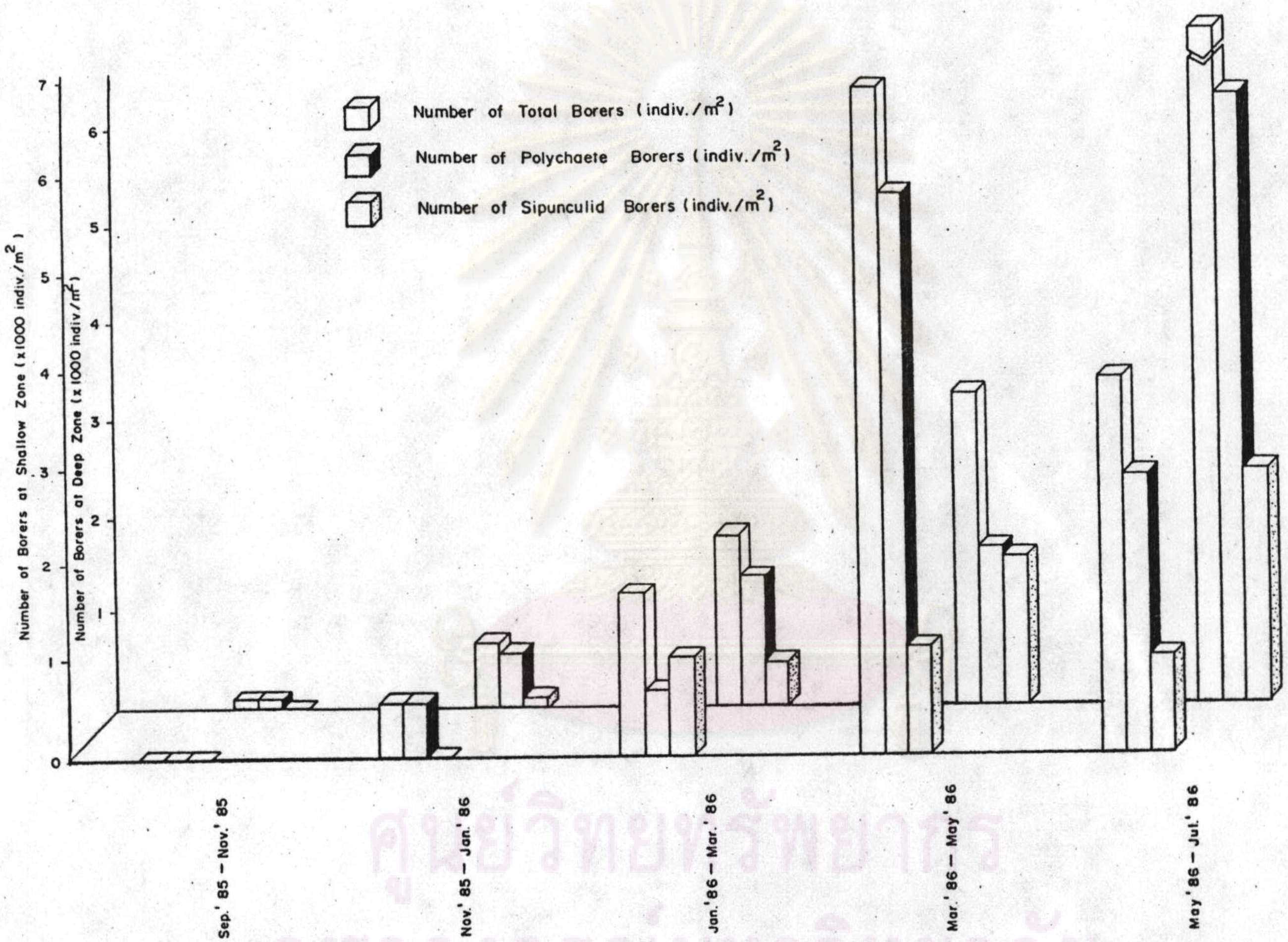


Figure 27 Dynamic of borers density in each period.

consistant throughout the experiment period in shallow zone, meanwhile in deep zone, the sipunculids increased with time as shown in Figure 27. Likewise, boring polychaetes also increased in the same aspect.

The results showed that only two predominant boring polychaetes; Dodecaceria sp. in shallow zone and Megalomma quadrioculatum in deep zone, were fast growing species during May to July period.