

THE ECHINODERM FAUNA OF SEDIMENT STRESSED REEFS IN SINGAPORE

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ABSTRACT

Thirty-two species of echinoderms were recorded from a 7-month survey carried out in sediment-stressed reefs of Singapore: 3 species of asteroids, 14 species of crinoids, 2 species of echinoids, 6 species of holothurians and 7 species of ophiuroids. It can be concluded that the echinoderm fauna of Singapore reefs is generally poor, especially the classes Asterozoa, Echinozoa, Holothurozoa and Ophiurozoa. The family Crinozoa, however, was comparable with that in other reefs in the region.

Fifty-two species of echinoderms were known to occur in Singapore reefs prior to this study. Fourteen of these have been confirmed to be present in our reefs, but 20 species have not been found by us. However, 18 species are new records to the reefs. It is possible that changing conditions in Singapore reefs, especially the increase in sedimentation in the surrounding waters, may have affected the composition of the echinoderm fauna, allowing only more resilient and adaptable species to survive. The success of the 2 dominant echinoderms in Singapore reefs, *Diadema setosum* and *Comaster gracilis*, may be attributed their resilience and adaptability to high sedimented waters.

INTRODUCTION

Large scale land reclamation activities since 1966 have resulted in increased sediment load and reduced visibility in Singapore waters. Many islands south of mainland Singapore have been directly affected (Wong 1985, Chia and Khan 1987).

Earlier published records of the echinoderms in Singapore were by Bedford (1900) and Clark (1934). Some mention of echinoderms was made by Chuang (1961, 1973, 1977) and Chou (1986). This study represents the first comprehensive survey of the echinoderm fauna found in Singapore reefs.

It had been observed that there has been a decline in the echinoderm fauna since the onset of the reclamation work and gradual increase of shipping and other marine industry activities in the vicinity of the reefs (personal observation). However, since no survey was carried out prior to these activities, we were unable to monitor the effect of these activities on the echinoderm fauna.

SURVEY SITES AND FIELD METHODS

The reefs in Singapore comprise fringing and patch reefs, all situated to the SW of Singapore (figure 1). Six sites were surveyed: Pulau Hantu, Pulau Semakau, Pulau Jong, Raffles Lighthouse, Terumbu Pandan and Beting Bemban Besar. The latter 2 are patch reefs. Major reclamation work in vicinity of

the sites have also been included in figure 1.

Water visibility around the reefs ranged between <1.0m to 4.7m. Sedimentation rates were approximately 11 mg/cm<sup>2</sup>/day (Chou 1987). As a result of high turbidity, light penetration was calculated to be reduced by 99.65% at the depth of 16m (Chuang 1977, Chou 1986).

Generally, live coral cover was observed to be poor on the reef flat, but increased progressively to the reef crest and upper reef slope. From the upper reef slope down to the sea-floor, coral growth decreased drastically, diminishing at a depth of about 13m (Chuang 1977, Chou and Teo 1985, Chou and Wong 1985, Chou 1986, 1987 and Chou and Koh 1986).

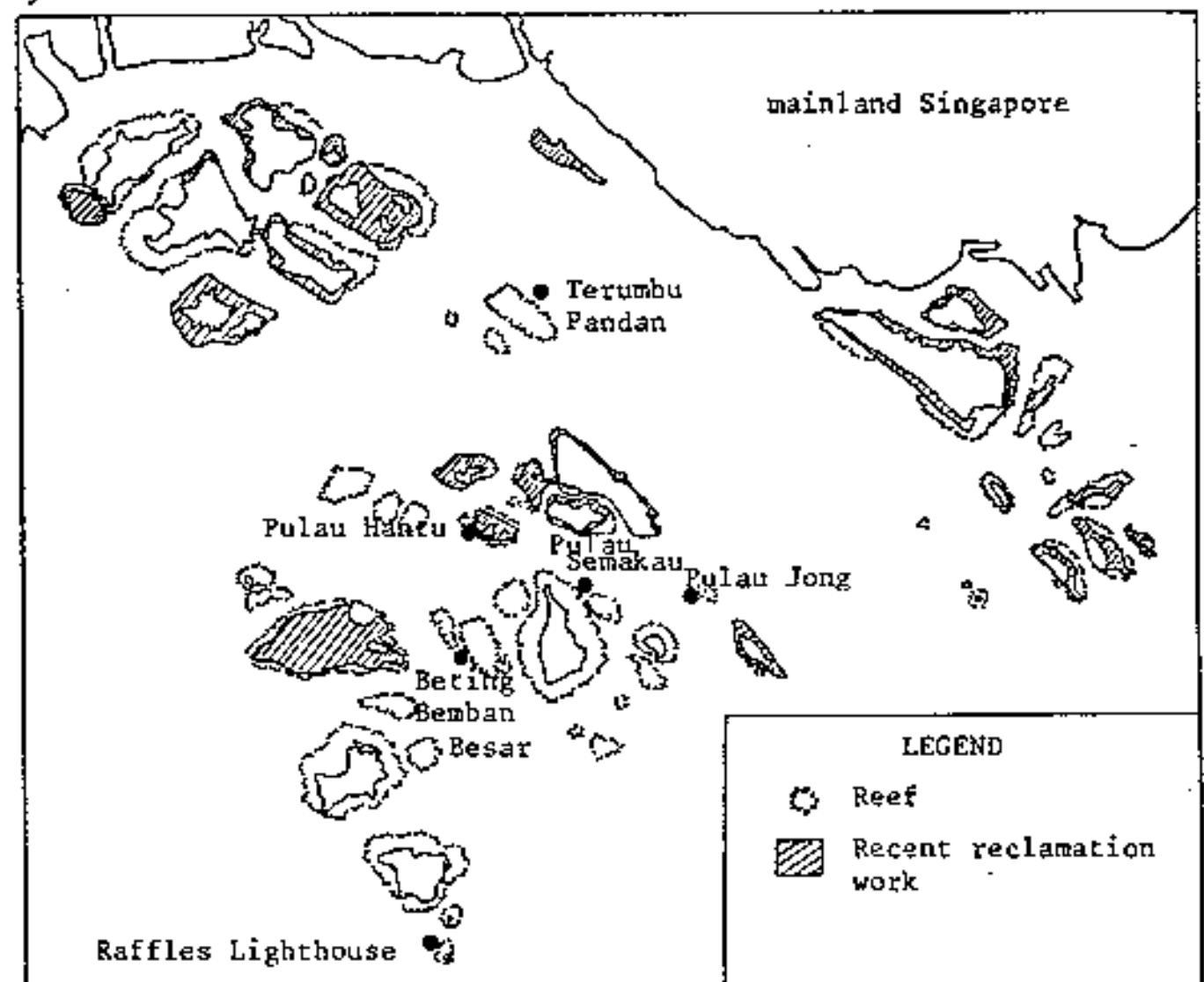


Figure 1. Map of southern islands, showing survey sites and recent reclamation work

SCUBA diving was used for data collection. At each site, 100m of reef was surveyed from the reef flat to the lower limits of the reef slope (13m). Coral rubble and sponges were collected for the ophiuroids they harbour. Underwater photographs were also taken.

Asteroids, crinoids, echinoids and ophiuroids were fixed in 70% alcohol. Holothurians were first relaxed with menthol, injected with 90% alcohol and preserved in 70% alcohol. The echinoderms were identified using the keys by Clark and Rowe (1971), Rowe, Hoggett, Birtles and Vail (1986) and Hoggett and Rowe (1986). Slides of holothurian spicules were prepared using the procedure described by Rowe and Doty (1977).

RESULTS

A total of 32 species were recorded. Table 1 shows the occurrence of these taxa in the 6 sites and the estimation of their abundance.

Three species of asteroids, from the families Asterinidae, Goniasteridae and Oreasteridae, were observed during the survey. Culcita novaeguineae was recorded at all reef sites except at Pulau Hantu. At each site, 1 or 2 individuals were observed between 3m and 10m, on live coral or more commonly, on algae-covered rubble. Iconaster longimanus was observed at Pulau Jong and Pulau Hantu on algae-covered rubble and on the sea-floor. The third asteroid Asterina burtoni is a new record. Several individuals were found at the base of coral Pocillopora damicornis (Linnaeus 1758).

Fourteen species of crinoids were recorded: 7 from the family Mariametridae, 4 from Comasteridae, 2 from Himerometridae and 1 from Colobometridae. The most abundant species observed was the comasterid Comaster gracilis, which was ubiquitous over all the surveyed reefs. The next most abundant crinoid, Lamprometra palmata, was found at all survey sites except the patch reef Beting Bemban Besar. Less commonly seen were Colobometra perspinosa, Stephanometra tenuipinna, S. spinipinna and S. oxyacantha, Himerometra martensi and H. magnipinna. Six species of crinoids recorded during the survey were new records in Singapore reefs. They were Comaster gracilis, Comanthus parvicirrus, Comanthina schlegeli, Stephanometra echinus, Stephanometra spinipinna and Stephanometra oxyacantha.

Comanthus parvicirrus was observed to be cryptic by day, deeply hidden in coral crevices. Comaster gracilis and C. multifidus were semi-cryptic and were seen beneath laminate corals in an inverted position or hidden in coral crevices. The mariametrids were also semi-cryptic and were observed beneath coral ledges, within coral crevices, and among the branches of digitate corals. Four species of crinoids exhibited rheophilic behavior: Comanthina schlegeli, Himerometra magnipinna, H. martensi and Colobometra perspinosa. They were seen to be perched on coral heads, with the exception of Colobometra perspinosa which was found clinging onto sea-fan Melithaea sp.

Two species of echinoids, both from the family Diademataidae, were recorded during the study. Diadema setosum was found at all survey sites between the depths of 3m and 8m. They occurred at particularly high densities at Pulau Hantu, Terumbu Pandan, and Beting Bemban Besar, on the reef crest and upper reef slope. Diadema savignyi had not been previously reported in Singapore reefs. They were rare, with only several individuals found at Raffles Lighthouse, Pulau Jong and Beting Bemban Besar.

Six species of holothurians from the families Holothuriidae, Stichopodidae and Cucumariidae were observed. Only 1 species, Actinopyga lecanora was previously recorded in Singapore reefs. The other 5 species were new records in our reefs. Aspidochirots Stichopus variegatus, Actinopyga lecanora, Holothuria impatiens and Holothuria sp. were found on sandy patches on reef flats, while dendrochirots Stolus buccalis and Hemithyone sp. were among corals.

A total of 7 species of ophiuroids, from 3 families (Ophiactidae, Ophiotrichidae and Ophiuridae) were recorded. Ophiactis maculosa and O. savignyi

occurred in large numbers in sponge Suberites sp. while Macrophiothrix longipeda and Ophiocnemis marmorata were common in coral rubble.

At Terumbu Pandan, the dominant echinoderm was Diadema setosum, occurring in large numbers at about 3m, just below the Sargassum sp. belt. Four species of ophiuroids and 3 species of crinoids were recorded in the reef. Only 1 species each of asteroid, echinoid and holothurian were observed.

The most conspicuous echinoderm at Pulau Hantu was Diadema setosum. Large numbers were seen to aggregate at the reef crest. The maximum depth it occurred at was 13m. Two species of asteroids, 2 species of holothurians, 5 species of crinoids and 5 species of ophiuroids were also recorded in the reef.

At Pulau Semakau, crinoids were the dominant echinoderms, with 6 species recorded. Compared to the other reefs, Comaster gracilis was most abundant on this reef. Lamprometra palmata and Stephanometra spicata were also common. Six species of ophiuroids were observed. Diadema setosum was the only echinoid recorded, while Culcita novaeguineae was the only asteroid. No holothurians were recorded in the reef.

Diadema setosum was the dominant echinoderm observed on the patch reef of Beting Bemban Besar. Five species of crinoids, 4 species of ophiuroids, 2 species of echinoids and 1 species of asteroid were also recorded. No holothurians were observed in this reef.

At Pulau Jong, the crinoids were the most conspicuous echinoderm. Seven species were recorded, of which comasterid Comaster gracilis, was the dominant species. The less common species Comanthus parvicirrus, Himerometra martensi and H. magnipinna were observed on this reef. Also recorded here were 4 species of ophiuroids, 2 species of asteroids, 2 species of echinoids and 1 species of holothurian. The holothurian Hemithyone sp. observed in this reef was not recorded in other reefs.

The reef at Raffles Lighthouse supported the greatest diversity of crinoids and holothurians, with 9 and 3 species respectively. Unlike the other reefs, the mariametrids were more abundant than the comasterids here. Colobometra perspinosa was recorded only on this reef. Two species of asteroids, 2 species of echinoids and 1 species of ophiuroid were also recorded.

Among the survey sites, Raffles Lighthouse supported the greatest number of species of echinoderms, with a total of 17. The other 3 fringing reefs of Pulau Jong, Pulau Semakau and Pulau Hantu supported 16, 14 and 13 species of echinoderms respectively. The 2 patch reefs at Beting Bemban Besar and Terumbu Pandan seem to be poorer in echinoderms, with a total of 12 and 10 species respectively.

In terms of abundance, crinoids were found at highest densities at Raffles Lighthouse and Pulau Semakau. Echinoid density was especially high at Pulau Hantu, Terumbu Pandan and Beting Bemban Besar.

Table 1. Echinoderms of Singapore Reefs, showing distribution and relative abundance

CLASS	FAMILY	GENUS	AUTHOR	REEFS AT						DEPTH (m)	SUBSTRATE	
				TP	PH	BBB	PS	PJ	RL			
ASTEROIDEA (3)	ASTERINIDAE	<i>Asterina burtoni</i>	Gray, 1840	-	-	-	-	-	+	2	coral base	
	GONIASTERIDAE	<i>Iconaster longinamus</i>	(Mobius, 1859)	-	+	-	-	-	-	6	coral rubble	
	CREASTERIDAE	<i>Culcita novaeguineae</i>	Muller & Troschel 1842	+	-	+	+	+	+	3-10	algae-coral rubble, live coral	
CRINOIDEA (14)	COLOBOMETRIDAE	<i>Colobometra perspinosa</i>	(P.H.Carpenter, 1881)	-	-	-	-	-	+	5	sea-fan	
	COMASTERIDAE	<i>Comaster gracilis</i>	(Hartlaub, 1890)	+	++	+++	++++	+++	++	++	4-11	coral crevice, under coral ledge
		<i>Comaster multifidus</i>	(J.Muller, 1841)	-	+	+	++	+	-	-	4-6	coral crevice, under coral ledge
		<i>Comanthus parvicirrus</i>	(J.Muller, 1841)	-	-	+	-	+	-	-	5	deep within coral crevices
		<i>Comanthina schlegeli</i>	(P.H.Carpenter, 1881)	-	-	-	+	-	-	-	4-6	coral head
	HIMEROMETRIDAE	<i>Himerometra magnipinna</i>	A.H.Clark, 1908a	-	-	-	-	+	+	+	3	coral head
		<i>Himerometra martensi</i>	(Hartlaub, 1890)	-	-	-	-	+	+	+	2	coral head
	MARIAMETRIDAE	<i>Lamprometra palmata</i>	(J.Muller, 1841)	+	+	-	++	+	+	+	4-13	coral crevice, under coral ledge
		<i>Stephanometra echinus</i>	(A.H.Clark, 1908a)	-	-	-	+	-	+	+	5	coral crevice
		<i>Stephanometra indica</i>	(Smith, 1876)	+	+	-	-	+	++	++	3-13	coral crevice, under coral ledges
		<i>Stephanometra oxyacantha</i>	(Hartlaub, 1890)	-	-	-	-	-	-	+	5	coral crevice
		<i>Stephanometra spicata</i>	(P.H.Carpenter, 1881)	-	+	-	++	-	++	++	3-5	coral crevice, under coral ledges
		<i>Stephanometra spinipinna</i>	(Hartlaub, 1890)	-	-	+	-	-	-	-	4	coral crevice
		<i>Stephanometra tenuipinna</i>	(Hartlaub, 1890)	-	-	+	-	-	-	-	4	under coral ledges, branched coral rubble
ECHINOIDEA (2)	DIADEMATIDAE	<i>Diadema setosum</i>	(Leske, 1778)	++++	++++	++++	+++	+++	+++	3-8	rubble	
		<i>Diadema savignyi</i>	Michelin, 1845	-	-	+	-	+	+	7	rubble	
HOLOTHROIDEA (6)	CUCUMARIIDAE	<i>Hemithyone</i> sp.	-	-	-	-	-	+	-	3	live coral	
		<i>Stolus buccalis</i>	(Stimpson, 1855)	-	+	-	-	-	-	-	3	live coral
	HOLOTHURIIDAE	<i>Actinopyga lecanora</i>	(Jaeger, 1938)	+	-	-	-	-	-	-	5-11	reef flat : sand
		<i>Holothuria (Thymiosycia) inpatiens</i>	(Forsk. 1838)	-	-	-	-	-	+	+	3	reef flat : sand
		<i>Holothuria (Lessonothuria) sp.</i>	-	-	-	-	-	-	+	+	3	reef flat : sand
	STICHOPODIDAE	<i>Stichopus variegatus</i>	Semper, 1868	-	+	-	-	-	+	+	3	reef flat : sand
	OPHIUROIDEA (7)	OPHIACTIDAE	<i>Ophiactis maculosa</i>	von Martens, 1870	*	*	*	*	*	-	-	sponge
<i>Ophiactis savignyi</i>			Muller & Troschel 1842	*	*	*	*	*	-	-	sponge	
OPHIOTRICHIDAE		<i>Macrophiothrix longipeda</i>	(Lamarck, 1816)	*	*	*	*	*	*	-	-	coral rubble, crevices
		<i>Opiocnemis marmorata</i>	(Lamarck, 1816)	-	-	-	*	-	-	-	-	rubble, under crinoids
		<i>Ophiothrix ciliaris</i>	(Lamarck, 1816)	*	*	*	*	*	-	-	-	sponge, under crinoids
		<i>Ophiothrix (Acanthophiothrix) spinosissima</i>	Koehler, 1905	-	*	-	-	-	-	-	-	sponge, under crinoids
OPHIURIDAE		<i>Ophirolepis cincta</i>	Muller & Troschel 1842	-	-	-	*	-	-	-	-	coral crevices
Total no. of species				10	14	12	14	16	17			

TP : Terumbu Pandan PH : Pulau Hantu BBB : Beting Bemban Bersar  
PS : Pulau Semakau PJ : Pulau Jong RL : Raffles Lighthouse

Abundance: + : < 5 +++ : 11 - 20 +++++ : > 40  
++ : 5 - 10 +++++ : 21 - 40 \* : present

Table 2. Comparison of echinoderm fauna at survey sites

REEF	LOCATION	REEF DESCRIPTION	CURRENT	MAN ACTIVITY	ECHINODERMS *					DOMINANT ECHINODERM	AVERAGE %		REFERENCES
					No. of species	A	C	E	H		O	LIVE CORAL COVER	
Terumbu Pandan	1 15.4'N 103 44.6'E	patch reef, reef flat with Sargassum	moderate	near P. Bukum: petrochem. works	1	3	1	1	4	Diadema setosum	35.78	2.27	Chou & Koh 1986 Chou 1987
P. Hantu	1 13.6'N 103 45.5'E	fringing reef, reef flat with Sargassum some areas with coral rubble	moderate	Land reclamation in 1974; near P. Bukum: petro-chem. works	2	5	1	1	4	Diadema setosum	36.95	2.92	Chou & Koh 1986 Chou 1987
Beting Besar	1 12.5'N 103 45'E	patch reef, reef flat with Sargassum	moderate	-	1	5	2	0	5	Diadema setosum	-	-	-
P. Semakau	1 13'N 103 45.6'E	fringing reef Sargassum on reef flat less pronounced	strong	-	1	6	1	0	7	crinoids	50.91	1.24	Chou & Koh 1986 Chou 1987
P. Jong	1 12.8'N 103 47.3'E	fringing reef, reef flat with Sargassum	strong	near P. Bukum petro-chem. works	1	8	1	1	5	crinoids	-	-	-
Raffles Lighthouse	1 9.6'N 103 44.5'E	fringing reef, reef flat with coral & sandy patches	strong	-	2	9	1	3	1	crinoids	-	-	-

\* A : Asteroidea, C : Crinoidea, E : Echinoidea, H : Holothroidea, O : Ophiuroidea

### DISCUSSION

The echinoids in Singapore reefs comprise only 2.4% of the species found in the East Indies region (table 3). The echinoids, asteroids, holothurians and ophiuroids are only 2.0%, 3.4%, 4.2% and 4.9% respectively of the total species in the East Indies. The class Crinoidea, however, is better represented, with 15.4% of the species in the East Indies. Table 3 compares the number of species of the 5 classes of echinoderms in Singapore reefs with that of reefs in the immediate vicinity.

Table 3. Comparison of the echinoderm fauna in Singapore reefs and other reefs in the immediate vicinity

PLACE (REFERENCE)	ECHINODERMS *				
	A	C	E	H	O
East Indies (Clark & Rowe, 1971)	87	91	83	141	142
Singapore Number of species	3	14	2	6	7
% of fauna in E. Indies	(3.4%)	(15.4%)	(2.0%)	(4.2%)	(4.9%)
Thailand (W coast) (Sriyakorn, 1970)	13	3	16	9	13
Sabah (George & George 1987)	19	13	11	22	20
Indonesia (immediately S of S'pore) (Aziz & Jangoux, 1984)	19	-	-	-	-

\* A : Asteroids, C : Crinoids, E : Echinoids,  
H : Holothuroids, O : Ophiuroids

Six species of crinoids found here have also been reported in the gulf of Thailand and Sabah (Sriyakorn, 1970, George & George, 1987). These were Comaster gracilis in Thailand, and Comaster multifidus, Comanthina schlegeli, Comanthus parvicirrus, Lamprometra palmata, Stephanometra echinus and S. spicata in Sabah. Comaster gracilis and C. multifidus were also observed in some reefs of West Malaysia (personal observation). This suggests that the larvae of these species are prevalent in the region.

The record of only 2 species of echinoids in Singapore reefs is poor. Of the 2, Diadema setosum was abundant, while only a few individuals of Diadema savignyi were observed. The asteroid fauna too is poor although the larvae of several species seem to be present in nearby waters. Aziz & Jangoux (1984) recorded 19 species of asteroids in Indonesian waters, immediately south of the limits of Singapore water, but only 2 out of the 19 species, Culcita novaeguineae and Iconaster longimanus were recorded here. Although Culcita novaeguineae, Archaster typicus, Protoreaster nodosus and Acanthaster planci are considered as common in the Indo-West Pacific region (Yamaguchi 1977), only Culcita novaeguineae was recorded in Singapore reefs. The reefs in Singapore were also generally lacking in holothurians and ophiuroids.

Comparing past and present records, only 14 species, out of the 52 which were previously recorded in the reefs, still persist (table 4). Twenty species which were previously reported were not found by us. However 18 species were new records on our reefs.

We have yet no explanation why the echinoderm fauna is generally poor or how the echinoderms might have been affected by the surrounding human activities. However we would like to suggest that high sedimentation and marine pollution may have possibly been the main factors affecting coral

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Table 4. Comparison of previous and present records of echinoderm species in Singapore reefs

CLASS	NO. OF SPECIES			
	PREVIOUSLY RECORDED	PRESENT RESULTS	CONFIRMED	NEW RECORDS
Asteroidea	8	3	2	1
Crinoidea	18	14	8	6
Echinoidea	10	2	1	1
Holothuroidea	6	6	1	5
Ophiuroidea	10	7	2	5
Total	52	32	14	18

reefs in Singapore, and in this case, the echinoderm fauna.

The dominant echinoderms found in Singapore reefs in terms of numbers are the echinoid *Diadema setosum* and crinoid *Comaster gracilis*. Their success on the reefs may have been due to a greater resilience and adapting ability to the changing reef conditions.

From the survey, the number of species of echinoderms at each survey site seemed to increase as one moves away from the mainland. This seems to support the above suggestion that sedimentation and pollution have considerable effect on the reefs, as the reefs further south (e.g. Raffles Lighthouse) are less sedimented and less polluted, being located away from the main reclaimed areas and marine industrial areas to the north.

Slight differences were seen in the local distribution of the echinoderm fauna (table 1 and 2). This may be due to differences of local conditions at each reef e.g. richness of the reef (live coral cover), degree of sedimentation, currents and availability of shelter (degree of surface relief). The different combination of these factors may affect the ability of a species to settle in and adapt to these local conditions.

Generally, conditions at the patch reefs (Terumbu Pandan and Beting Bemban Besar) are harsher and they tended to support poorer echinoderm fauna.

Although a major part of the reef flat of Pulau Hantu was reclaimed (Chou and Lim 1986), the survey showed that the echinoderms in the reef have not been completely excluded and recolonisation from neighbouring reefs had taken place.

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