Site Investigations for the Potential Development of Artificial Reefs in Singapore

L. M. Chou and Lilian H. L. Hsu

Department of Zoology
National University of Singapore
Singapore 0511

ABSTRACT

Site selection surveys for the possible establishment of artificial reefs were carried out at four sites south of the Singapore mainland (Cyrene reefs, Terumbu Jarat, Terumbu Pempang Tengah and Terumbu Bemban) between February to August, 1987. Measurements of physico-chemical parameters of the waters and the visual inspection of the seafloor by SCUBA diving were conducted at each proposed site. A 100-metre line-intercept lifeforms transect and a 150-metre visual census fish transect were carried out on reef slopes adjacent to these sites. The survey results showed that except for Terumbu Jarat, the other three sites are suitable for the establishment of artificial reef.

INTRODUCTION

Fish catches in Singapore waters from local fishing stakes such as kelongs and beach seines have declined compared to the mid-thirties (Tham, 1973). Since most of the territorial waters lie within the port limits, kelongs have been phased out and commercial fisheries prohibited within the waters. Recreational and subsistence fishing indicate that the fisheries resource is not abundant and this may be attributed to human activities such as the massive land reclamation projects and heavy traffic of increasing number of vessels. Living marine resource enhancement, through the establishment of artificial reefs has been demonstrated as feasible in various parts of the world, such as Japan and Taiwan (Sheehy, 1981), where commercial fisheries were enhanced, and America (Stone, 1981), where recreational fisheries were improved. All the other five ASEAN countries have or are in the process of developing artificial reef programmes.

Although the waters of Singapore are turbid due to the high sediment load, observations have shown that sunken structures on the sea-floor attracted fish and are coated with encrusting organisms. The development of artificial reefs in our waters can help to increase and restore areas of critical habitat for the purposes of increasing fish production, enhancing recreational fishing activities and also preserving genetic diversity. Four areas within the southern islands were identified as possible sites for the establishment of artificial reefs. These were away from the shipping lanes and close to the coral reefs. They were Cyrene reefs, Terumbu Jarat, Terumbu Pempang Tengah and Terumbu Bemban (figure 1).

MATERIALS AND METHODS

The survey locations at each of the four sites are shown in figure 2. At each site, physico-chemical parameters at the

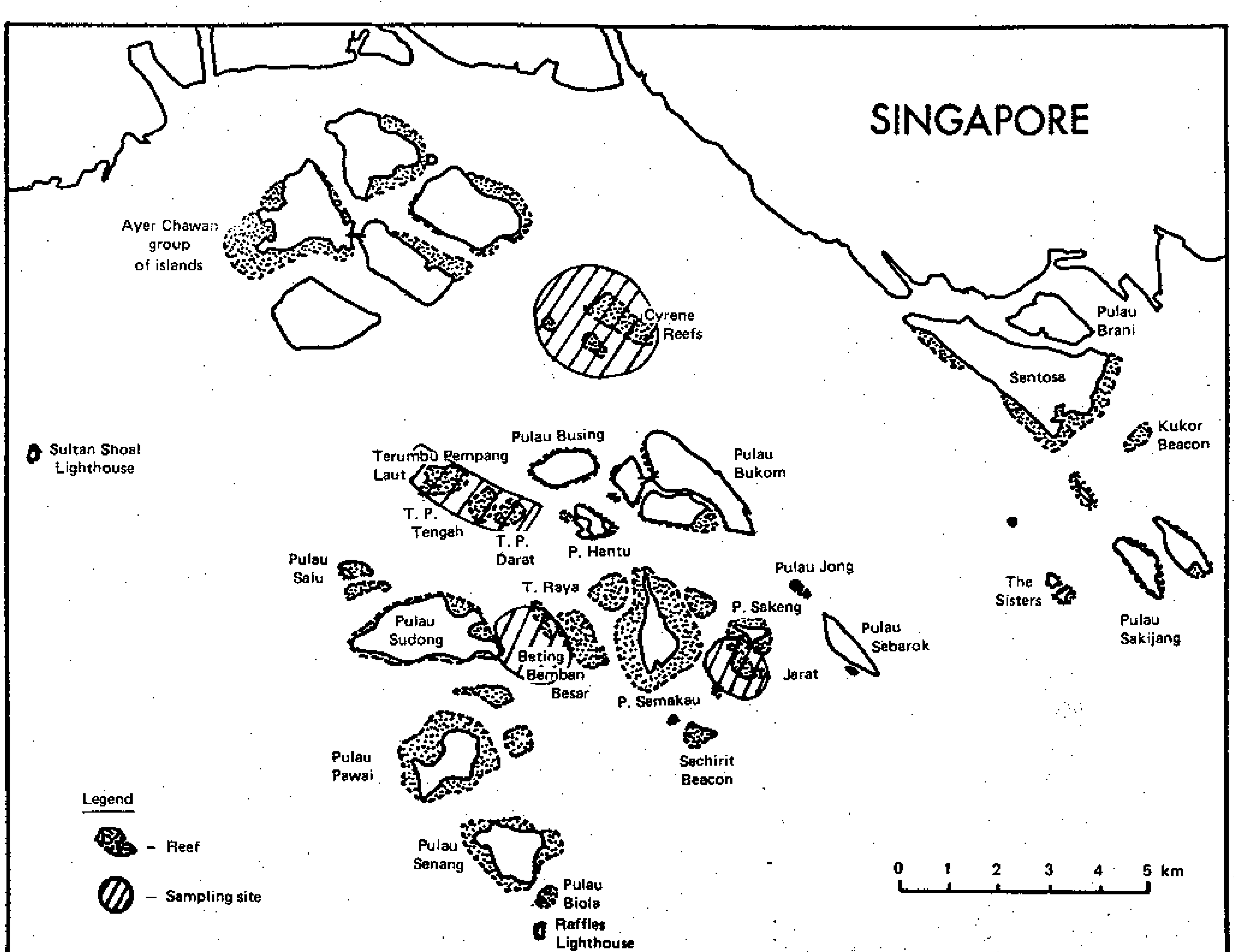

Figure 1. Map of southern islands showing location of sites investigated.

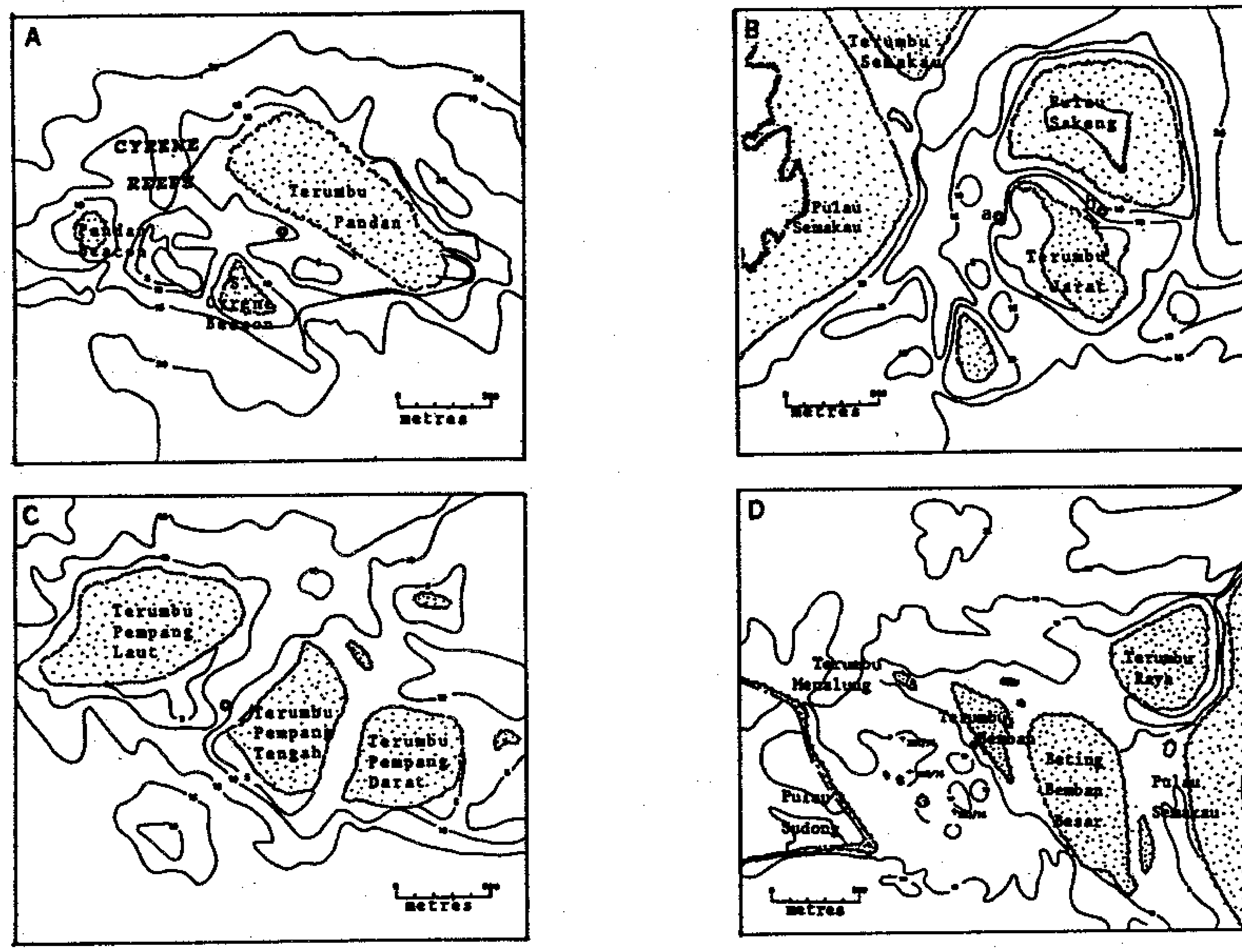

Figure 2. Survey locations at the sites investigated. a. Cyrene reefs, b. Terumbu Jarat, c. Terumbu Pempang Tengah, d. Terumbu Bemban.

Legend:

Site surveyed — Line transect — reef — + borehole — mangroves

Isobath depths indicated are in metres

surface and bottom levels of the water column were measured. Salinity was measured with an Atago refractometer, pH with a pocket pH meter (Hanna Instruments), dissolved oxygen and temperature bya YSI oxygen meter (model 57), turbidity by a Horizon Ecology Co. digital colorimeter (5965–50 calibrated against formazin turbidity standards), light intensity by a Licor underwater quantum sensor (LI—1925A) and light penetration by a secchi disc. Bottom water samples were obtained with a bottom sampler for the measurement of pH, salinity, and turbidity.

A 30-minute visual inspection of the sea-floor was carried out by SCUBA diving where the depth, substrate quality and biological components were noted. The bearing capacity of the bottom substrate was determined by probing it with the hand to determine extent of penetration with one push (Mathews Jr., 1981). On the adjacent reef slopes closest to these sites, the reef community was investigated along a 100m line transect, at the 3m depth from the reef crest, using the method described in Anon. (1986). The reef fishes were censured along a 150m line traansect, also at the 3m depth and where possible along the 10m depth of the reef slope, also using the method described in Anon. (1986), but modified to 3m (instead of 5m) on either side of the line and 3m (instead of 5m) of water column above the line because of reduced visibility. In the visual census, individuals of 7 families of fishes considered visually obvious were counted or estimated. These were Lutjanidae, Carangidae, Serranidae, Pomacentridae, Labridae, Apogonidae and Chaetodontidae. The Chaetodontids were identified to species level as they served as 'indicator' species.

RESULTS

The physico-chemical parameters of the waters at the survey sites are presented in table 1. There were negligible differences between the surface and bottom salinities and temperatures. The salinity at Terumbu Jarat was less than that at the other sites due possibly to the run-offs from Pulau Sakeng. Water temperature was almost constant throughout all the sites. Dissolved oxygen content was generally higher at the surface except for Terumbu Bemban. Turbidity increased substantially at the bottom and caused reductions in light intensity at this level. The decrease in light intensity between the surface and the bottom was 85.68% at Cyrene reefs, 78.54% at Terumbu Jarat, 90.25% at Terumbu Pempang Tengah and 36.11% at Terumbu Bemban. Values for pH showed no variation between the surface and bottom levels except at Cyrene reefs where the bottom pH was slightly more alkaline than the surface.

The bottom substrate at Terumbu Jarat was silty and soft, with a thin sand-coloured covering layer of approximately 1 cm. This layer is easily swept away by diving movements to reveal a jet black layer of mud and silt which extended into the deeper levels. No resistance was met when pushing with the hand perpendicularly into the sub-

Table 1. Comparison of the Physico-chemical parameters of the waters the survey sites. (s = surface, b = bottom)

Site	Depth (m)	Salinity (ppt)		Dissolved oxygen (ppm)		Temperature (°C)		pH		Turbidity (ppm)		Light intensity (um/sm^2)			Light penetration (m)	Bottom substrate
		S	B	S	B	S	B	S	B	S	B	Air	S	B		
Cyrene	15	27	27	6.1	5.4	28.5	28.0	7.4	7.6	6	15	867.3	33.58	4.81	2.0	sand (firm)
Terumbu Jarat	10	25	26	6.5	6.0	28.5	28.0	7.9	7.9	6	15	1236.0	60.15	12.91	3.0	silt/mud (soft)
Terumbu Pempang Tengah	13	27	28	7.8	6.0	28.0	28.0	8.0	8.0	6	10	6673.0	564.3	55.06	2.0	sand/rock (firm)
Terumbu Bemban	10	29	28	6.3	6.9	28.5	28.0	8.2	8.2	10	15	1832.0	23.65	15.11	5.5	sand/silt (firm)

strate to a depth of 45 cm. The silt was easily swept up and remained in suspension for a long time, reducing visibility to almost nil. The bottom substrates at all the other 3 sites were firmer and sandier. They could be penetrated by hand to a depth of 10cms before resistance was encountered.

The sandy sea floor at Cyrene supported gorgonians, (sea-whips and sea-fans), hydroids and sea anemones, but no hard corals. There are tufts and assemblages of filamentous algae growing on boulders and on the seabed. The lack of hard corals and macroalgae can be accounted for by the low light intensity. A submerged cylindrical concrete block about 4m long and 0.5m in diameter supported a proliferation of encrusting organisms and a film of filamentous algae. A few other concrete blocks in the area all had encrusting organisms on them but the age of these blocks could not be ascertained. At Terumbu Jarat, few lifeforms were observed on the sea bottom. Other than a couple of holothurians (*Stichopus coronatus*), there were encrusting organisms and filamentous algae growing on rubble. At the base of the reef slope, however, small colonies of *Physogyra, Pectinia* and *Symphyllia* were seen attached to rocks.

On rocky areas of the seafloor at Terumbu Pempang Tengah many encrusting organisms were found. Various types of sponges, including Neptune's cup (*Petrosia* sp.) were growing on rocks and rubble. Sea whips were also common. Amongst the encrusting organisms on rocks and on the seabed were bryozoans, soft coral, sea cushion (*Culcita novaeguineae*) and small colonies of the hard corals *Tubastrea* and *Pseudosiderastrea*. The common organisms observed on the sea floor of Terumbu Bemban were the gorgonians. Small colonies of hard corals, *Favia, Echinopora, Pachyseris, Goniopora* and *Fungia,* were encountered. Encrusting sponges were common on rocks and rubble.

The summarised results of the lifeform transects carried out on the slopes of reefs adjacent to the study sites are shown in table 2. Live coral cover was highest at Terembu Bemban and lowest at Terembu Jarat, which also had the highest percentage of abiotic components. Dead coral cover was low at Terembu Bemban and Cyrene reefs. Terembu Jarat was devoid of algae while Terumbu Pempang Tengah had the highest algal cover among all the reefs. The lifeforms cover on the 100-metre transect carried out at 3m depth on the reef slope at Cyrene showed that the live coral cover was 48.6%, with dead coral cover amounting to 2%. The most common live coral on the transect was *Merulina, Pectinia* and *Platygyra,* but *Acropora* was absent. The dominant coral growth forms were the massive and foliose type. The main macroalgae on the reef but not on the transect was *Sargassum*. Other marine fauna recorded on the line transect made up 1.66% of the lifeforms cover. The abiotic components which comprises sand, rubble and water, made up 46.7% of the line transect.

At Terumbu Jarat, the live coral cover on the 100-metre transect at 3m depth of the reef slope was only 22.65%. The abiotic components took up 62.28% of the transect line. The most common live corals recorded on the transect line were *Physogyra* and *Pavona*. No algae was recorded on the transect but the reef flat was rich with algae. Dead corals consisting mostly of algal covered skeletons took up 12.73% of the transect. The transect carried out at Terumbu Pempang Tengah revealed a reef rich in lifeforms. The live coral cover was 54.42% with 19.16% of recently dead corals. The most dominant coral was *Pachyseris,* covering over 10% of the transect line. The next most dominant genera were *Pectinia, Merulina, Favia, Porites, Echinopora, Pavona* and *Montipora*. The algal coverage, mainly in the form of coralline algae was 5.22%. Other non-coral fauna took up 2.19% of the transect. The abiotic components, the majority of which was sand and rubble, covered 19.01% of the transect.

Table 2. Lifeform cover at 3 metres depth on the reef slope of the of the surveyed sites (based on 100m line transect)

Surveyed Site	Live coral	Reefal Habitat Percentage Cover Dead coral	Algae	Other fauna	Abiotic components
Cyrene Reefs	48.06	2.00	1.58	1.66	46.70
Terumbu Jarat	22.54	12.73	0.00	2.35	62.38
Terumbu Pempang Tengah	54.42	19.16	5.22	2.19	19.01
Terumbu Bemban	65.88	3.91	1.53	2.21	26.47

Terumbu Bemban had a high percentage of live coral cover of 65.88%. This comprised mainly foliose, encrusting and branching corals, of which the foliose forms were the most abundant. Dominant genera were *Montipora* and *Pectinia*. Other non-coral organisms recorded on the transect were sponges (*Petrosia*), anemones, zooanthids and sea urchins (*Diadema setosum*). These took up 2.21%. Algal cover was generally low occupying 1.53%. Abiotic components comprised a high percentage of water fissures (17.23%) and 9.24% of sand and rubble. The results of the visual census of fish carried out at the 3m depth of all reefs and the 10m depth at Cyrene and Terembu Pempang Tengah are shown in table 3. At the Cyrene 3m depth fish transect, five families on the selected family list were observed, of which the pomacentrids were dominant. Other common families were Serranidae (*Diploprion bifasciatum*), the butterflyfishes (Chaetodontidae) and the wrasses (Labridae). No 'target' fishes were observed. Two species of 'indicator' fishes were observed. For the 10m depth transect at Cyrene, five families were also recorded. The 'target' fish observed at this depth were snappers (Lutjanidae) of which 2 individuals of 15 to 20cm length were sighted. Only 1 species of 'indicator' fish was recorded.

Five families were also observed at Terumbu Jarat 3m depth fish transect. The dominant family was Pomacentridae. Six 'target' fishes from the family Lutjanidae were recorded. Their estimated lengths ranged between 10 and 15 cm. Only 1 butterflyfish was recorded along the transect. Six families on the selected family list were recorded at Terumbu Pempang Tengah 3m depth transect, with Carangidae and Pomacentridae dominating. Other common fishes observed were the butterflyfishes (Chaetodontidae), the cardinal fishes (Apogonidae) and the serranid, *Diploprion bifasciatum*. The 'target' fishes were the carangids, *Selaroides leptolepis* (local Malay name, 'kuning'). These occurred in large numbers amounting to 300. Their sizes ranged from 7 to 12 cm, representing the sub-adult age. Three species of 'indicator' fishes recorded were *Chelmon rostratus, Chaetodon octofasciatus* and *Chaetodontoplus mesoleucus*, the last being the most abundant. At the 10m depth transect, only 5 families were observed, the dominant one being Carangidae followed by Pomacentridae.

At Terumbu Bemban, six families on the selected list were recorded. The family Pomacentridae was most abundant, accounting for 61.6% of the total fish count. The Carangidae was the next most abundant fish. These 'target' fishes were of the species *Selaroides leptolepis*, with lengths ranging from 10 to 15 cm. The butterflyfishes recorded in this transect was the largest number obtained for all the sites surveyed. Of the 67 butterflyfishes recorded, 61.2% were of the species *Chaetodon octofasiatus,* 32.8% were *Chaetodontoplus mesoleucus* and 6% were *Chelmon rostratus*.

DISCUSSION

The investigations revealed that of the four selected sites, Terumbu Jarat is not suitable for the establishment of artificial reefs. The bottom substrate is soft and except for the thin superficial layer, is devoid of oxygen which explains the lack of benthic life. Temperature readings were consistent at all sites. Slight variations were observed for salinity, dissolved oxygen and pH. The variation in dissolved oxygen between the surface and the bottom reading could be due to wave and wind action on the surface. The light intensity readings ranged widely because of variable weather conditions. Terumbu Pempang Tengah had high light intensity readings because of very sunny weather. However, the extent of light intensity reduction between surface and bottom levels was consistent for all sites.

The waves and water currents of all four sites are considered neither destructive to artifical reefs, nor strong enough to move these reefs away from the original sites of deposition. The depths of the seabeds surveyed were not m more than 15 metres. The substrate that is suitable for artificial reef construction should be firm so that the reefs will not sink significantly into the substrate (Mathews Jr., 1981). Out of the four sites surveyed, Cyrene Reefs, Terumbu Pempang Tengah and Terumbu Bemban have firm sandy seafloors which is suitable for artificial reef construction. The soft silty seabed of Terumbu Jarat is unsuitable as any modules laid down will sink and be rendered useless in providing additional habitats and niches for the benthic community. Soft silty substrates are also very easily disturbed and will significantly reduce light penetration and visibility. Siltation of the water may restrict low life-chain growth because of the reduced light reaching the bottom. Silt that is easily stirred up by the current have a scouring effect and reduces the settling success of organisms on the artificial substrates and the survival of organisms already settled (McAllister, 1981).

The seabed of the sites surveyed had low lifeform cover and hence the construction of artificial reefs at these sites would enhance the productivity of the benthic community by providing additional habitats and niches. However, the resource enhancement will be affected by the recruitment potential of adjacent natural reefs. Results of the lifeform transects at 3m depth at all sites showed that over 50% of the transect comprised lifeforms, except for Terumbu Jarat.

The type and abundance of fishes that frequent an area before an artificial reef is established is a vital factor in affecting the final population composition of the reef (Ranasinghe, 1981). As shown in the summarised results of this study (table 3), the 10m depth transect at Cyrene Reefs and the 3m depth transect at Terumbu Jarat had low fish counts/estimates. By comparing tables 2 and 3, it can be seen that for these sites surveyed, the fish abundance and reef 'richness' (lifeforms cover) varied directly with each other. The lifeforms cover and fish abundance at Terumbu Pempang Tengah and Terumbu Bemban were higher and hence offer a better recruitment potential for artificial reef than Cyrene and Terumbu Jarat. Reef enhancement by artificial reef construction will also increase fish abundance (Randall, 1963). The only comprehensive fish survey previously carried out in Singapore reefs was by Tay and Khoo (1984). From their study at Pulau Salu, they recorded 75 species of reef fishes from 20 families on the reef slope. The pomacentrids and the lutjanids were the most represented families with 22 and 14 species respectively. However, no detailed estimation of fish abundance was done. Comparing their study and this present one, a greater diversity of fish was recorded by Tay and Khoo (1984). This may be due to their use of multi-sampling method.

These site selection surveys showed that except for Terumbu Jarat which has a soft silty seabed, poor visibility, high turbidity and low lifeforms cover; all the other sites are suitable for artificial reef construction.

Table 3. Reef Fish Abundance at 3m and 10m depth of Reef Slope.

Category	Family	Taxon	Cyrene Reefs 3m	Cyrene Reefs 10m	Terumbu Jarat 3m	Terumbu Jarat 10m	Terumbu Pempand 3m	Terumbu Pempand 10m	Terumbu Bemban 3m	Terumbu Bemban 10m
Indicator Fish	Chaetodontidae									
		Chelmon rostratus	7	2	0	–	3	2	4	–
		Chaetodon octofasciatus	0	0	1	–	1		41	
		Chaetodontoplus mesoleucus	4	0	0	–	13	0	22	–
		sub-total	11	2	1	–	17	2	67	–
Target Fish	Lutjanidae		0	2	6	–	0	0	0	–
	Caramgodae	*Selaroides leptolepis*	0	0	0	–	*300	*85	*172	–
	Serranidae	'groupers'	0	0	0	–	0	0	0	–
Trophic Fish	Pomacentridae		219	*25	*55	–	*132	14	*410	–
	Serranidae	*Diploprion bifasciatum*	16	1	4	–	12	2	4	–
	Labridae		6	2	3	–	3	3	9	–
	Apogonidae		2	0	0	–	12	0	4	–
		Total	245	32	69	–	476	106	106	–

* estimated number

ACKNOWLEDGEMENTS

This site-selection study was carried out as part of the sub-project "Role of artificial reefs in living resource enrichment" within the Singapore component of the ASEAN-US Coastal Resources Management Project funded by USAID. We thank Ms Grace Lim, Ms Maylene Loo and Ms Chan Yee Ngoh of the Department of Zoology for their invaluable assistance.

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