

Assessment of reef resources at sites identified for artificial reef establishment in Singapore

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ABSTRACT

High sedimentation levels accompanying large-scale land reclamation and heavy shipping activity in the Singapore seas over the past 20 years have reduced the abundance, but not the diversity, of coral reef life-forms. Since artificial reefs have shown in many parts of the world that they can enhance living marine resources, they were considered part of a habitat restoration effort. Site selection surveys for possible artificial reef establishment were carried out at seven sites between February 1987 and June 1988. Results showed that Terumbu Bemban has the highest percentage of live coral cover (65.88%) and the largest average size of coral colonies. Cyrene Reefs has the highest diversity, with 28 genera covering 48.06% of the transect. Pulau Semakau has the lowest average coral cover and diversity, as well as the lowest average coral colony size. Although Terumbu Jarat and Pulau Semakau have poor community structure and low recruitment potential, reef enhancement using artificial reefs will be more significant.

INTRODUCTION

Singapore has one of the highest population densities in the world with 2.6 million people and a land area of just over 600 km². This shortage of land has resulted in a heavily utilized and highly modified coastline. Much of the original coastal resources have been reduced by the country's effort to use all available space. Massive land reclamation, which was started in the 1960s, was intended to reach its target of increasing the land area of Singapore by 10%. However, in doing so,

living marine resources have been affected by the reclamation (Chou 1987). The fringing reefs along the southern coast have long been destroyed and fish catches over the past 20 years have declined (Tham 1986).

Artificial reefs have been used in many parts of the world to enhance and restore living marine resources in disturbed environments. Sunken structures on the seafloor have been known to attract fish and serve as substrates for encrusting organisms. These human-made reefs have been shown to provide habitats for many reef organisms and to enhance living marine resources (Higo and Notonakano 1984; Munro and Polovina 1984). Under the ASEAN/US Coastal Resources Management Project, seven potential sites were surveyed for the establishment of artificial reefs in Singapore between February 1987 and June 1988 (Figs. 1 and 2).

As the diversity and abundance of organisms of nearby reefs will affect the final composition of the artificial reef, the reef life-forms of site-adjacent reefs were surveyed. Results of physico-chemical parameters and seafloor characteristics of selected sites have been earlier documented (Chou and Hsu 1988). Summarized results of adjacent reef characteristics of seven sites were reported (Chou and Hsu 1987). This paper focuses on the reef community of the natural reefs adjacent to the sites.

METHODOLOGY

The natural reefs next to the seven sites examined were Cyrene Reefs (1°15'N, 103°45'E), Terumbu Jarat (1°12'N, 103°47'E), Terumbu Pempang Tengah West (1°12'N, 103°44'E), Terumbu Bemban (1°12'N, 103°45'E), Kukor Beacon (1°14'N, 103°45'E), and Terumbu Pempang Tengah North (1°14'N, 103°44'E). The reefs were

surveyed using a 100-m line-intercept life-forms transect set on the reef slope at a depth of 3 m from the reef crest (Dartnall and Jones 1986). The data were analyzed in terms of the percentage cover of the live coral, dead coral, algae, other fauna and abiotic components with respect to the 100-m transect at each site. The community structure of the hard corals at each reef was then examined.

RESULTS

Summarized results of the line-intercept life-forms transect on the site-adjacent reefs with reference to their biotic and abiotic components are shown in Table 1. The analyses of hard coral community at the generic level and the Shannon and Weaver diversity indices of all the transects are shown in Table 2.

The transect at Terumbu Bemban had the highest live coral cover of 65.88% and the highest number of colonies. Pulau Semakau had the lowest number of colonies on its transect. From the diversity indices in Table 2, Cyrene Reefs had the most diverse hard coral community (2.96) and the highest total number of genera. Terumbu Pempang Tengah West had the second highest diversity index of 2.44 and the second highest total number of genera. Terumbu Jarat had the lowest coral diversity of only 1.99. The average size of the colonies of each transect (Table 2) was calculated by dividing the total percentage cover by the number of colonies on each transect. The average size of coral colonies was highest at Terumbu Pempang Tengah North (0.66 m), followed by Terumbu Bemban (0.44 m). Pulau Semakau had the smallest average coral colony size.

The most common corals found on the transect at Cyrene Reefs were mainly the massive and the foliose types. The dominant genera were *Merulina*, *Pectinia* and *Favites*, each covering over 5% of the transect. The genus *Acropora* was absent. Three colonies of the nonscleractinian *Heliopora* were encountered at this site only. Dead corals comprised mainly those with algal coating and none were recently dead. The algae observed on the transect were filamentous ones in the form of algal assemblages. The other types of reef fauna observed included sponges, soft coral and hydroids but these were predominated by zoanthids. The abiotic components were mainly rubble and silt.

The transect at Terumbu Jarat had only 22.54% live corals (Table 1), of which the genera *Physogyra* and *Pavona* were dominant. Although the transect there had the lowest coral cover, there were two occurrences of *Acropora* taking up 0.1% of the 100-m transect (Table 2). The common growth forms were the encrusting, massive and foliose types. The dead corals were predominantly those with algal covering. Coralline algae and algal assemblages were also observed along the transect. Other reef fauna were mainly sponges and hydroids. At this transect, the highest percentage of abiotic components (62.38%), like rubble and water fissures, were recorded.

The second highest live hard coral cover was encountered at Terumbu Pempang Tengah West with the genera *Pachyseris*, *Favia*, *Merulina*, *Porites* and *Pectinia* among the more abundant. The transect had two colonies of *Acropora* with a percentage cover of 0.4%. The dominant growth forms were the encrusting type (*Pachyseris* and *Merulina*). The submassive and branching growth forms each had only one representative on this transect. Like the previous two sites, dead corals had algal covering and the algae encountered were either coralline algae or in the form of algal assemblages. Sponges were observed covering 0.94%. Among all the transects, this site had the lowest abiotic components (19.01%), comprised mainly of rubble. The site north of this patch reef, however, did not have the high live coral cover encountered in the west. But the dominant genera were common for the two sites minus the genus *Merulina*. The transect on the north site did not have any algae although filamentous algae were plentiful in other parts of the reef. Patches of sand were found interspersed between the living part of the reef.

The dominant corals at Terumbu Bemban were the foliose forms of *Montipora* (43 colonies, 21.70%) and *Pavona* (21 colonies, 14.35%). One colony of *Acropora* was observed on the transect. The dominant growth form was the foliose type, comprising mainly of *Pavona* and *Pectinia*. It is interesting to note that on this transect, and even more so on the reef flat, there was an abundance of the branching form of *Porites*, which is not very common in other Singapore reefs. Apart from the usual occurrences of algal assemblages, the macroalgae *Sargassum* was present. Other reef fauna included sponges, sea urchins and sea anemones. There were 58 occurrences of abiotic components like sand, rubble and water fissures, but these occupied only 26.47% of the transect.

Pulau Semakau had the lowest percentage cover of live corals (15.61%) and the highest percentage cover of dead corals (49.81%). The genus *Acropora* was absent. The predominant coral was the encrusting form of *Montipora*. The algae that occurred were in the form of filamentous assemblages. Zoanthids formed the highest percentage cover of noncoral life-forms. There was a total of 12 occurrences of zoanthids covering 2.35% of the transect. Other fauna included sponges, hydroids and soft corals. The majority of the abiotic components was made of rubble, although other components like silt, sand, water fissures and rocks were present on the transect.

DISCUSSION

The high percentage cover of life-forms on the transects at Terumbu Bemban, Terumbu Pempang Tengah (North and West) and Cyrene Reefs offers good recruitment potential for the artificial reefs (Chou and Hsu 1987). The low percentage cover of live corals at Terumbu Jarat and Pulau Semakau offers lower recruitment potential compared to the other sites, but reef enhancement using artificial reefs will be more significant there. It is interesting to note that the life-forms transect carried out very near the site at Pulau Semakau a year ago had 42.09% live corals and 9.82% dead corals. This is a good reef cover, especially when compared to the transect carried in June 1988, which had 15.61% live corals and 49.81% dead corals. Although the abundance of hard corals was reduced significantly, the reef remains diverse, with a Shannon and Weaver index of 2.25. This drastic drop in coral abundance

can be attributed to the dumping of earth spoils southeast of this site. The increase in the level of sediment in the water and the subsequent reduction of water visibility have resulted in the death of many corals and other life-forms. If this dumping at Pulau Semakau is contained, the construction of artificial reefs may be a possible solution to the enhancement and restoration of the natural reef. The rich and diverse reef that existed here before the dumping shows this area to be ideal for rapid reef recolonization.

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Table 1. Life-forms cover at 3-m depth on the reef slope of the surveyed sites (based on a 100-m line transect).

Surveyed site	Live coral	Dead coral	Percentage cover		
			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 West	54.42	19.16	5.22	2.19	19.01
Terumbu Bemban Kukor Beacon	65.88	3.91	1.53	2.21	26.47
Terumbu Pempang Tengah North	38.05	25.90	0.00	1.85	34.20
Pulau Semakau	15.61	49.81	1.60	4.35	28.63

Table 2. Hard coral community analyzed at generic level (figures indicate percentage cover with colony number in parentheses).

Genera	Cyrene Reefs	Reef Site				Pulau Semakau
		Terumbu Jarat	Terumbu Pempang Tengah (W)	Terumbu Bemban	Terumbu Pempang Tengah (N)	
Acroporidae						
<i>Acropora</i>	-	0.10(1)	0.40(2)	-	-	-
<i>Montipora</i>	0.98(3)	0.30(1)	1.16(4)	21.7(43)	-	4.70(15)
Agariciidae						
<i>Leptoseris</i>	0.60(1)	-	-	-	0.85(1)	-
<i>Pachyseris</i>	1.94(4)	0.10(1)	13.07(26)	4.40(9)	10.75(12)	0.40(3)
<i>Pavona</i>	0.20(1)	4.13(9)	2.35(6)	14.35(21)	3.70(2)	0.43(2)
Fungiidae						
<i>Fungia</i>	0.30(2)	0.55(4)	0.75(7)	1.79(12)	1.70(4)	0.10(1)
<i>Heliopora</i>	-	-	-	-	-	0.20(1)
<i>Lithophylloids</i>	-	-	-	0.50(1)	-	-
<i>Podobacia</i>	1.24(3)	0.50(1)	1.50(5)	-	2.10(7)	-
Poritidae						
<i>Goniopora</i>	1.19(3)	-	1.14(5)	0.30(1)	-	-
<i>Porites</i>	2.15(5)	0.40(1)	2.50(8)	4.63(7)	2.65(9)	1.94(7)
Siderastreae						
<i>Psammocora</i>	-	-	-	-	0.20(1)	-
Faviidae						
<i>Cyphastrea</i>	0.08(1)	-	-	-	0.70(3)	1.96(4)
<i>Diploastrea</i>	-	-	-	-	-	1.40(2)
<i>Echinopora</i>	2.25(5)	1.35(3)	2.38(6)	0.90(2)	-	-
<i>Favia</i>	2.59(10)	0.45(3)	5.55(7)	-	7.00(4)	1.23(3)
<i>Favites</i>	5.28(10)	0.90(2)	1.40(5)	1.10(4)	0.30(1)	0.50(1)
<i>Goniastrea</i>	2.19(6)	0.50(3)	0.70(3)	-	1.70(2)	-
<i>Hydnophora</i>	1.31(2)	0.50(2)	1.90(4)	1.95(6)	-	-
<i>Leptastrea</i>	-	-	-	-	0.10(1)	-
<i>Montastrea</i>	2.46(6)	-	-	-	-	0.20(1)
<i>Platygyra</i>	2.93(10)	-	0.34(2)	0.75(4)	-	-
Trachyphylliidae						
<i>Trachyphyllia</i>	-	-	-	-	-	0.20(1)
Oculinidae						
<i>Galaxea</i>	1.46(8)	-	0.50(3)	0.14(1)	-	-
Merulinidae						
<i>Merulina</i>	5.87(13)	0.85(4)	8.15(18)	4.18(10)	-	-
Mussidae						
<i>Lobophyllia</i>	0.68(2)	-	-	0.90(1)	-	-
<i>Symphylia</i>	1.00(3)	0.50(2)	0.50(4)	-	-	-
Pectiniidae						
<i>Echinophyllia</i>	2.50(3)	-	0.72(1)	-	-	-
<i>Mycedium</i>	-	-	-	-	5.15(5)	0.80(3)
<i>Oxypora</i>	1.08(2)	-	-	0.60(2)	0.40(2)	-
<i>Pectinia</i>	5.34(15)	1.65(8)	8.51(27)	4.99(21)	0.15(2)	1.20(3)
Caryophylliidae						
<i>Euphyllia</i>	1.10(2)	-	0.50(2)	-	-	-
<i>Physogyra</i>	0.10(1)	9.76(11)	0.40(1)	2.35(3)	-	-
<i>Plerogyra</i>	0.30(1)	-	-	-	0.10(1)	-
Dendrophylliidae						
<i>Tubastraea</i>	-	-	-	-	-	0.05(2)
<i>Turbinaria</i>	0.09(1)	-	-	-	-	0.30(1)
Helioporidae						
<i>Heliopora</i>	0.85(3)	-	-	-	-	-
Total percentage cover	48.06	22.54	54.42	65.88	38.05	15.61
(Number of colonies)	(126)	(56)	(146)	(148)	(58)	(50)
Total number of genera	28	16	21	17	17	16
Shannon and Weaver diversity index ^a	2.96	1.99	2.44	2.12	2.12	2.24
Average colony size (m)	0.38	0.40	0.37	0.44	0.66	0.31

^aOdum (1971).

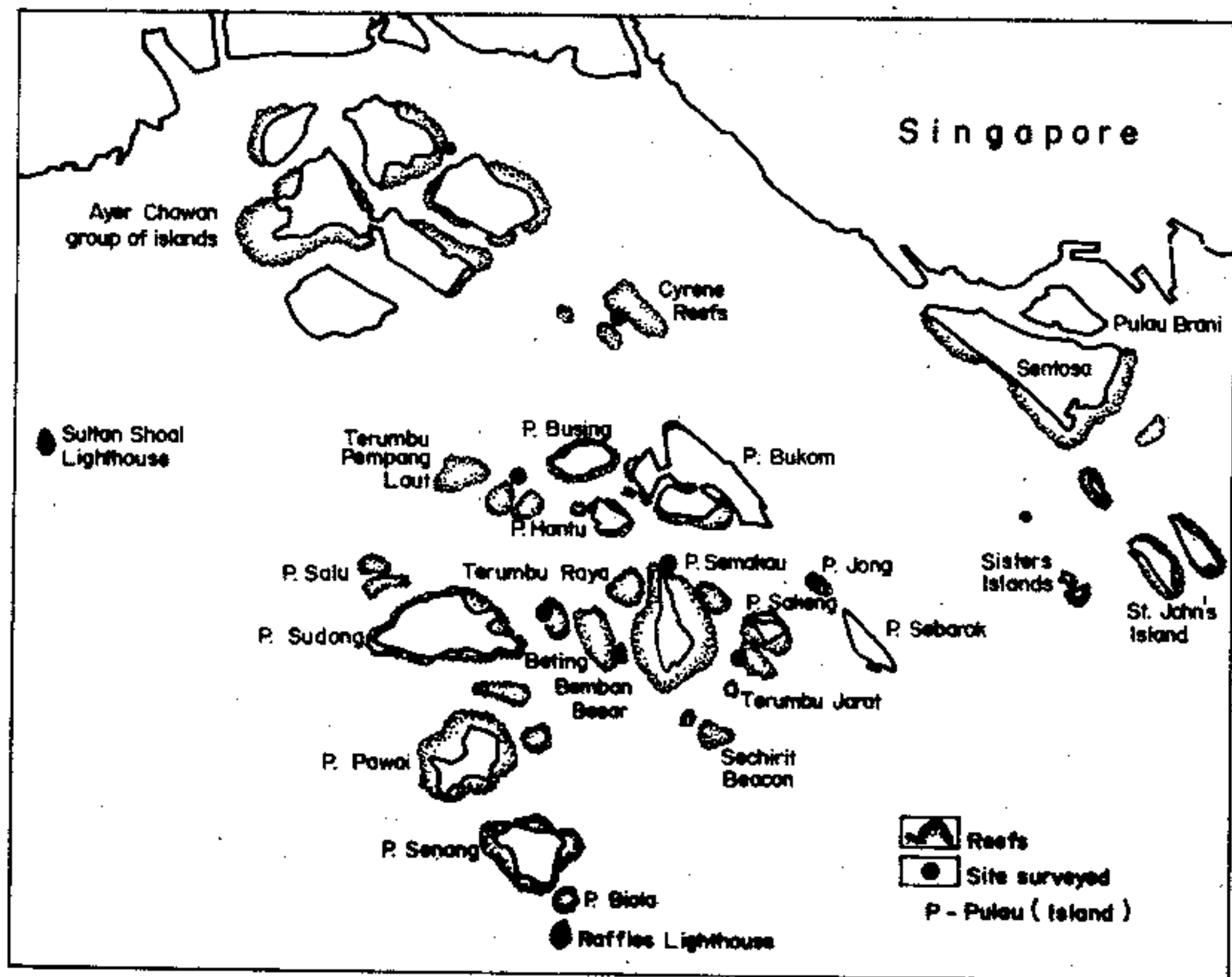


Fig. 1. Map of coral reefs in Singapore showing sites surveyed.

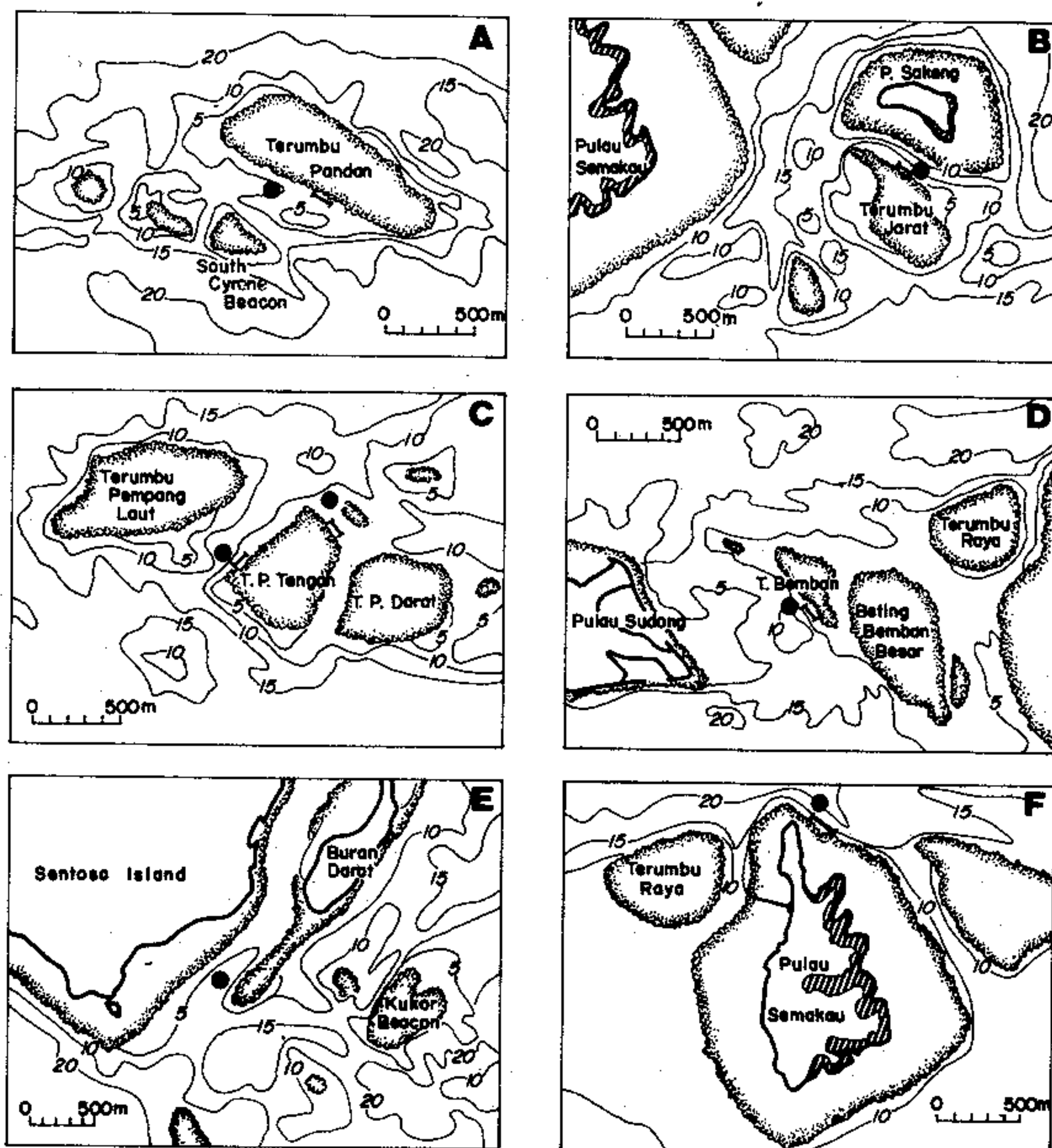


Fig. 2. Map showing location of sites investigated: A - Cyrene Reefs; B - Terumbu Jarat; C - Terumbu Pempang Tengah; D - Terumbu Bemban; E - Kukor Beacon; F - Pulau Semakau. (Isobath depths indicated are in meters.)

