

## SINGAPORE REEFS REPORT 2002

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### ABSTRACT

Singapore reefs are affected by over four decades of land reclamation and coastal development. Sedimentation rates as high as  $44.64 \text{ g cm}^{-2} \text{ day}^{-1}$  reduced visibility from 10m in the 1960s to 2m today. This is accompanied by a decrease in live coral cover at almost all sites monitored since 1986. The outermost reef at Raffles Lighthouse with considerably less sedimentation impact also registered a decrease in live coral cover from 76.35% to 48% between 1987 and 1997. The widespread bleaching event of 1998 affected Singapore reefs at level previously unknown. Exceptionally elevated water temperature up to  $35^{\circ}\text{C}$  coinciding with low tides resulted in 90% of hard corals bleached of which 25% failed to recover. Overall reduction in the total percent live coral cover through bleaching was most evident at the reef crest. Recovery rates varied among genera and growth forms. The submassive coral, *Goniopora*, showed the most complete recovery, while massive corals recovered at a lower rate.

### INTRODUCTION

The Republic of Singapore consists of a main island and about 60 small offshore islands and patch reefs. The main and offshore islands cover a land area approximately  $660 \text{ km}^2$ , and the territorial waters, an almost equal area of  $630 \text{ km}^2$ . It has a population of approximately 3.9 million people, giving a high population density of 5,900 persons per  $\text{km}^2$  (Anon., 2000). The country underwent large-scale economic development since the 1960s, which transformed it from an economic backwater to one of the newly industrialised economies (NIEs), often described as one of the four "dragons" of Asia (Hilton & Manning, 1995). Singapore's marine environment is an important resource, playing a large role in its economic growth and prosperity, supporting one of the world's busiest harbours and one of the largest oil refining centres. An estimated 60% of the total coral reef areas have been lost through foreshore reclamation (Chou, 1995; Chou & Goh, 1998).

In Singapore's highly urbanised society, fishing and collecting from reefs and other coastal areas, either for the aquarium trade or for subsistence, declined steadily since the 1980s with stronger enforcement by the Police Coast Guard. The first, and so far the only, arrest of coral smugglers was made in Oct 1991 (Anon, 1991).

## STATUS OF CORAL REEF BENTHOS AND FISHES

### *Coral reef fish status*

No further monitoring of reef fish was carried out since 1993. Singapore's reef fish fauna, with a total of 111 species from 30 families, was poorest among the five ASEAN countries of Indonesia, Malaysia, Philippines and Thailand (Chou, *et al.*, 1994). Abundance and diversity decreased with depth, and increased with distance from the mainland.

### *Coral reef benthos status*

Results of the monitoring programme since 1987 show live coral cover declining with both increasing depth and over time (Table 1). Corals generally do not occur beyond the 6m depth due to the effect of suspended sediment on light penetration. While coral diversity and cover in most localities declined steadily, some localities, such as Lazarus Island (site L4) and Cyrene Reefs (site C1 and C2), suffered close to 100% loss in coral cover.

### *Coral bleaching impacts*

The first mass bleaching event reported on Singapore reefs occurred in June 1998. Sea temperature around St. John's Island and Pulau Hantu (Tables 2 & 3) remained elevated by 1 to 2°C from March to June 1998, with several short term increase in excess of 3°C between May and June. Bleaching was widespread on all fringing and patch reefs. It was most apparent along the reef flats and reef crests, affecting 50% to 90% of reef organisms, mainly hard corals, soft corals and anemones. The bleaching effect extended to the 6m depth, which is within the lower depth limit for coral growth in Singapore (6-8 m). Sea temperature readings at Pulau Hantu in August 1998 indicated that it returned to normal levels.

Response of reefs to the bleaching event was investigated in a 6-month study between 31 July 1998 and 14 December 1998. Two types of surveys were conducted; a visual and photographic monitoring of 35 coral colonies, and 10m permanent line intercept transects at three depths.

Towards the end of the study, 23 colonies recovered completely while 10 colonies died. Of the 11 genera monitored (including one soft coral genera, *Sinularia*), *Fungia*, *Goniopora* and *Galaxea* showed complete recovery, while *Sinularia* and *Euphyllia* showed complete mortality. Other colonies showed various signs of stress, such as growth of turf algae and silt accumulation, leading to partial or total colony mortality. The line-intercept transects showed an overall reduction in percent live coral cover, but at the same time indicated that recovery from the bleaching event improved by December 1998.

## STATUS OF CORAL REEF FISHERIES

No statistics are kept of coral reef fish harvested from the reefs. There is really no reef

fisheries to speak of in Singapore. Marine food fish (pelagics and demersals) from trawlers is landed at the Jurong Fish Port. These trawlers operate in the open seas such as the South China Sea. Boat-operated commercial fishing is prohibited in territorial waters due to limited space and risk to navigational safety. Local fish catch is marketed through Senoko Fishing Port (Anon., 2000) and most of this comes from the diminishing numbers of commercial palisade trap operations and local production from marine aquaculture. Local fish production (including aquaculture production) decreased from 14,101 tonnes in 1994 to 9,477 tonnes in 1999. Imports have fluctuated from 18,090 tonnes in 1995 to 135,408 tonnes in 1999. Export of fish also declined, from 136,909 tonnes in 1995 to 93,419 tonnes in 1999. There is however, no breakdown on the types of fish imported or exported.

Table 1. Percent live coral cover at 12 sites in the southern island of Singapore between 1987 and 1999. Surveys for 1007-99 are split into pre- and post- bleaching event (1997 - Jun 1998 and Jul 1998 - 1999 respectively).

Island	Reef site / depth (m)	1986-88	1990-91	1992	1993	1997-Jun 98	Jul 1998-99
Cyrene Reefs	C1-0	4.47	4.59	-	3.27	-	0.00
	C1-3	23.50	1.27	-	6.91	-	0.00
	C1-6	0.00	0.61	-	0.00	-	*
	C1-10	4.81	0.00	-	0.00	-	*
	C2-0	19.89	2.29	-	12.94	-	21.13
	C2-3	48.53	9.30	-	19.50	-	0.00
	C2-6	1.29	12.49	-	5.25	-	*
	C2-10	0.00	0.00	-	0.41	-	*
	Hantu West Reef	HW1-0	41.45	-	37.29	41.61	19.78
HW1-3		64.00	-	28.01	24.95	18.86	-
HW1-6		7.78	16.43	-	19.67	7.26	-
HW1-10		4.01	-	0.29	1.17	3.74	-
HW2-0		70.35	-	63.88	61.59	33.77	-
HW2-3		36.59	-	48.39	45.32	-	27.51
HW2-6		22.50	36.42	-	36.22	-	15.90
HW2-10		13.96	-	5.50	5.46	-	2.88
Lazarus Island		L2-0	-	60.70	47.26	21.62	21.48
	L2-3	-	19.64	25.69	16.44	7.03	-
	L2-6	-	0.91	4.36	6.43	0.92	-
	L2-10	-	0.54	0.10	0.00	0.00	-
	L4-0	-	2.62	3.34	7.13	0.24	-
	L4-3	-	0.63	2.01	0.61	1.73	-
	L4-6	-	0.00	0.59	0.15	0.25	-
	L4-10	-	0.05	0.00	0.13	0.00	-

Pulau Hantu	H1-0	31.06	-	8.40	10.18	10.20	-	
	H1-3	27.66	-	5.48	15.96	12.39	-	
	H1-6	3.89	-	1.83	9.19	17.77	-	
	H1-10	0.35	-	0.00	0.00	2.55	-	
	H2-0	49.19	-	48.70	41.10	41.74**	-	
	H2-3	50.71	-	29.97	32.93	27.00**	-	
	H2-6	3.75	-	7.03	17.32	24.92	-	
	H2-10	5.49	-	5.49	2.44	5.85	-	
	Pulau Semakau	S1-0	26.05	-	19.08	8.87	9.89	-
		S1-3	43.96	-	15.33	16.91	7.93	-
S1-6		5.97	-	0.00	6.98	6.67	-	
S1-10		2.48	-	0.00	0.92	0.00	-	
S2-0		52.21	-	59.61	56.27	40.63	-	
S2-3		61.09	-	30.71	32.59	22.73	-	
S2-6		1.69	-	5.33	1.15	5.76	-	
S2-10***		0.00	-	-	-	-	-	
Raffles Lighthouse		R1-0	76.51	78.06	-	73.39	48.00	-
		R1-3	30.82	40.47	-	25.82	40.50	-
	R1-6	7.94	11.62	-	13.65	-	8.35	
	R1-10	5.37	1.86	-	4.02	-	1.75	
	R2-0	76.35	67.02	-	75.17	-	50.09	
	R2-3	45.57	40.18	-	55.76	-	36.55	
	R2-6	7.45	6.35	-	33.86	-	18.62	
	R2-10	1.074	2.21	-	1.85	-	3.30	

\* no data

\*\* mean of two observations, both done before the bleaching event of June 1998

\*\*\* site-depth was lost due to sediment build up

*Table 2. Sea surface temperatures at St. John's Island, Singapore.*

Date	Sea surface temperature range (°C)
08 Aug 1997	28.0-30.3
07 Jan 1998	27.2-28.7
19 May 1998	30.6-34.3

Table 3. Twenty-hour sea temperature ( $^{\circ}\text{C}$ ) data from Pulau Hantu (from an underwater temperature sensor).

Date	24 hr average	Average temperature (degC)		Maximum/Minimum temperature (degC)	
		Day-time	Night-time	Day-time	Night-time
27 Nov 1997	30.28	30.28	30.15	31.00-29.75	30.35-29.75
02 Dec 1997	30.49	30.58	30.40	32.40-30.20	30.60-30.00
09 Dec 1997	30.33	30.47	30.19	32.60-30.10	30.50-29.90
21 Jan 1998	30.04	30.44	30.10	31.70-30.00	30.50-29.70
05 Mar 1998	31.01	31.19	30.76	31.90-30.50	30.90-30.40
06 Mar 1998	33.89	33.98	33.77	34.55-26.55	34.30-32.95
13 Mar 1998	31.08	31.20	30.91	31.50-30.75	31.05-30.60
15 Mar 1998	31.04	31.13	30.91	31.55-30.65	31.05-30.65
16 Mar 1998	31.43	31.51	31.31	31.95-31.05	31.50-31.05
18 Mar 1998	31.33	31.43	31.22	31.85-30.95	31.40-30.60
03 Jun 1998	34.25	34.35	34.12	36.15-32.15	35.70-31.85

### ANTHROPOGENIC THREATS TO CORAL REEF BIODIVERSITY

The Singapore economy and population continues to grow. Over 40 years of coastal development have increased Singapore's land area to 660 km<sup>2</sup>, of which 324 km<sup>2</sup> is built up for industries, cargo container and warehousing facilities, the airport, and recreation and living space (Anon., 2000). Severe degradation of the marine environment has resulted, either by direct destruction of the coral reef habitat through coastal reclamation, or the indirect effects of increased sediment in the waters. Visibility has been reduced from 10m in the 1960s (Chua & Chou, 1992) to less than 2m presently. Sedimentation rates of up to 44.64 g cm<sup>-2</sup> day<sup>-1</sup> have been recorded (Low & Chou, 1994) and input of sediment into the marine environment continues from several large scale reclamation and development projects in progress. These include the extension of Changi at the eastern end, and the development of cargo container facilities along the south-western coast of the mainland. In the southern islands, the expansion of Sentosa Island, the merger of the Ayer Chawan group of islands (to create a single "Jurong Island") and the creation of a land fill on the eastern side of Pulau Semakau have added to sediment loading of the seas.

### CURRENT AND POTENTIAL CLIMATE CHANGE IMPACTS

The most recent impact of climate change was the mass bleaching event of 1998, when sea surface temperatures soared to 35 $^{\circ}\text{C}$ . Air temperatures have also risen by 1.5 $^{\circ}\text{C}$

over the last 50 years (Chandradas *et al.*, 1999), from 26.6°C to 28.3°C. The El Nino also affected rainfall throughout 1998, extending the dry season and causing more rain to fall during the wet monsoon periods.

## CURRENT MPAS AND MONITORING AND CONSERVATION MANAGEMENT CAPACITY

There are currently no marine protected areas in Singapore. The closest is the designation of the St. John's group of islands as a marine nature area in 1996 (Nathan, 1996a). It is administered by the National Parks Board (Ministry of National Development), with the Police Coast Guard acting as the enforcement agency. There has been little progress in the further development of the protection status, particularly for the marine environment. The 1992 Green Plan which drew attention to four reef areas proposed for some form of protection is now undergoing a major review and this shortcoming is being addressed. In early 2002, Labrador nature reserve, a coastal hillside forest was fully gazetted as a Nature Park. It has a coastal component consisting of a rocky shore with coral communities. This is the first protected area with reef communities in Singapore. Another new development in early 2002, is the coordination of marine conservation by National Parks, which had formerly concentrated on terrestrial conservation.

Much of the monitoring of the reefs in Singapore is undertaken by researchers from the National University of Singapore, mainly the Reef Ecology Study Team (REST) of the Department of Biological Sciences and the Tropical Marine Science Institute (TMSI). Past and present research initiatives, both local and regional, include:

- \* The ASEAN-Australia Marine Science Project: Living Coastal Resources (1985 to 1996, funded by AIDAB)
- \* The ASEAN-US Coastal Resources Management Project (1987 to 1992, funded by USAID)
- \* The monitoring of artificial reefs as an enhancement tool in the rehabilitation of degraded reefs (1992 to 1997, funded by National University of Singapore)
- \* The Reef Survey and Conservation Project (1987 to 1990, funded by local business community)
- \* Monitoring of the reef health status of Singapore reefs and other anthropological effects, especially sedimentation (1997 to 2000, funded by National Science and Technology Board)
- \* Modelling productivity, nutrient fluxes and other reef responses in coral reef ecosystems in relation to environmental factors (1993 to 2001, funded by National

### Conservation Capacity

Many non-government agencies are involved in reef conservation activities (Chou & Goh, 1998). They include:

#### *The Singapore Reef Survey and Conservation Committee (SRSCC)*

This committee comprising representatives from the Republic of Singapore Yacht Club, the Singapore Institute of Biology and the Singapore Underwater Federation was formed in 1988. It launched the Reef Survey and Conservation Project (RSCP) which is a major effort involving the local diving community in surveying coral reefs. Some 150 volunteer divers were trained to survey reefs using the line-intercept transect method. They were deployed in teams to survey almost all reefs and generated data from 65 sites of 41 islands (Chua & Chou, 1992). Over three-quarters of the reef locations supported live coral cover of more than 30%. A proposal based on the findings was submitted to the government in 1991, recommending four reef areas as possible marine protected areas. The four areas were subsequently included in the country's "Green Plan", and one such area was declared a Marine Nature Area in 1996.

#### *Singapore Reef and Marine Conservation Committee (SRMCC)*

This committee evolved from the SRSCC in 1995 by natural expansion to include representatives from the Nature Society (Singapore) and Raffles Marina Pte. Ltd. The intention is to provide more effective co-ordination of reef conservation efforts, and to combine resources and develop a stronger role in forwarding recommendations to the government.

#### *Nature Society (Singapore)*

This society is active in educating the public through talks and publications, such as "The Singapore Red book" (Ng & Wee, 1994). They are also involved in the current review of the Green Plan. However, their emphasis is heavily on terrestrial ecosystems. The Society organised two major coral translocation programmes involving volunteer divers in the earlier half of the 1990s. An assessment showed less than 11% of the translocated corals survived (Chou & Tun, 1997).

#### *Singapore Environment Council (SEC)*

The Council (previously known as National Council on the Environment) initiated a number of projects aimed at increasing the awareness of school children on reef conservation issues, including the Reefs Insights programme, targeted at secondary and pre-university students. Most recently, they launched the "Singapore Green Map" (Wee, 2000), listing the locations of Singapore's nature areas, eco-friendly stores and recycling points. The SEC also works with private enterprise to promote eco-friendly projects, such as the courtesy mooring buoys (together with Raffles Marina Ltd, Singapore Underwater Federation and Shell Pte Ltd).

### *Singapore Underwater Federation (SUF)*

Primarily focussed on scuba activities, the Federation organised beach and reef cleanups, and snorkelling programmes for schools. They have been active in expanding the deployment of the mooring buoys at Pulau Hantu reefs with an "adopt-a-buoy" scheme. The SUF is intensifying efforts towards reef conservation among the diving community and public.

## GOVERNMENT POLICIES, LAWS AND LEGISLATION

Singapore, being one of the busiest ports in the world, has heavy shipping activity and shipyards along its coastline. There is an ever-present risk of pollution to the marine environment. To maintain the high standards of pollution prevention, the Maritime and Port Authority of Singapore (MPA) monitors hydrocarbons in the sea and uses technology such as satellite imagery to convict polluters (Teo, 1997). Singapore is also a participating member in the following regional and international programmes to minimise the risk of marine pollution:

\* ASEAN oil spill contingency plan, initiated by the ASEAN Expert Group on Environment (AEGE) in 1970, and includes the International Maritime Organisation (IMO) and the United Nations Environment Programme (UNEP). The implementation of the plan lies with the ASEAN Senior Officials on the Environment (ASOEN), formed in 1990.

\* Oil Spill Preparedness and Response Plan (OSPAR), supported by Japan, to combat oil spills in the region and also to operate an information network documenting oil spills.

\* East Asia Response Ltd (EARL), formed by the major oil refining companies of BP, Exxon, Mobil; and Shell, maintains an inventory of equipment capable of managing oil spills of between 10,000 and 30,000 tonnes (Chua, 1994).

\* Traffic Separation Scheme (TSS), developed by the Tripartite Technical Experts Group (TTEG), which was adopted and implemented by Singapore, Malaysia and Indonesia in 1981 to reduce accidents along the heavily used Straits of Malacca and Singapore. A Vessel Traffic Information Scheme was set up in Singapore to ensure compliance with TTS.

\* Asia-Pacific Memorandum of Understanding on Port State Control in the Asia-Pacific Region (1993). This establishes and maintains a system to ensure that all foreign ships visiting ports comply with the international conventions of MARPOL 73/78, the International Convention on Standards for Training, Certification and Watchkeeping for Seafarers (1978), the Convention on the International Regulations for Preventing Collisions at Sea (1972) and the ILO Convention No. 147 Concerning Minimum Standards in Merchant Ships (1976) (Koh & Lim, unpublished).



The Pollution Control Department (PCD), Ministry of the Environment is the central agency co-ordinating and implementing controls on pollution. They are responsible for environmental planning and building development control, air and water pollution control, hazardous substances and toxic wastes management. Industries are required to include measures to reduce and control discharges of waste water and cooling water and the disposal of wastes. Industrial effluent and sewage must meet standards set by the PCD, which is backed by several Acts and Regulations, for example, the Trade Effluent Regulations, 1976 and the Poisons Act (Hazardous Substances Rules 1986). The collection and disposal of toxic industrial waste is also controlled through licensing. Monitoring of the inland waterways and coastal waters is carried out regularly by the Strategic Planning and Research Department (SRPD) at over 80 points in and around the island. Inspections and checks on industrial premises are also carried out by the Sewerage Department and Singapore Power. Heavy penalties are imposed on offenders.

### GAPS IN CURRENT MONITORING AND CONSERVATION CAPACITY

While protection of terrestrial habitats is well established and managed by specific agencies having the appropriate legislative framework, an integrated management strategy for coastal waters still does not exist. The lack of institutional mechanisms for co-ordinated protection of coral reefs and marine life makes it difficult to extend any meaningful management of reefs. The formulation of an "umbrella" law (Anon., 1994), encompassing four separate Acts that cover the environment (the Water Pollution Act, the Clean Air Act, the Environment Public Health Act and the Poisons Act) did not address the management of the marine environment and its living resources. Review of existing industrial site laws are also underway (Nathan, 1996b).

### CONCLUSIONS AND RECOMMENDATIONS FOR CORAL REEF CONSERVATION

Economic progress in Singapore has been achieved largely at the expense of the country's natural resources including coral reefs. Much of the initiative in promoting the conservation of Singapore reefs has come from non-governmental organisations. These efforts have raised public consciousness. Government agencies responsible for development can direct more attention to reef conservation as it is evident that much of the present reef degradation resulted from ad hoc planning. Reef protection measures against the impacts of development are frequently delayed or compartmentalised responses. Most of the reef degradation could have been avoided or minimised with better planning.

Clearly needed is an integrated management approach for the marine environment and its living resources. A coastal integrated management plan is needed to address apparent lack of ownership, jurisdiction and management of coral reefs. A greater commitment from the government is essential if Singapore is to fulfil its obligation to

the Convention on Biological Diversity, which the government signed and ratified.

An extension of reef monitoring capacity to the region is demonstrated by an initiative of the Singapore International Foundation in collaboration with the National University of Singapore. In 2001, the Youth Expedition Programme of the Singapore International Foundation started a programme on marine conservation. Singapore youth volunteers are trained to carry out reef surveys (Line Intercept Transect and Reef Check) by the National University of Singapore and sent overseas to carry out these surveys. The first programme consisted of two expeditions to Cambodia (in June and December of 2001) to conduct reef surveys in the Koh Kong Province in response to the provincial Government's need for information to formulate ecotourism policies. The next location under this programme is North Borneo where volunteers will carry out reef surveys in collaboration with University Kebangsaan Sabah. The information obtained will be used to propose the islands and reefs in North Borneo as a marine protected area.

In 1997, the Aseanarean Expeditions initiative was launched by the author and two other colleagues. This volunteer programme is aimed at highlighting the national marine parks of the Asean region through books and documentaries. A book on the Marine Parks of Thailand was published in 1997 after a series of expeditions. In 1998, a major expedition to the marine parks of Indonesia was completed. A book will be published in late 2002 or early 2003. Three half-hour documentaries on the marine parks of Indonesia will be televised on National Geographic Channel Asia in the later half of 2002.

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