

COUNTRY REPORT: SINGAPORE

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ABSTRACT

Singapore reefs show the impact of over four decades of land reclamation and coastal development. High sedimentation rates persist, causing declining live coral cover at almost all sites monitored since 1987. Live coral cover of reefs close to or in the path of sediment plumes dropped drastically. The widespread bleaching event of 1998 affected Singapore reefs at an unprecedented level. Exceptionally elevated water temperature up to 35°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 slower. The lack of a national policy on coral reefs and the absence of an identified national agency to manage coral reefs are factors against reef protection. However, strong measures in controlling marine pollution (other than sedimentation) and a diversity of reef protection activities by non-governmental organisations are helping to mitigate the deficiency within obvious limitations.

INTRODUCTION

The Republic of Singapore consists of a main island and over 60 small offshore islands with fringing and patch reefs. It has a combined land area of approximately 660 km², and territorial waters cover 630 km². The human population of 3.9 million gives a high density of 5,900 persons per km² (Anon., 2000). The marine environment is an important resource contributing to economic growth. It supports one of the world's busiest ports and one of the largest oil refining centers. Close to 60% of the total coral reef areas have been lost through foreshore reclamation (Chou, 1995; Chou and 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. Illegal collection of corals and other reef invertebrates stopped with stronger enforcement by the Police Coast Guard and a more informed public. The first, and so far only, arrest of coral smugglers was made in Oct 1991 (Anon, 1991). Effective regulatory measures prevent marine pollution. The greatest impact however, is the high sediment load generated by land reclamation, the regular dredging of rivers and shipping lanes, and the dumping of these materials out at sea.

TRENDS IN CORAL REEF CONDITION*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 high sediment load. 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. This is attributed to their proximity to sedimentation-generating activities such as dumping of dredged spoils and reclamation respectively.

Coral bleaching impacts

A mass bleaching event of Singapore reefs occurred in June 1998 on a scale previously unknown. Sea temperature around St. John's Island and Pulau Hantu (Tables 2 and 3) remained elevated by 1 to 2°C from March to June 1998, with intermittent short term increases above 3°C between May and June. Bleaching was widespread on all fringing and patch reefs and most apparent along reef flats and crests, affecting 50% to 90% of reef organisms, mainly hard corals, soft corals and anemones. Bleaching extended to the 6m depth, about the lower depth limit for hermatypic coral growth. Sea surface temperature returned to normal in August 1998.

A 6-month study (31 July 1998 to 14 December 1998) of bleaching impact showed that 23 of the 35 individual coral colonies monitored recovered completely while 10 colonies died. Of 11 genera monitored over fixed line transects (including the soft coral, *Sinularia*), *Fungia*, *Goniopora* and *Galaxea* recovered completely, while *Sinularia* and *Euphyllia* succumbed completely. Other genera exhibited various signs of stress, such as growth of turf algae and silt accumulation, leading to partial colony mortality. Line-intercept

transects (LITs) revealed overall reduction in percent live coral cover. Recovery from the bleaching event however, improved by December 1998.

Climate change impacts are further anticipated. The 1998 El Nino event has been the most severe sending sea surface temperatures to a record 35°C. Average air temperature has risen by 1.5°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.

Coral reef fish status

Monitoring of reef fish was carried out almost yearly between 1987 and 1993 at 5 reef locations (Cyrene Reefs, Pulau Hantu, P. Hantu West, P. Semakau, Raffles Lighthouse, Lazarus Island). Total species diversity of 111 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.

Records are not available of coral reef fish harvested from reefs as reef fisheries is practically non-existent. Boat-operated commercial fishing is prohibited in territorial waters due to limited space and risk to navigational safety. Local fish catch comes mainly from the diminishing numbers of licensed commercial palisade trap operations and local production from marine aquaculture, and these are not reef-related.

Issues on reef management

The Singapore economy and population continue to expand. Coastal development in the past 40 years has increased Singapore's land area to 660 km², of which 324 km² 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 is reduced from 10m in the 1960s (Chua and Chou, 1992) to less than 2m presently. High sedimentation rates of 44.64 g cm⁻² day⁻¹ have been recorded (Low and Chou, 1994) and input of sediment into the marine environment continues from several large-scale, on-going reclamation and development programmes. These include the extension of Changi coast 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.

Legal and institutional arrangements

There is no national policy on coral reefs and neither is there a government agency with the distinct responsibility of managing reef resources. The Land Office (Ministry of Law) issues licenses/approvals for reef exploitation. Most of these have been given to groups from research institutions for controlled removal of corals and other reef resources. As far as is known, none has been given to commercial operators. The Police Coast Guard have been alerted to look out for illegal removal of reef resources, but their main agenda is to control smuggling, piracy, and generally to maintain law and order.

Indirectly, Singapore reefs have benefited from effective management of marine pollution. As one of the busiest ports and largest oil-refining centres in the world, there is a high risk of pollution to the marine environment. To maintain adequate 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 also participates in the following regional and international programmes on marine pollution management:

- 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 and 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 wastewater 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.

Reef management and monitoring 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, 1996). It is administered by the National Parks Board (Ministry of National Development), with the Police Coast Guard providing some enforcement. There is 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 addresses this shortcoming. Arising from the current review, a proposal to transform the Pulau Hantu reefs into a community marine park was submitted in early 2001 to the National Parks Board. The Singapore Underwater Federation spearheaded the effort with the support of many other non-governmental organisations.

Monitoring of Singapore reefs is carried out 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 monitoring and research initiatives, both local and regional, include:

- The ASEAN-Australia Marine Science Project: Living Coastal Resources (1986 to 1994, 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 the local business community)
- Monitoring of Singapore reef health status 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 Science and Technology Board)

MAJOR ACCOMPLISHMENTS IN THE CONTEXT OF ICRI AND AGENDA 21

The country's pollution control measures have been in place before the 1992 Rio Declaration on the Environment and serve to enhance its contribution to Agenda 21. Management of land- and ship-based marine pollution has prevented the rapid loss of the sea's environmental capacity. Monitoring of coral reefs within the context of ICRI has been maintained. Five reefs monitored by the LIT method under the ASEAN-Australia Living Coastal project between 1987 and 1994, continue to be monitored under research projects funded by the National University of Singapore. A centralised database on reef condition has been established based mainly on the LIT surveys of these 5 reefs, but supplemented by similar surveys of other reefs as well as research information from other reef studies. Temporal and spatial data on reef condition have been provided to Reef Base maintained by ICLARM (International Center for Living Aquatic Resources Management) and the regional Reefs at Risk Analysis (World Resources Institute and ICLARM).

An outreach extension has been initiated through the Singapore International Foundation's (SIF) new programme on marine and coastal conservation. Volunteer sport divers are trained on the LIT surveys and will carry out reef surveys in countries within the region where such capacity is required. The first volunteer group of 15 divers led by researchers from the National University of Singapore (Department of Biological Sciences and Tropical Marine Science Institute) proceeded to Koh Kong, Cambodia, in March 2001. This is in response to the provincial government's request to conduct resource inventory surveys to support policy formulation on ecotourism.

CHALLENGES AND OBSTACLES TO REEF MANAGEMENT

While protection of terrestrial habitats is well established and managed by specific agencies supported by the appropriate legislative framework, the same does not apply to marine living resources.

Without a national policy on marine resources, and a distinct reef management structure, protection of reefs remains largely unsolved. There is no integrated management strategy for coastal waters, although a functional zonation scheme on marine space utilisation is apparent. The lack of institutional mechanisms for coordinated protection of coral reefs and marine life makes it difficult to extend any meaningful management of reefs. Legislation on the protection of marine life is outdated and has little relevance to current issues facing reef protection (Lye, 1991). 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.

Effective management of land- and sea-based sources of marine pollution has kept water quality at levels suitable for recreational activities and fish farming. Increased public awareness of the importance of reef resources has forced attention to the plight of coral reefs. A variety of reef protection action and education programmes launched by non-governmental organisations, ranging from underwater clean-up to deployment of courtesy mooring buoys, has helped to relieve stress levels on reefs. However, the management of sedimentation is beyond the scope of non-governmental organisations. It is the largest problem contributing to reef decline and requires management intervention at government level. Such intervention is relevant to the country's commitment to international conventions such as Agenda 21 and the Convention on Biological Diversity, as well as to the nation's Green Plan.

Economic progress in Singapore has been achieved largely at the expense of the country's natural resources including coral reefs. A high degree of effort in promoting the conservation of Singapore reefs has come from non-governmental organisations. These activities have raised public consciousness. Government agencies responsible for development need to direct greater 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 and responses are often compartmentalised. A large degree of reef degradation could be avoided or minimised with better planning and coordinated response.

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 over coral reefs. A greater commitment from the government is essential for the country to meet its obligation to the Green Plan and to international legal instruments such as the Convention on Biological Diversity.

SUCCESS IN CORAL REEF MANAGEMENT

While there is no government agency with the distinct responsibility of managing Singapore's coral reefs, the efforts of non-governmental organisations particularly in the last 15 years, have been crucial in drawing attention to this deficiency. In addition, many non-government organisations are involved in reef conservation activities (Chou and Goh, 1998).

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 and 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, one of which 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 and 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 due to lack of effective anchorage of colonies at the new site (Chou and 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 clean-ups, 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. It recently submitted a proposal to turn Pulau Hantu into a community marine park. If accepted, that will become the country's first marine park.

FUTURE PLANS AND PROGRAMS

Monitoring of Singapore reefs with the LIT technique will continue as part of the country's involvement with GCRMN (Global Coral Reef Monitoring Network) and ICRI.. Further research on coral reefs will be conducted focusing on reef response to human and natural stress, and on reef rehabilitation. Through the Singapore International Foundation, reef survey and monitoring capacity will be expanded into the region subject to financial and personnel constraints. Reef conservation efforts will be intensified through vehicles such as the Aseanarean Expeditions Series (AES). The AES aims to promote the nautical identity of the region, and to bring greater attention to its rich marine biodiversity. Efforts to conserve these resources will be given greater exposure through books, films and other educational media. It completed a book "Marine Parks of Thailand" based on its expedition in 1997, and undertook an expedition to the marine parks of Indonesia in 1999 (Chou, 2000). The Indonesian expedition will result in the publication of a book and the production of 3 half-hour documentaries to be aired on National Geographic Channel Asia in the second half of 2001.

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

Island	Reef site / depth	Year					
		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	HW1-0	41.45	-	37.29	41.61	19.78	-
West Reef	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	H1-0	31.06	-	8.40	10.18	10.20	-
Hantu	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	S1-0	26.05	-	19.08	8.87	9.89	-
Semakau	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	R1-0	76.51	78.06	-	73.39	48.00	-
Lighthouse	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		Maximum/Minimum temperature	
		Day	Night	Day	Night
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

Table for SINGAPORE

A. Capacity Building Programs Pursued*

Top 5 Achievements	Agenda 21 Program Areas**							Challenges and Obstacles	Critical Success Factors	Priority Actions for 2002
	1	2	3	4	5	6	7			
1. MPA-TMSI Marine environmental monitoring programme (5 years from 2001)		♦		♦					Joint research activity between Maritime & Port Authority, and Tropical Marine Science Institute, National University of Singapore.	
2. Coastal and marine management focus, Singapore International Foundation							♦	Training volunteers to conduct reef surveys.	Large group of willing volunteers.	Expansion of programme within region.

B. Research and Monitoring Programs Conducted*

Top 5 Achievements	Agenda 21 Program Areas**							Challenges and Obstacles	Critical Success Factors	Priority Actions for 2002
	1	2	3	4	5	6	7			
1. Research (graduate program), Dept. Biol. Sci., Natl. Univ. Singapore.		♦		♦					Research infrastructure and funding support.	
2. Research program on reef biology, Trop. Mar. Sci. Instit., Natl. Univ. Singapore.		♦		♦				Transient nature of research personnel.	Research infrastructure and funding support.	

C. Regular Review Undertaken*

Top 5 Achievements	Agenda 21 Program Areas**							Challenges and Obstacles	Critical Success Factors	Priority Actions for 2002
	1	2	3	4	5	6	7			
1. Reef assessment		♦		♦					Trained researchers	