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SINGAPORE CORAL REEFS — BALANCING DEVELOPMENT AND CONSERVATION

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ABSTRACT

Singapore's rapid development has resulted not only in a successful economy, but also a drastic transformation of its coastal areas. Extensive reclamation has caused the disappearance of coastal ecosystems including coral reefs in Singapore. Although the protection of highly visible terrestrial ecosystems like forests and mangroves in Singapore has traditionally received more attention, the preservation of marine ecosystems, including coral reefs is gaining increasing prominence. Non-governmental organisations in Singapore have taken many initiatives to promote the conservation of marine natural resources. These activities include the training and mobilisation of recreational scuba divers to participate in conservation-related programmes, education and highly publicised general public awareness campaigns. While the public is generally receptive to conservation issues, the scientific community must ensure that the information provided by conservation groups is sound, and the activities that they promote properly managed. The activities of local conservation groups have prompted the government to pay more attention to marine ecosystems in the planning and management of developmental projects. However, the unique geography and economy of Singapore presents constraints that must be considered in resource conservation. The Singapore experience has shown that it is indeed possible to successfully promote realistic conservation of coral reefs within the confines of sustainable development.

INTRODUCTION

The Republic of Singapore consists of a main island and almost sixty small offshore

important resource, playing a large role in its economic growth and prosperity, supporting the world's busiest harbour and world's second largest oil refining centre.

In the early part of the development of Singapore, due to the immediate need for housing the population and aggressive economic growth, much of its natural coastal habitat was destroyed to make way for public housing and industries. It is estimated that only 1% of the original mangrove forests remain on mainland Singapore (Chou *et al.* 1980), while an estimated 60% of total reef areas have been lost through foreshore reclamation (Chou 1995a).

On the other hand, in recognition of the need to create a pleasant living environment, the Government has actively pursued the reduction and control of pollution in Singapore's waterways and coastal areas. This was successfully established through the strict enforcement of pollution control laws which ensure that all industrial wastewater is pretreated and that both treated industrial and domestic waste water is discharged into the public sewerage system. Due to the nature of Singapore's maritime industry, strict controls of pollution by oil and other contaminants in the sea are also enforced. The cleaning up of two main river systems, the Singapore and Kallang Rivers, costing a total of S\$200 million, is often cited as one of the Government's successful endeavours in transforming heavily polluted water bodies into environments that now support aquatic life and suitable recreational activities (Chou 1995b).

From pollution control, Singapore has gradually moved towards nature conservation and environmental management. Only the more prominent terrestrial ecosystems have however received substantial attention to date. Forest reserves began to be established earlier in the century to prevent the loss of tropical rain forests to crop plantations (Chou 1995a). Singapore's nature reserves comprising primary and secondary forests, presently occupy a total area of approximately 28 km².

Similarly, the protection of mangrove habitats has been implemented by the Government. Several mangrove forests located at different parts of mainland Singapore totalling 259 hectares (out of an existing 500 hectares) of mangroves in the country have been conserved to date, including the 80 ha Sungei Buloh Nature Park on the northwestern coast of Singapore. Sungei Buloh is well known by nature enthusiasts because of its diverse bird life and extensive mudflats frequented by wintering bird species (Chou 1995a). In addition to amenities for the general public to visit the conserved areas, some mangrove areas also have accompanying management strategies for habitat enhancement, for example the extension of mudflats and rehabilitation of mangrove species. More attention is increasingly being paid to marine habitat conservation in Singapore, particularly coral reefs.

This paper describes the changes that have taken place in the coastal habitats of Singapore since the 1960s, in particular the transformation of the various coral reef areas for development, and the constraints in this country that have necessitated these changes. The paper goes on to describe the various activities that the non-governmental organisations (NGOs) in Singapore have initiated to raise awareness of coral reef degradation and conservation issues, and the response of the Government to these efforts.

COASTAL CHANGES IN SINGAPORE

The coastal habitats in Singapore have undergone tremendous changes since the 1950s. Large-scale intensive land reclamation, in particular, has taken place along the entire southern coastline of Singapore from the 1960s, to fulfil the need for land for massive public housing and industries (Fig. 1) (Chia *et al.* 1988). This large-scale foreshore reclamation has added some 40km² of land. The entire reclaimed south-eastern coastline now contains Singapore's international airport and a high proportion of high-rise buildings for residential, commercial and recreational uses, while the southwestern coastline which used to contain fringing reefs has been developed for industrial, shipping and port facilities. This programme of reclamation is expected to continue until the year 2000, after which the country is estimated to be 25% larger than its size in 1967 (Loo and Chou 1995).

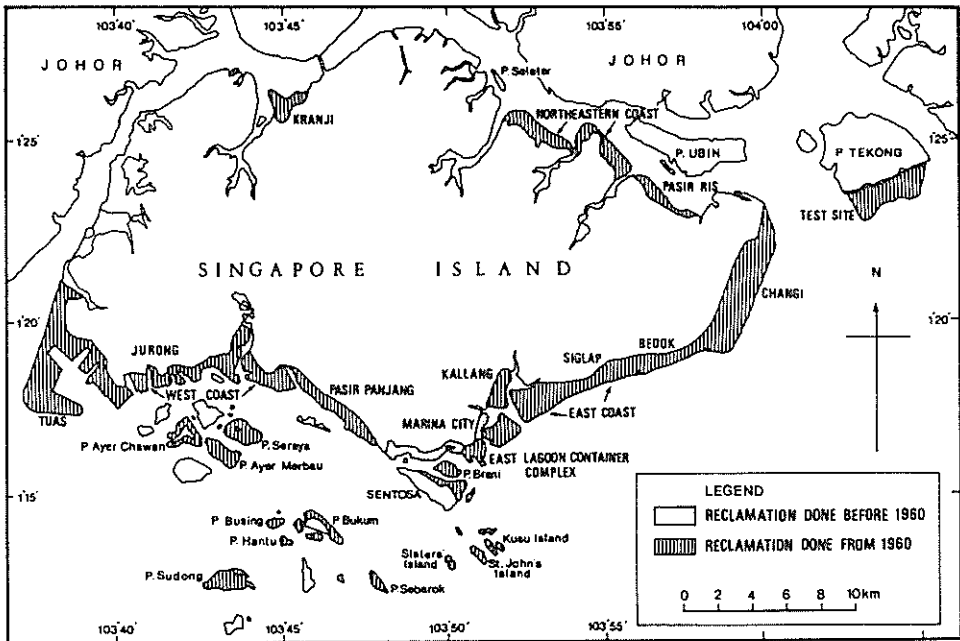


Fig. 1. Map of Singapore showing the extent of land reclamation (adapted from Chia *et al.* 1988).

With regard to coral reef habitats, Hilton and Manning (1995) have documented the loss of intertidal and subtidal coral reefs along the south coast and the southern islands of Singapore from 1953 to 1993, and projected further changes until the year 2030. The authors described the transformation that the southern islands and their

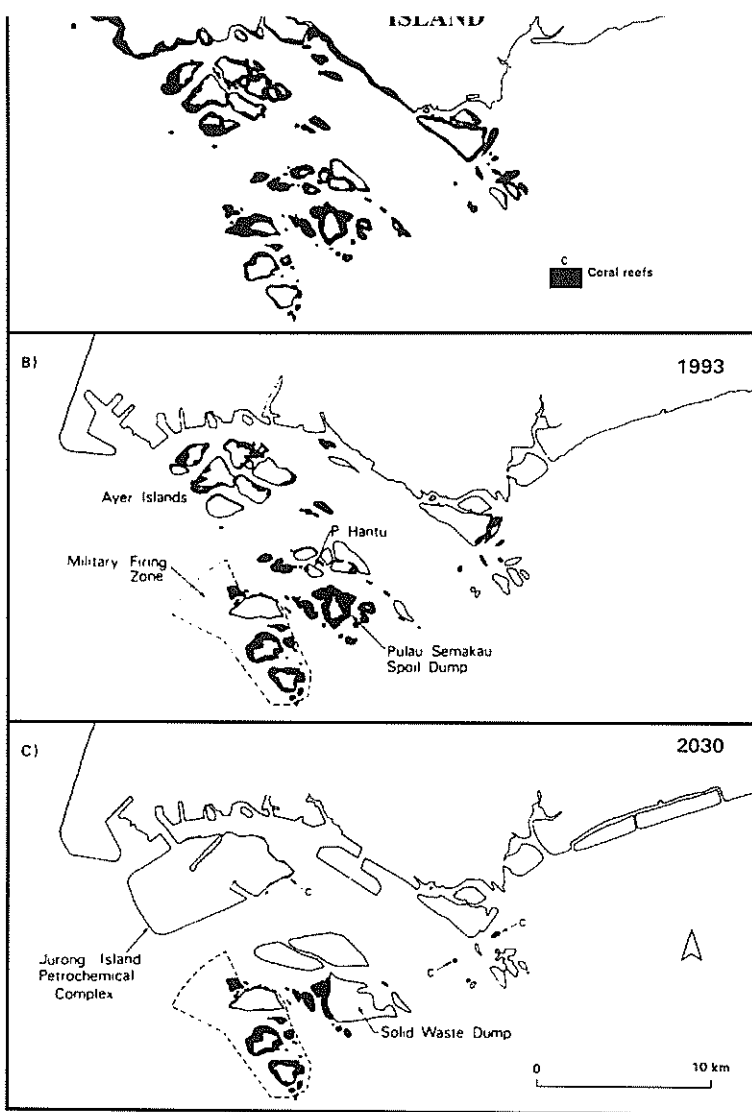


Fig. 2. Transformation of Singapore's southern islands and reefs from A, 1953 to B, 1993, and projected changes until C, 2030 (adapted from Hilton and Manning 1995).

waters caused by dredging of shipping lanes and the dumping of earth spoils (Chia *et al.* 1990; Chua and Chou 1991; Hilton and Manning 1995). Apart from land reclamation that directly buries and smothers coral reefs, the dumping of earth spoils at sea has been highlighted as one of the major detrimental activities. From the end of 1988 to 1993, approximately 1.5 million m³ of irrecyclable clay spoils from construction activities on

mainland Singapore was disposed of at sea. The spoils were dumped using excavators on barges, at a specific designated location in the southern waters of Singapore. The location is in the vicinity of Pulau Semakau, on which a rock wall/retaining bund has been constructed in preparation for a garbage landfill to meet the solid waste disposal needs of Singapore for the next 50 years (Loo and Chou 1995). The ineffective use of protective measures to minimise the spread of sediment and tidal currents have, however caused the fine sediments to be dispersed over a large area. In some areas within the vicinity of the dumping site (including coral reefs), clay deposition has been estimated to be between 1–3 m thick (Chia *et al.* 1990).

Foreshore reclamation over the last three decades, the dumping of earth spoils and other related activities have resulted in a significant increase in the sediment load of Singapore's waters. Sedimentation rate has been estimated to increase from 3.2 – 5.9 $\text{mg}\cdot\text{cm}^{-2}\cdot\text{d}^{-1}$ in 1979 (Chan 1980), to present day rates of between 15 – 30 $\text{mg}\cdot\text{cm}^{-2}\cdot\text{d}^{-1}$ (Lane 1991; Low and Chou 1994), causing a reduction in water visibility from an approximate 10 m in the early 1960s to approximately 2 m today (Chou 1996). This has resulted in a decrease in live coral cover at the crest and slope of reef flats which have been reclaimed in comparison to reefs around which no development has taken place (Chou 1996)

Detailed coral reef community studies in Singapore have been carried out since the early 1980s, by many researchers at the National University of Singapore (Teo 1982; Chou and Teo 1985; Chong 1986; Chou 1986; Chou and Koh 1986; Chou and Lim 1988; Lim *et al.* 1990; Chua and Chou 1991; Goh and Chou 1991). In particular, surveys carried out over a ten year period from 1985 to 1994 as part of an ASEAN-Australia Living Coastal Resources Project have resulted in the accumulation of a comprehensive database on Singapore coral reef characteristics (Chou 1989; 1992; 1995c). The Singapore reef surveys have revealed a total occurrence of 197 species of hard corals from 55 genera, with live coral cover observations in the first survey of up to 76% at the reef crests and 3m depths. Subsequent second and third surveys reported live coral covers of 72% and 69%, respectively, at the reef crests and 3m depths (Loo and Chou 1995).

In addition, a broad-scale survey of sixty-five sites on forty-one coral reefs carried out under a Reef Survey and Conservation Project (RSCP) from 1987 to 1991 revealed that at the zone of the reef crests, four sites had live coral cover of over 70%, twenty-one sites exhibited cover of between 50 and 70%, twenty-two sites had live coral cover of between 30 and 50% and eighteen sites were shown to support less than 30% of live corals (Fig. 3) (Chou 1996). This and other surveys conducted in the 1980s and early 1990s reported a direct correlation between decreasing live coral cover and increasing depth from reef crests. These observations were attributed directly to the high sedimentation load in the waters of Singapore that decreases light penetration at the lower slopes, effectively narrowing the depth at which scleractinian corals can survive (Loo and Chou 1995).

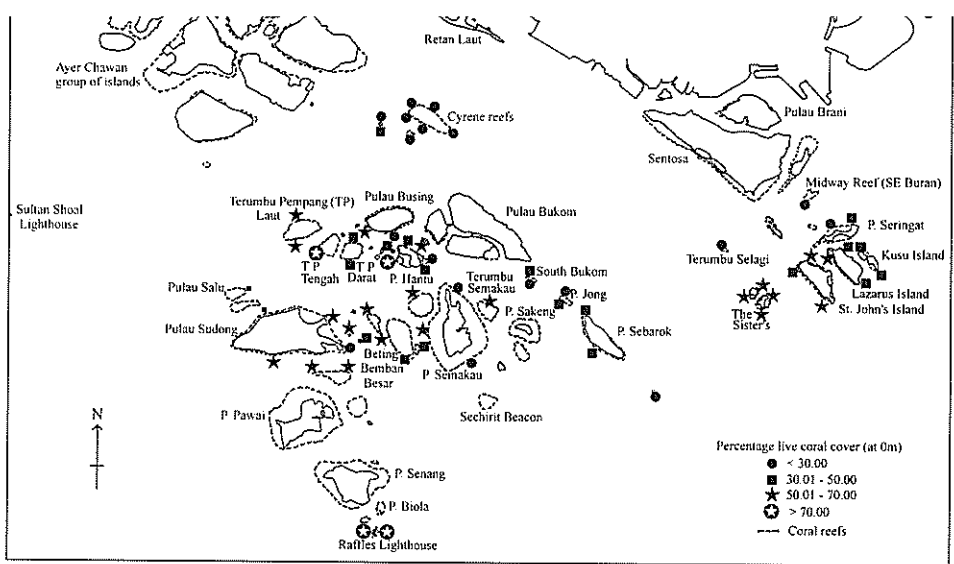


Fig. 3. Map of Singapore's southern islands showing live coral cover at the reef crests (0m) (from Loo and Chou 1995).

viewed as necessary. This is because of the constraints that such a rapid rate of economic progress imposes on a small country.

In the 1960s, the Government concentrated its efforts on rapid commercialism and industrialisation to achieve high economic growth rates (Chen 1981). This necessitated a vigorous construction industry resulting in ecological losses, as forest areas were transformed and coastal areas expanded through reclamation. Although it is believed that the development strategies adopted by the Government in those early years could have been adjusted to significantly reduce negative impacts on natural resources, e.g., if proper environmental impact assessment, or EIA legislation had been implemented, (Hilton and Manning 1995), the immediate need then for rapid economic progress should not be overlooked. Understandably, environmental concerns were limited to the immediate need for a clean environment suitable for economic and social development.

The constraints of a small land area in Singapore has not only affected the choice of an economic development strategy, but also the strategy that the Government pursued to solve the immediate need of housing its population. Foreshore reclamation undertaken since the 1960s has resulted not only in the development of port facilities, but also the construction of high-rise public housing. Today, Singapore has an estimated population density of 4,600 persons.km² of which at least 80% live in these high-rise apartments.

It is evident that if Singapore is to continue developing economically, issues relating to the sustainable utilisation of our natural resources will become increasingly important. Singapore has now ratified the Convention on Biological Diversity, one of the treaties arising from the United Nations Convention on Environment and Development

(UNCED) held in 1992. This indicates the Government's commitment to the Earth Summit, including guidelines on sustainable development laid out in Agenda 21, one of the approved documents from UNCED.

INITIATIVES OF NON-GOVERNMENTAL ORGANISATIONS IN SINGAPORE

Increasingly, Singapore citizens have been made more aware of the threats that coastal resources have been subjected to over the last three decades. This heightened awareness has come about as a result of a good number of initiatives by local non-governmental organisations in Singapore. Activities relevant to the conservation of coral reefs include:

- The Reef Survey and Conservation Project
- The Reef Rescue Project
- Installation of mooring buoys for pleasure craft
- Marine clean-up volunteer programmes
- Various educational programmes, e.g., 'The Coral Reef Naturalist Course' and 'The Reef Insights Programme'

The Reef Survey and Conservation Project

This was a project undertaken by three NGOs, the Republic of Singapore Yacht Club (RSYC), the Singapore Institute of Biology (SIBiol) and Singapore Underwater Federation (SUF), from 1987 to 1991 (Chou 1990). It was prompted by a shared concern for the deterioration of corals in Singapore resulting from developmental projects and the effort was aimed at fostering a better recognition and appreciation of coral reefs by the general public and Government of Singapore. Funds for the project were initially provided by the RSYC, as well as various sponsors and commercial organisations. In all, the expenses for the entire project amounted to approximately US\$12,000.

The project essentially involved the training of some 150 volunteer recreational divers on basic scientific techniques to conduct coral reef surveys, using the 100m line intersect transect method. Scientific training for the volunteers was provided by researchers from SIBiol, while SUF organised the field training. The trained volunteers were then deployed in teams and given instructions to survey specific reefs over sixty-five sites on forty-one coral reefs in Singapore. Results of the surveys by the teams of divers, collected over two years from 1987 to 1989 were entered into a database and analysed by marine biologists from SIBiol.

From the analysed results of the surveys conducted by the volunteers, the targeted coral reefs were classified based on the percentage of live hard coral cover recorded. This parameter of percent live coral cover was used as an indication of the condition of the surveyed reefs. The sixty-five sites were classified into four categories; namely, poor (< 30% live coral cover), fair (31–50% live coral cover), good (51–70% live coral cover)

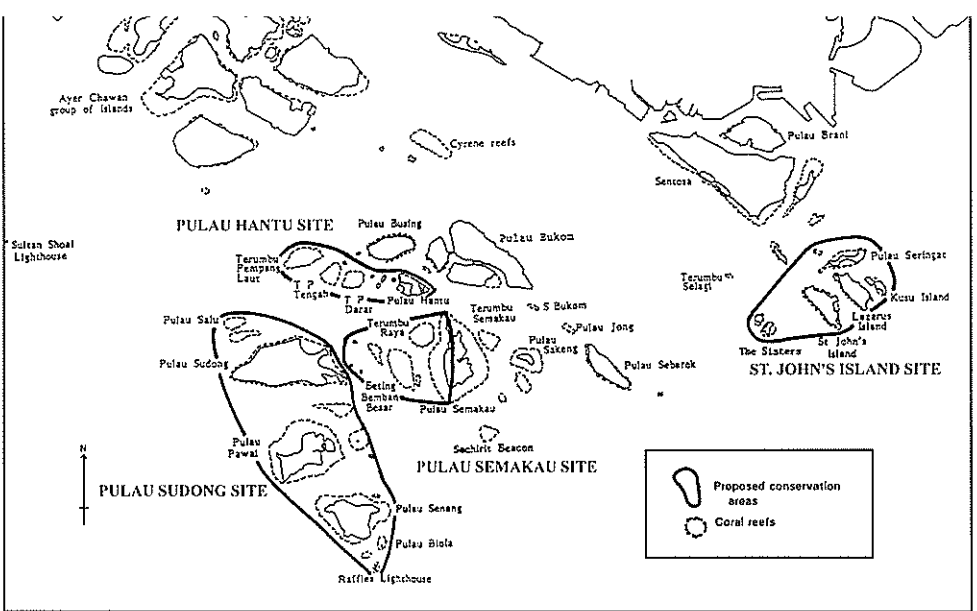


Fig. 4. Map of Singapore's southern islands showing the four marine areas identified for conservation (from Loo and Chou 1995).

In the comprehensive proposal, containing scientifically sound recommendations, it was also emphasised that if the healthier reefs could be protected effectively, Singapore could serve as an example of a country that placed a high value on reef conservation in spite of having intensively used waters (Chou and Lee 1994). The proposal was well received by the Singapore Government, who commissioned a detailed feasibility study through the National Parks Board in 1992, on the protection and management of coral reefs in Singapore, as recommended in the proposal.

The Reef Rescue Project

This project consisted of two initiatives by the Marine Conservation Group (MCG) of the Nature Society of Singapore (NSS), to relocate corals and some reef organisms from reefs earmarked for reclamation and development (Newman and Chua 1994). The initiatives were aimed at the preservation of corals and reef organisms by relocation and the assessment of the viability of the large-scale translocation of corals, as well as the enhancement of public awareness on reef conservation issues.

The first initiative took place over twenty-five days in 1991 and involved the translocation of randomly selected corals and reef organisms covering an area of approximately 200 m² of a reef fringing an island that was scheduled to be reclaimed, to a site about 1.5 km away. An estimated 140 volunteers from twenty scuba diving clubs, as well as divers from the Republic of Singapore Navy, took part in the relocation project that cost approximately US\$7,100 (The Straits Times 1992a). Surveys conducted

by the MCG (NSS) reported initial overall survival rates of 90%, 80%, and 69% six months after the exercise. These success rates were given good publicity by the local press (The Straits Times 1992a, b).

Spurred on by the first initiative, the MCG (NSS) embarked on a second, more ambitious, translocation exercise which took place between mid-1993 and early 1995. Corals and reef organisms were removed from the fringing reef of a group of islands scheduled to be reclaimed and combined to house oil refineries and other industries. Reef organisms were relocated to a site close to the translocation site of the first reef rescue initiative (Newman and Chua 1994). This larger-scale effort was estimated to involve some 450 volunteers from six diving clubs utilising a total of 10,000 hours of underwater time. This second phase involved the selective removal of larger pieces of corals and reef organisms covering an area of over 500m². The project costs of US\$36,400 and US\$8,500 were borne by HongKong Bank's 'Care for Nature' Trust Fund and Exxon Chemicals (Singapore), respectively (The Straits Times 1993a; 1996b).

The survival of corals translocated in the second reef rescue initiative was monitored subsequently by marine biologists from the National University of Singapore (NUS). One year after the translocation exercise, however, preliminary survey results revealed that the translocated corals were not surviving as well as previously reported, with <35% survival rate in some areas. The marine biologists also noted that the translocation exercise could have yielded much better results if sound methodologies were used and a more stringently controlled, smaller-scale, exercise embarked upon (L.M. Chou pers. comm.).

Mooring buoys

This project, initiated by the National Council on the Environmental (NCE; presently called the Singapore Environmental Council, SEC), involved the installation of mooring buoys on Pulau Hantu, an island south of Singapore with a fringing reef frequented by recreational divers and boaters (The Straits Times 1994). The purpose was to discourage the use of anchors and reduce damage to the reef. This exercise also involved volunteer scuba divers to help deploy and maintain the buoys. Costs for the project amounted to US\$25,000, and was sponsored by Shell Eastern Petroleum (Pte.) Ltd. The Council also announced that it was preparing to set up similar buoys around other islands used for recreation.

Marine Clean-up Volunteer Programmes

The SUF, in collaboration with other organisations, has spearheaded regular programmes to mobilise volunteer divers and snorkellers to clean up rubbish from the sea bed. These activities are often conducted at coral reef locations on the southern islands of Singapore frequented by recreational divers and timed to coincide either with the annual 'Clean and Green Week' activities organised by the Ministry of Environment or the annual 'Earth

also initiated several programmes to educate school children and the general public on issues related to coral reef conservation. The following are two examples:

In early 1992, the SIBiol and the SUF launched a 'Coral Reef Naturalist (CRN)' course aimed at giving recreational divers the opportunity to obtain basic training in reef biology and ecology. Training courses were conducted by marine biologists from the SIBiol and consisted of classroom sessions as well as openwater dives. This highly popular course, which is still ongoing, aims to educate the sport diver not only to recognise reef organisms and the various ecological groups they belong to, but also the biological interactions in the marine environment and issues related to the protection and conservation of marine habitats in simple terms.

The 'Reef Insights' programme was initiated by the SEC and the Singapore Science Centre with the assistance of the Zoology Department of the National University of Singapore in 1995. This ongoing programme consists of half-day activities aimed at teaching school children at the primary and secondary levels the importance of the marine environment. The activities consist of workshops, video and games sessions to illustrate the interactions in coral reef ecosystems and the present day threats that reefs around the world are subjected to. This coral reef education programme, that is expected to educate some 5,000 school children over the period of one year, has been so popular that the organisers intend to continue the activities as long as sponsorship is available (The Sunday Times 1995).

Besides NGO-initiated environmental education programmes, the Education Ministry of Singapore has also been active in organising public awareness programmes, particularly involving seminars and workshops in schools and often in conjunction with annual Earth Day activities (The Straits Times 1992c).

More recently, NGOs in Singapore have begun to collaborate closely in co-ordinating their efforts and resources to present stronger recommendations to the Government on marine conservation (Loo and Chou 1995). This collaboration will ensure the continued representation of the general public in promoting the protection and conservation of coastal ecosystems in Singapore.

SINGAPORE'S GOVERNMENT EFFORTS

Parallel to the activities initiated by NGOs with regard to nature conservation, the Singapore Government has also indicated its commitment to progressing in the direction of resource conservation with development. In 1991, the Government released a national concept plan 'Living the Next Lap' (Urban Redevelopment Authority 1991), aimed at developing Singapore into a tropical city of excellence. A subsequent Green Plan published by the Ministry of Environment (Ministry of Environment 1992), detailed the Government's long term plan for developing Singapore into a model green city, and the policy directions on environmental management (including nature conservation), education, participation in international environmental programmes and technology development.

Workgroups were established by an Inter-ministerial Steering Committee to

recommend practical action plans to implement the policy directions contained in the Green Plan. One of the workgroups (with representatives from various government agencies and the NSS) focused on nature conservation and identified eighteen nature areas for conservation, encompassing habitats ranging from primary and secondary rain forests to mangroves and marshlands. In addition, four marine areas were also identified, coinciding with the four recommended coral reef conservation areas proposed by the Reef Survey and Conservation Project (The Straits Times 1993b). The four marine areas encompassing islands, territorial waters and coral reefs covered a total of 37 km² within which coral reefs occupied 7 km² (Loo and Chou 1995).

Following consultation with various agencies and the public, an action programme of the Green Plan was published (Ministry of Environment 1993). In the action programme, the Government reiterated its commitment to the protection and conservation of some natural habitats by laying out policy directions on nature conservation. The action programme specifically called for the protection of coral reefs against commercial harvesting within the four identified conservation areas and tighter enforcement of laws for the protection of corals by the Coast Guard (Chou 1995a). To further manage the conserved reef areas, water quality and future land reclamation projects will be closely monitored to minimise pollution and excessive siltation in the sea. In addition, the action programme also advocated widespread education and public awareness activities to promote nature appreciation.

This commitment by the Government to the protection of coral reef areas in Singapore was further strengthened this year when the Urban Redevelopment Authority (URA) announced that five southern islands (which occupy one of the four proposed marine conservation areas) have been designated as a Marine Nature Area (The Straits Times 1996c). This effectively means that all development proposals for the islands will be assessed and subjected to detailed controls by the National Parks Board, the body which manages all national parks and nature reserves.

Despite the progress that has already been made in Singapore in the direction of sustainable use of natural resources, there is still more scope to promote the protection and conservation of these resources. For example, although coastal management in Singapore has for a long time been based on development with little attention given to sustainable use of the coastal and marine ecosystems (Chou 1995b), some measures are only now being implemented to include the protection of marine living resources in coastal management strategies. An integrated approach, involving multisectorial participation in coastal management, has yet to be adopted and the management of Singapore's coastal resources remains compartmentalised within several Government agencies. This is of particular importance to the newly designated Marine Nature Area in Singapore's southern waters where no administrative structure presently exists to support its management (The Straits Times 1996c). It has been highlighted by various coastal resource management experts that if Singapore is to maximise its restricted natural resources, an integrated management approach to coastal management is imperative (Chou 1995b).

the conservation and protection of what little remains of our natural resources in the country. Singapore is a signatory to the UN Convention on Biological diversity, reflecting its commitment to finding the balance between conservation of natural resources and economic development.

Much of the initiative in promoting the conservation of marine resources, in particular coral reefs in Singapore, has been undertaken by the NGOs. Despite the fact that these efforts have raised not only public awareness on issues related to coral reef protection in Singapore but also prompted the various government ministries responsible for development to pay more attention to the conservation of our natural resources, much more can still be done in this direction. The coastal areas of Singapore are still undergoing much change and development activities are intensifying as Singapore moves into the next century. Clearly, the responsibility for ensuring a balance between conserving natural resources and the economic progress of Singapore should be a concerted effort by a well-informed public, scientists, NGOs and decision makers.

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