

## ENVIRONMENTAL PROTECTION AND BIODIVERSITY CONSERVATION IN SINGAPORE

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### ABSTRACT

Singapore's rapid development particularly over the last three decades has not only resulted in a successful economy, but also contributed to a decline in natural habitats and biological diversity. From a traditional perception of environmental protection as merely the control and management of pollution, there is currently increasing emphasis on habitat conservation, as seen in the Singapore Green Plan. The protection of highly visible terrestrial ecosystems like forests and mangroves has received substantially more attention compared with the preservation of marine habitats. However, marine habitats are beginning to be noticed and the protection and conservation of coral reef areas have recently been initiated by the Singapore Government. Although the pursuit of economic excellence is still of high priority, particularly since Singapore is land-scarce, there is clearly much scope for the incorporation of habitat protection and the conservation of biological diversity into development plans and strategies, and of maximising sustainable utilisation of the remaining natural resources.

### INTRODUCTION

The Republic of Singapore consists of a main island and some sixty small offshore islets, covering an area of approximately 647 km<sup>2</sup>, and its surrounding territorial waters cover an almost equal area of 630 km<sup>2</sup>. With a population of approximately three million people, the population density in 1995 was 4,600 persons / km<sup>2</sup> (Ministry of Information and the Arts, 1996).

Since the 1960's Singapore has been aggressively developing its industrial capacity, and presently continues to target the development of high value-added industries, as well as its housing, commercial and service sectors (Hesp, 1995). Singapore's marine environment has been and continues to be an important resource, playing a large role in the economic growth and prosperity of the country. The marine environment has undergone tremendous change, and now supports the world's busiest harbour and world's second largest oil refining centre (Chou & Goh, in press).

Development along the coastline of Singapore has largely been in the form of land reclamation that has taken place since the 1950s. Foreshore reclamation to fulfil the need for land for massive

public housing and industries (Chia *et al.*, 1988) has added some 40 km<sup>2</sup> of land to the country. This includes areas in the southeastern coastline which now contains Singapore's international airport and a high proportion of high-rise buildings for residential, commercial and recreational uses, and the southwestern coastline which houses industrial, shipping and port facilities (Chou & Goh, in press). This extensive programme of reclamation is expected to continue until the turn of the century, and is estimated to result in a 25% increase in land area since 1967 (Loo & Chou, 1995).

Singapore is presently highly urbanised and developed, with a built-up area of almost half its total land area. With a steadily growing economy, Singapore's per capita gross national product (GNP) in 1988 was S\$16000, and contains a relatively affluent population comparable to many developed countries. The country's limited natural resources have been taxed heavily due to the increasing population, changing lifestyles and expanding economy, resulting in a chronic shortage of land. This has prompted the Government to optimise the use of these resources (Tun & Chou, 1995).

The Singapore Government's position on the protection of the environment has traditionally been the reduction and control of pollution on land, waterways and coastal areas. This has been successfully achieved through strict enforcement of pollution control laws by the Ministry of the Environment and various other departments, e.g. the Maritime and Port Authority of Singapore. These laws (e.g. the Water Pollution Control and Drainage Act) ensure that all industrial wastewater is pretreated to prescribed standards, and that both treated industrial and domestic wastewater is discharged into the public sewerage system. The Prevention of Pollution of the Sea Act ensures the enforcement of strict controls of pollution by oil and other contaminants in the sea (Chou & Goh, in press). One of the often cited successes of the Government's efforts in pollution control is the cleaning up and transformation of two heavily polluted main river systems (Singapore and Kallang Rivers) to environments that now support aquatic life and are suitable for recreational activities (Chou, 1995a).

From pollution control, the Government position has gradually developed to include nature conservation and environmental management. Although the more prominent terrestrial ecosystems (e.g. primary and secondary rainforests and mangrove habitats) have traditionally received substantially more attention, conservation issues pertaining to coral reefs and other marine ecosystems are beginning to be noticed, largely due to the efforts of various non-governmental organisations (NGOs). In addition, the Government also actively advocates widespread education and public awareness activities to promote nature appreciation (Chou and Goh, in press).

This paper describes the status of the natural habitats of Singapore, and the constraints of conserving biological diversity in a rapidly expanding economy. The paper also details the priorities and strategies undertaken by the Government and NGOs in Singapore to enhance the protection and conservation of natural resources and the environment.

# NATURAL HABITATS IN SINGAPORE AND STATUS OF CONSERVATION

## *Forested areas*

Prehistoric Singapore was typically covered with lowland tropical forests and freshwater swamp forests in the interior, and mangrove forests along the coast (Turner, 1994). The prehistoric vegetation of Singapore has been estimated to comprise 13% mangrove, 5% freshwater swamp forest and 82% lowland rain forest. These were cleared in massive fellings in the mid-1800s, and the primary rainforests have now been reduced to some 200 ha (Corlett, 1991).

The primary rainforest vegetation in Singapore is typically lowland dipterocarp forest dominated by the plant family Dipterocarpaceae, similar to that occurring in the rainforests of Southeast Asia (Thailand, Peninsula Malaysia, Sumatra, Borneo and the Philippines; Turner, 1994). These forests are typified by tall evergreen trees, acidic and nutrient-poor soils and large woody climbers (lianas) comprising the climbing palms and rattans, of which 30 species have been documented in Singapore. The trees also support many species of epiphytes, ranging from figs and vascular plants (ferns and orchids) to microscopic algae, lichens and bryophytes. The lowland rainforests also provide shelter in which many animals live, particularly insects, reptiles and some mammals (Turner, 1994).

The main core of primary lowland rainforest in Singapore can be found at the Bukit Timah Nature Reserve, and fragments located at the Central Catchment Area (mainly MacRitchie Reservoir). Much of the remaining primary rainforests in Singapore have been disturbed, and more commonly encountered are secondary forests, occurring around the Central Reservoirs, Western Catchment, Pulau (P.) Ubin, P. Tekong and several parks (Fig. 1; Turner *et al.*, 1994).

Forest reserves in Singapore began to be established earlier in the century to prevent the loss of tropical forests to crop plantations (Chou, 1995b). Currently, Singapore's nature reserves comprising primary and secondary forests occupy a total area of approximately 28 km<sup>2</sup> or 2800ha (Chou & Goh, in press). Perhaps one of the more prominently conserved forests in Singapore is the Bukit Timah forest, which has been protected in some form or other since the 1840s (Corlett, 1988). The Bukit Timah Nature Reserve covers an area of approximately 72 ha, of which 50ha is primary rainforest (Turner, 1994).

## *Mangrove and wetland areas*

When Singapore was founded in 1819, mangrove forests covered 10-13% of its coastline (Corlett, 1986; Rao, 1987). Economic development, particularly over the last four decades, has caused the disappearance of mangrove forests, to make way for port development, industries, housing and other projects (Chia *et al.*, 1988). Currently, less than 1% (or 500 ha) of mangroves including adjacent coastal wetlands (e.g. mudflats) remain in Singapore, occurring in very much fragmented small pockets along the northern coast, at Sungei (S.) Buloh, Mandai, Kranji and Lim Chu Kang (Fig. 1). In addition, a few small stands of mangroves still remain on the offshore islands P. Ubin and P. Tekong in the north, and P. Semakau and P. Pawai in the south (Low & Chou, 1995).

Similar to the lowland forests, the Singapore Government has implemented mangrove habitat protection and conservation. Several mangrove forests located at different parts of mainland Singapore totalling 259 ha have been conserved to date, including the 80 ha Sungei (S.) Buloh Nature Park on the northwestern coast of Singapore (Chou & Goh, in press; Table 1). Originally the site of traditional prawn, pig and duck farming, the S. Buloh area was gazetted a Nature Park and bird sanctuary in 1993. Some habitat enhancement measures were taken which included the draining of aquaculture ponds to serve as feeding grounds for some 163 species of mostly migratory birds, the protection of associated mudflats and rehabilitation of mangrove trees (Chou & Lee, 1994; Low & Chou, 1995). In addition to research aimed at assisting in the formulation of appropriate management strategies for the Nature Park, public appreciation of the mangrove forest has been facilitated by the construction of a raised walkway and Visitor Centre (Low & Chou, 1995).

Another example of a mangrove forest protected as a nature area is the Pasir Ris mangrove area located in the northeastern coast of Singapore. The area was previously reclaimed in the 1970s, resulting in a termination of water circulation to a 5 ha patch of mangroves containing 26 mangrove and associated plant species. The National Parks Board conferred with ecologists and engineers on the measures to take to preserve the patch of mangroves. Subsequently, an underground channel was built next to S. Tampines (an estuary supporting the mangrove area) to channel freshwater (mainly rainwater runoff) from the river, together with the formation of a rivulet to allow periodic inundation of the mangrove plot by seawater. As early as three months after the diversions, it was observed that mangrove regeneration had taken place along S. Tampines, and after 16 years, mangrove vegetation along the banks of the river had thickened and extended further upstream (The Straits Times, 1992; Low & Chou 1995). Reforestation of mangrove trees (*Avicennia*) carried out along S. Api-api, a river adjacent to S. Tampines was also successful (The Straits Times 1993), and replanted propagules grew to heights of 1.2 to 2.4 m after 14 months.

Table 1. Conserved mangrove habitats in Singapore (adapted from Chou & Lee, 1994).

Location	Area (ha)
Sungei Buloh Nature Park	87
Mandai Mangroves (Kranji)	60
Sungei Khatib Bongsu (Sembawang)	57
Loyang	30
Pasir Ris	10
Pulau Semakau	15
TOTAL	259

### *Coral Reefs*

In 1922, the southern islands of Singapore contained some 73 patch-reefs and 35 fringing reefs, and a fringing reef extending along the southern coast of mainland Singapore, covering a total area of 32.2km<sup>2</sup>. The construction of oil refinery and storage facilities, and port development in

1953 resulted in a reduction of the total reef flat area in Singapore to 30.5km<sup>2</sup> (Hilton & Manning, 1995). From 1953 to 1993, there was an extensive loss of intertidal and subtidal coral reefs along the south coast and southern islands in Singapore, as documented by Hilton & Manning (1995; Fig. 2). The transformation of the southern islands of Singapore, mainly in the form of reclamation to accommodate petrochemical industries, port facilities, military purposes and landscaped recreational facilities over the last three decades has led to the smothering of intertidal reef flats and the general decrease in reef flat area.

Presently, no fringing reefs exist on mainland Singapore, and only clusters of reefs among the southern islands are relatively unimpacted, making up 30% of the total area of reef flat that were present in 1922 (Fig. 3). Hilton and Manning (1995) have reported that the largest remaining areas of fringing coral reefs include those found at P. Semakau (159.37 ha), and a group of islands used for military training: P. Pawai (134.37) and P. Senang (84.37 ha), while remaining large patch reefs include Being Bemban Besar (56.25 ha), Terumbu (T.) Pempang Laut (37.5 ha), T. Pempang Tengah (23.44 ha) and T. Pempang Darat (23.42 ha).

A project 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, undertook to conduct an extensive survey of coral reefs in Singapore, and classified the condition of reefs (based on live coral cover observed) into four categories ranging from poor to excellent (Chou, 1990). The project highlighted four general areas of reefs in Singapore that had high coral cover, and presented a recommendation to the Singapore Government for these four areas to be conserved (Fig. 4). The proposal resulted in these four recommended coral reef conservation areas being included as marine areas (encompassing islands, territorial waters and coral reefs covering a total area of 37 km<sup>2</sup>) identified for nature conservation in the Government's Green Plan (Ministry of Environment, 1992, 1993). Within the four marine areas, coral reefs occupied a total of 7 km<sup>2</sup> (or 700ha). Subsequently, the Urban Redevelopment Authority (URA) of Singapore announced in 1996 that five southern islands (occupying one of the four proposed marine conservation areas, St. John's Island Site) have been designated as a Marine Nature Area (The Straits Times, 1996a). This Marine Nature Area is presently the only area of coral reefs in Singapore that enjoys some protection by the National Parks Board, the body which manages all national parks and nature reserves, in the form of controls over impacts of development activities.

## **CURRENT THREATS TO BIODIVERSITY**

### *Economic Development*

The major threats that affect the biodiversity of natural habitats in Singapore today are related to economic development. Whereas agriculture and aquaculture activities like prawn and poultry farming were previously responsible for pollution and degradation of inland wetlands and coastal habitats, they have declined significantly, largely due to the phasing out of these industries. From the period 1965 - 1985 alone, there was an approximate 300% decrease in agricultural farming areas in Singapore (Tun & Chou, 1995).

The constraints of a small land area in Singapore has not only affected the direction of economic development strategy, but also the strategy that the Singapore Government has pursued to solve the immediate need of housing its population (Chou & Goh, in press).

### *Pollution*

Singapore currently enforces strict anti-pollution legislation, especially targeted at industries. While past polluting activities like agriculture, shipping and heavy industries, unlicensed hawkers and a poor sewerage system resulted in stagnant and highly polluted watercourses, and deteriorating coastal ecosystems, changes instituted by the Government over the last 2 decades have drastically reduced or eliminated them. In addition to infrastructural development (e.g. tertiary sewage treatment facilities), the Government has also implemented numerous legislations and regulations, and developed comprehensive pollution control and management strategies to ensure that citizens enjoy a high standard of environmental quality in spite of economic and industrial growth.

### *Fragmentation of Habitats*

Besides the direct clearing of forests for development, the loss of native biodiversity of plants and animals in Singapore has been attributed to forest fragmentation (Turner, 1994). For example, the Bukit Timah Nature Reserve contains only a 50ha core of primary rainforest. It has been reported that this reduced area of forest is not large enough to support viable populations of many plant and animal species, as foraging areas are reduced and nesting sites lost (Turner, 1994). Corlett (1992) reported a loss of at least 87 species of forest birds (trogons, hornbills and broadbills) through extinction. Forest fragmentation is also seen in the severing of links between the Bukit Timah Nature Reserve and Central Catchment Area which also contains primary rainforest vegetation, by the development of the Bukit Timah Expressway (Turner, 1994).

### *Sedimentation*

Presently, the development of industries and housing, particularly in the coastal areas and offshore islands of Singapore remains the direct threat to the destruction and degradation of natural ecosystems, especially coastal ecosystems like mangrove forests and mudflats, coral reefs and seagrass beds. Perhaps the most significant activity that has had impacts on coastal ecosystems (particularly coral reefs) is sedimentation caused by land reclamation. Foreshore reclamation over the last three decades, the dumping of earth spoils and other related activities have resulted in a significant increase in sedimentation in Singapore's waters. Sedimentation rate has been estimated to increase from 3.2 - 5.9 mg.cm<sup>-2</sup>.d<sup>-1</sup> in 1979 (Chan, 1980), to present day rates of between 15 - 30 mg.cm<sup>-2</sup>.d<sup>-1</sup> (Lane, 1991; Low and Chou, 1994). This has caused a drastic reduction in water visibility from an approximate 10m in the early 1960s to approximately 2m today (Chou, 1996). The loss of live coral cover in fringing and patch reefs of Singapore's southern coastline and southern islands may be directly attributed to reclamation, and the effects caused by increased sediment load in the water (e.g. decreased light intensity), particularly since corals require sunlight for growth and calcification.

## **TOP PRIORITIES FOR CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY**

The conservation of terrestrial habitats in Singapore has traditionally received substantially more attention compared with marine habitats, presumably because of their visible prominence. Forest reserves in Singapore already began to be established early in the century, while mangrove habitats gained prominence in the early 1990's. Presently, although a marine area which contains coral reefs has been designated a Marine Nature Area, how much protection the coral reefs within this area will receive remains to be seen, due to the paucity of clear cut laws regulating the sustainable use of this habitat.

Soft-bottom benthic communities are presently the least appreciated and least understood amongst the biological habitats in Singapore (Chou, 1995b). Although on-going research on the soft-bottom benthic communities of the major rivers in Singapore continue to reveal the ecological and scientific importance of these habitats, they still remain unprotected.

With regard to the conservation of biological diversity in a land-scarce country like Singapore where economic progress is a top priority, it is understandable that any problems of conflicting use of biological habitats will be resolved with long-term development plans taking precedence over biological habitat protection. This is further compounded in Singapore by the fact that the natural resources available within these habitats are not exploited and are not of agricultural or economic importance to the country's growth. It has been argued that one reason for habitat biodiversity to be conserved in Singapore be that this would support the current trend of research into natural substances from marine and coastal biota (Chou, 1995b), as this trend has good economic implications.

## **CURRENT NATIONAL STRATEGIES FOR CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY IN THE COUNTRY**

### *Protected Areas*

The Singapore Government's strategy regarding the conservation and protection of natural areas of biological diversity has been spelt out in the Singapore Green Plan (Ministry of Environment, 1992). The Green Plan and its subsequent action programme (Ministry of Environment, 1993) were developed in consultation with relevant concerned groups and a Working Group on Nature Conservation formed by the Government. Under this plan, 5% (3,310 ha) of total land area in Singapore was identified for nature conservation, and included eighteen nature areas covering natural habitats ranging from primary rain forests and secondary forests to mangroves and marshlands. In addition, four marine areas rich in coral reefs were also identified (Chou, 1995b). Amongst other recommendations, the Working Group also proposed the following measures for the protection of marine nature areas: 1) protection from incompatible development; 2) restrictions of the issue of permits for coral collection to only scientific, conservation and research purposes; 3) enforcement of legislation to prevent the illegal harvesting of corals; 4) prevention of illegal dumping of materials within and around identified coral areas and pollution from land reclamation activities; 5) cultivation of nature appreciation among young

Singaporeans; 6) raising general public awareness of nature conservation and the improvement of resources; 7) avoiding indiscriminate promotion of ecotourism (Chou & Low, 1996).

Singapore presently has 2800 ha of primary and secondary rainforests designated as Nature Reserves, 259 ha of mangrove areas designated as Marine Parks, and one Marine Nature Area within which coral reefs occur. It is possible that the designated Marine Nature Areas may increase in the future, as three other proposed marine protected areas have been included in the Singapore Green Plan (Ministry of Environment 1993, 1994).

### *Environmental Laws*

Stringent environmental laws pertaining to pollution issues are aimed at ensuring that infrastructure and industrial development take place without compromising the environmental standards of the country, and are achieved through the implementation of numerous legislations and regulations on pollution control and management (Lim *et al.*, 1987).

Some wildlife protection laws also exist in Singapore (Lye, 1991). In addition, Singapore is party to the Convention on the International Trade of Endangered Species (CITES), which essentially protects endangered species by prohibiting their international trade. Similarly, 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 (Chou & Goh, in press).

### *Development Strategies*

Development in Singapore has traditionally been aimed at Singapore's continued prosperity and economic progress. Although comprehensively prepared, the Government's strategic development plans have often excluded the conservation of biological diversity, as issues relating to conservation have a low national priority.

Clearly, the Singapore Green Plan (Ministry of Environment, 1993, 1994) marked the beginning of a change in perspective on biological habitat conservation, particularly the marine and coastal habitats. As this change gains momentum, it may be possible that future developmental plans also take into consideration the conservation of habitats with naturally high biodiversity.

Another important consideration in coastal and marine habitat conservation is implementing an integrated approach for development and management. Presently, management of coastal areas in Singapore is sectorial and compartmentalised within various Government ministries. An integrated approach involving multisectorial participation in coastal management should be adopted in order to maximise Singapore's restricted natural resources (Chou & Goh, in press). This is especially needed in the management of the designated Marine Nature Area where no administrative structure exists presently to support its management (The Straits Times, 1996a).



## *Rehabilitation of Degraded Areas*

There is currently no policy in Singapore regarding the rehabilitation of degraded habitats (e.g. reforestation) except in already designated nature areas/parks where some restoration and rehabilitation measures have been instituted to enhance the natural characteristics of the area. This is clearly illustrated in the rehabilitation of mangrove trees and the protection of associated mudflats in the Sungei Buloh Nature Park (Chou & Lee, 1994; Low & Chou, 1995).

## *Public Awareness*

The Government's efforts at promoting public awareness on environmental protection may be seen not only in regular programmes for schools, but also campaigns for the general public. In relation to the control of pollution, the Singapore Environment Ministry has regularly organised activities to educate the public on environmental issues through its "Clean and Green Week" and other programmes that coincide with the annual international "Earth Day". For example, marine environmental programmes include the mobilisation of volunteer scuba divers and snorkellers in underwater clean-up activities at recreational sites in Singapore (The Straits Times, 1995, 1996b). The Ministries of Environment and Education also hold exercises to educate school-going children and the general public on wise use of resources (especially water and energy).

In addition, various non-governmental organisations (NGOs) have also initiated programmes aimed at fostering public awareness of environmental and conservation issues. The following are some examples:

The Reef Survey and Conservation Project was undertaken by three NGOs between 1989 and 1991 (Chou, 1990), and involved the training of volunteer recreational divers to conduct an extensive survey of the coral reefs in Singapore in order to assess reef health. The Reef Rescue Project was undertaken to translocate corals threatened with reclamation and also involved volunteer divers (Chou & Goh, in press). Educational programmes to teach school children and the general public on issues related to coral reef conservation were initiated recently. These included the "Coral Reef Naturalist Course" aimed at basic training on reef biology and ecology for recreational divers, and the "Reef Insights" programme initiated to teach children about coral reefs and present day threats that reefs around the world are subjected to (The Sunday Times, 1995; Chou & Goh, in press).

## *Technology Usage*

Since environmental quality is of great importance to the well-being of Singapore's population, the Government employs up-to-date technologies in the treatment and management of sewage pollution. It also enforces the Industrial Pollution Act which ensures that industrial waste and effluents are sufficiently treated before disposal.

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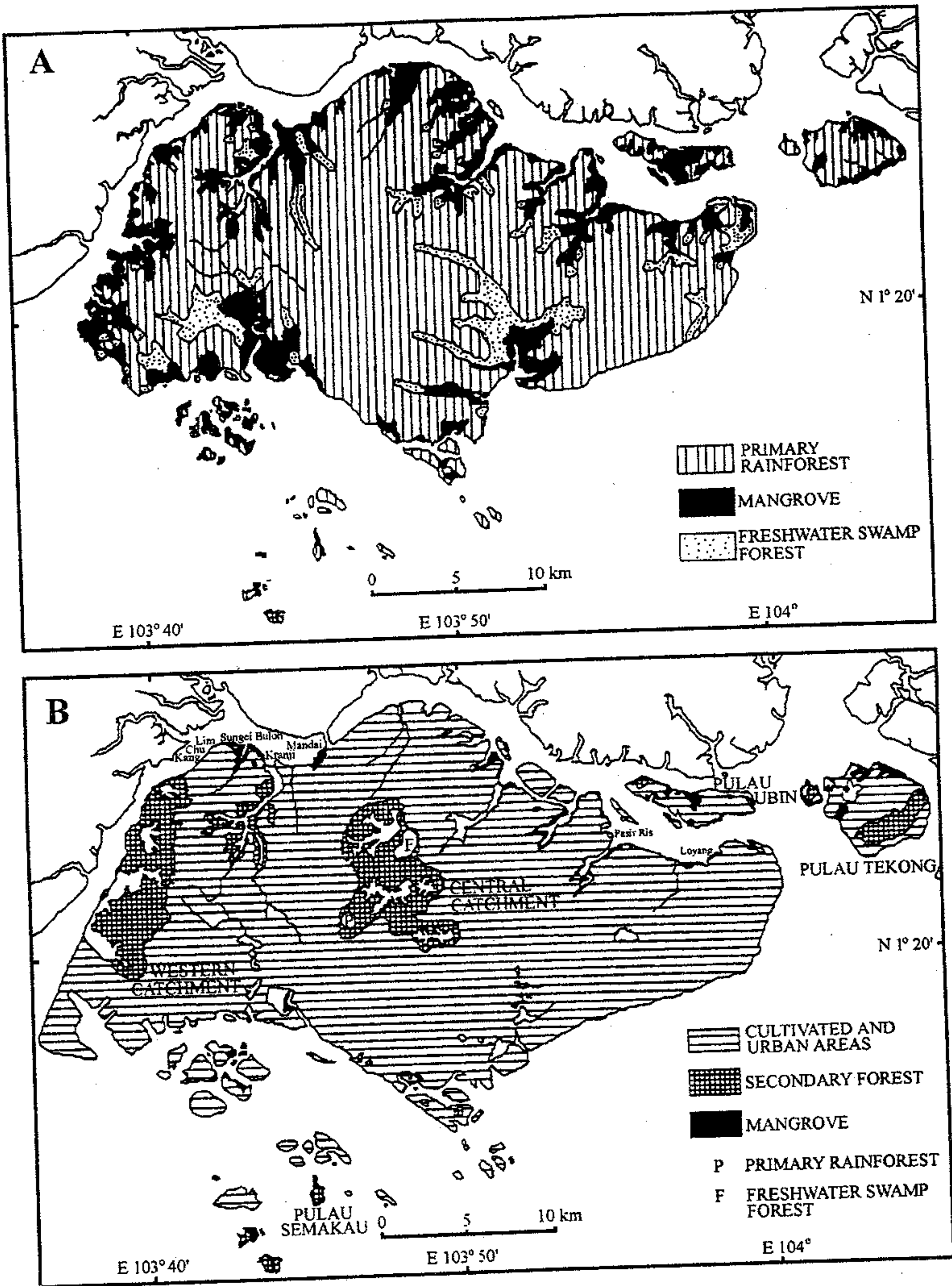


Fig. 1. Map showing changes in vegetation cover of Singapore from (A) 1819 to (B) 1991 (adapted from Turner *et al.*, 1994).

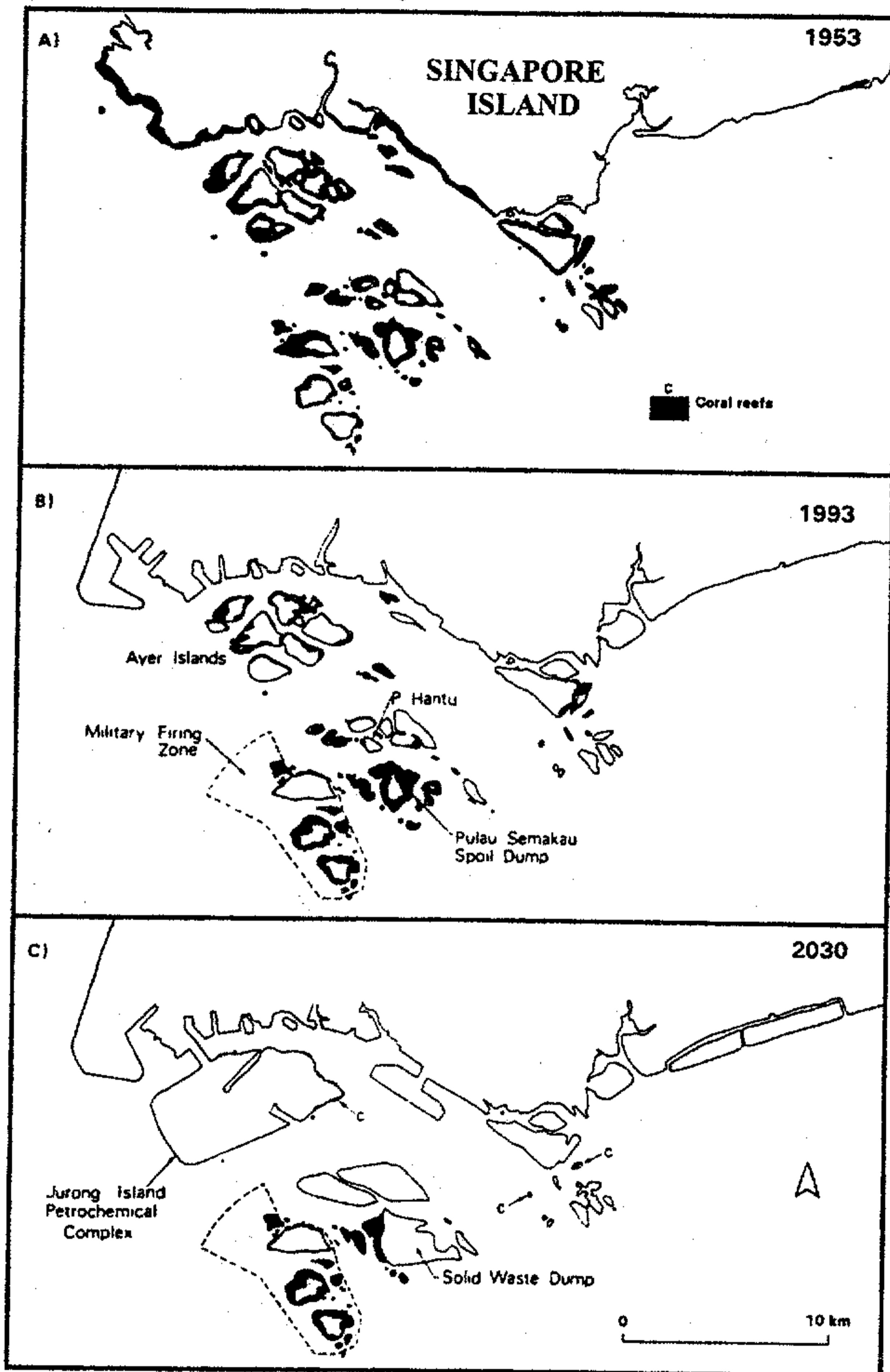


Fig. 2. Transformation of Singapore's southern islands and reefs from A) 1953 to B) 1993, and projected changes until C) 2030 (adapted from Hilton and Manning 1995).