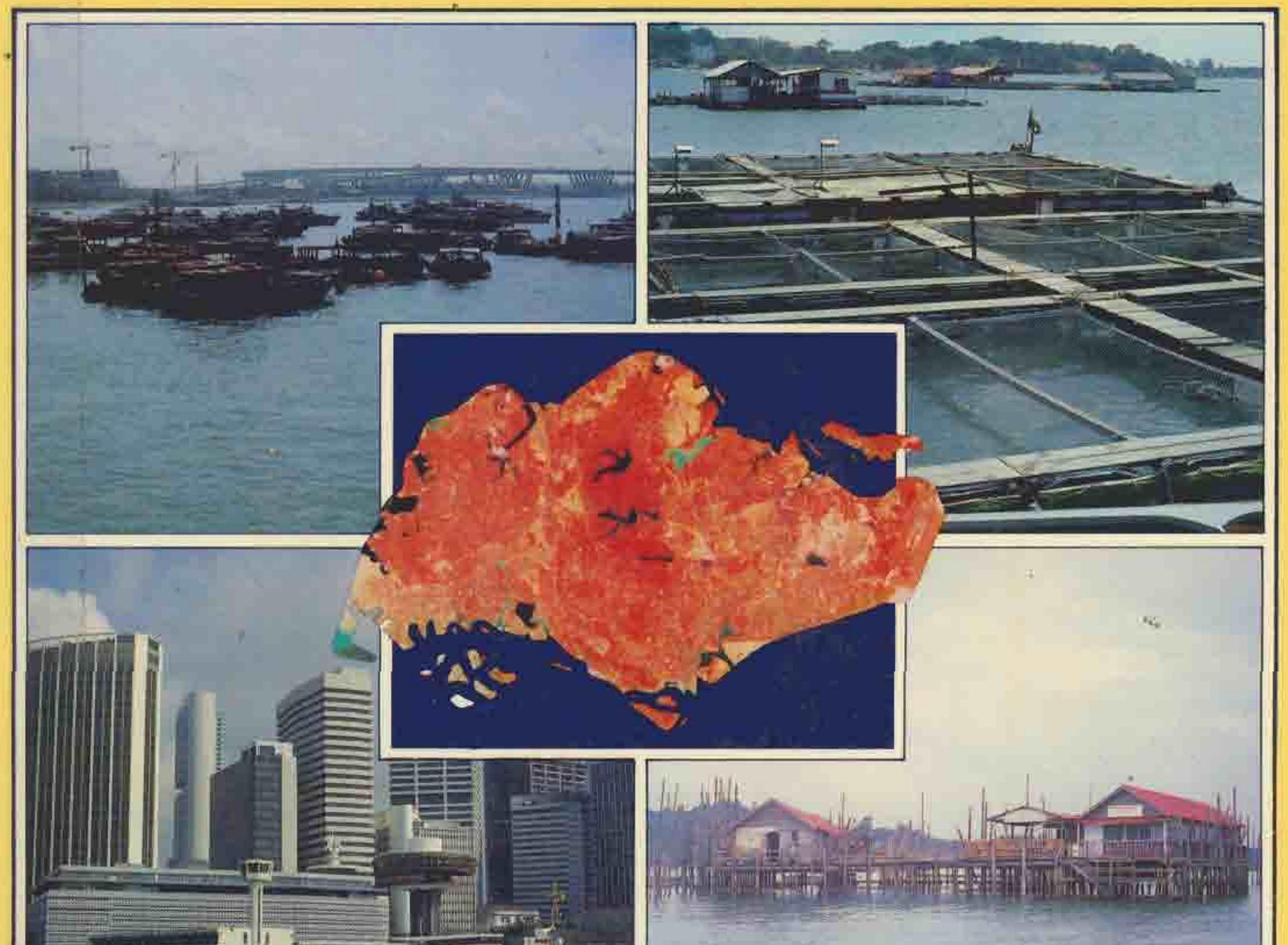
The Coastal Environmental Profile of Singapore

Chia Lin Sien, Habibullah Khan
and Chou Loke Ming



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Cover: (Clockwise) In Singapore: waterfront vessels; floating cage farm in Johor Strait; inshore palisade trap *(kelong)* integrated with floating cages in Johor Strait; and waterfront skyline. All photos by Chou Loke Ming. (Middle) Processed SPOT image of Singapore by Dr. Lim Hock and the Laboratory for Image and Signal Processing, Science Faculty, National University of Singapore.

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List of Acronyms and Abbreviations

ASEAN	Association of Southeast Asian Nations
BOD	Biological oxygen demand
bpd	Barrels per day
Bt.	Bukit (meaning mountain or hill)
CAAS	Civil Aviation Authority of Singapore
CBD	Central Business District
CRM	Coastal resources management
CRMP	Coastal Resources Management Project
DBS	Development Bank of Singapore
DOS	Department of Statistics
dwt	Deadweight ton
EDB	Economic Development Board
EEZ	Exclusive Economic Zone
ft	Freight ton
GDS	Geographically Disadvantaged State
GNP	Gross National Product
GRT	Gross registered ton
HDB	Housing and Development Board
HUDC	Housing and Urban Development Corporation
ICLARM	International Center for Living Aquatic Resources Management
IGMC	Inter-Governmental Maritime Committee
JTC	Jurong Town Corporation
Kg.	Kampong (meaning village)
KWH	Kilowatt hour
MD	Marine Department
MEAP	Marine Emergency Action Procedures
MNOC	Multinational oil company
MOCI	Ministry of Communications and Information
MOD	Ministry of Defense
MOE	Ministry of the Environment
MOND	Ministry of National Development
msl	Mean sea level
NIC	Newly Industrializing Countries
nm	Nautical mile
NMB	National Maritime Board
NUS	National University of Singapore
P.	Pulau (meaning island)
PCS	Petrochemical Corporation of Singapore Pte Ltd
PD	Planning Department
PMD	Port Master's Department
PPD	Primary Production Department
ppm	Parts per million
PRD	Parks and Recreation Department

PROC	People's Republic of China
PSA	Port of Singapore Authority
PUB	Public Utilities Board
ROV	Registry of Vehicles
S.	Sungei (meaning river)
SASAR	Singapore Association of Shipbuilders and Repairers
SDC	Sentosa Development Corporation
SHB	Singapore Harbour Board
SIT	Singapore Improvement Trust
SMS	Singapore Meteorological Services
SSC	Singapore Science Council
TAS	Telecommunications Authority of Singapore
Tg.	Tanjong (meaning cape)
UNCLOS	United Nations Conference on the Law of the Sea
URA	Urban Redevelopment Authority
USAID	United States Agency for International Development
VLCC(s)	Very large crude carrier(s)
WHO	World Health Organization

Preface

The Coastal Environmental Profile of Singapore is intended to serve the following purposes:

- To provide policymakers and researchers with a ready source of information, including a detailed listing of source materials;
- To describe the coastal changes that have taken place and to suggest factors that have brought about such changes;
- To highlight the interrelations among the many aspects of coastal zone, including possible conflicts;
- To raise issues relating to the management of the coastal zone with the intention that the zone be used more optimally; and
- To eventually help formulate a coastal area management plan for the country.

Initially, the profile was produced as a background document for the first National Workshop of the Singapore component of the ASEAN-US CRMP. The workshop was organized in late 1986 to provide a forum for discussions among representatives of various Singapore government agencies and the country's CRMP research team. The document has been substantially revised for publication. It should be noted that heavy reliance was put on secondary sources current during the time of the workshop. Over the following two years, much more information has since become available, which is incorporated in this profile.

This profile is but the first step towards the formulation of a coastal area management plan for Singapore. The plan will be aimed primarily at further development of the coastal areas in a multisectoral and integrated manner, taking cognizance of the existing pattern of resource use and the overall social and economic development framework of the country. To develop the plan, it is also essential to:

1. Seek more information on coastal resources and how they are being utilized;
2. Document the responsibilities, functions, legal provisions and activities of concerned government agencies; and
3. Illucidate the role and use of coastal resources by the public and by private and commercial enterprises both at present and in the future.

Thus, contained in this profile is preliminary information on the above which was gathered through library research, interviews with managers of various organizations and field observations and surveys on the major coastal resource users.

A multidisciplinary approach has been adopted. The profile covers physical and biological characteristics of the coastal resources; social and economic aspects of the coastal residents and users; past and present utilization of marine resources and their contributions to the economy; coastal land use problems; and the role of various institutions (government and private) in the management and development of coastal resources.

The authors wish to thank the United States Agency for International Development (USAID) for providing financial support for this research project. We gratefully acknowledge the help given to us by the Singapore Science Council (SSC) for its role in making the national project possible. Thanks must also go to Prof. Ooi Jin Bee and the National University of

Singapore's (NUS) Department of Geography for providing practical support for the project. We are greatly indebted to Dr. Chua Thia-Eng, ASEAN-US CRM Project Coordinator, for his personal interest and encouragement in producing this report. Dr. Kenneth Ruddle (of the National Museum of Ethnology, Japan) and Dr. Alan White and Mr. Jay L. Maclean (both of ICLARM) provided valuable comments and suggestions for improving the manuscript, while Mr. Leslie Cheong, Head of the Marine Aquaculture Unit, Primary Production Department, and also National Coordinator of the project provided much practical assistance and information.

In the course of the research, we received help from many agencies and individuals both in government and private organizations to whom we owe special thanks and appreciation. These agencies and individuals are: Ms. Caroline Kwauk Yu Pin, Mr. Ang Swee Loh, Ms. Yip Wai Kuan and Ms. Lilian Hsu, our research assistants; Ms. Koh Guat Wah and Betty Lin (SSC), for their willing cooperation and assistance; Mrs. Tan Lee Kheng (Department of Geography, NUS) and Ms. Rachel Atanacio (ICLARM), for drafting the maps; Ms. Marie Sol M. Sadorra (ICLARM), for so patiently and efficiently helping in the editing of the manuscript; and Ms. Cory Guerrero (ICLARM), for her cheerful and able assistance.

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Foreword

The coastal waters of Southeast Asian countries have some of the world's richest ecosystems characterized by extensive coral reefs and mangrove forests. Blessed with warm tropical climate and high rainfall, these waters are further enriched with nutrients from land which enable them to support a wide diversity of marine life. Because economic benefits could be derived from them, the coastal zones in these countries teem with human settlements. Over 70% of the population in the region live in coastal areas which are characterized by high-level resource exploitation brought about by increasing population pressure and associated economic activities over the last two decades. Large-scale destruction of the region's valuable resources has caused serious degradation of the environment, thus affecting the economic condition and quality of life of the coastal inhabitants. This lamentable situation is mainly the result of ineffective or poor management of the coastal resources.

It is essential to consider coastal resources as valuable assets that should be utilized on a sustainable basis. Unisectoral overuse of some resources has caused grave problems. Indiscriminate logging and mining in upland areas might have brought large economic benefits to companies undertaking these activities and, to a certain extent, increased government revenues, but could prove detrimental to lowland activities such as fisheries, aquaculture and coastal-tourism-dependent industries. Similarly, unregulated fishing efforts and the use of destructive fishing methods, such as mechanized push-netting and dynamiting, have caused serious destruction of fish habitats and reduction of fish stocks. Indiscriminate cutting of mangroves for aquaculture, fuel wood, timber and the like have brought temporary gains in fish production, fuel wood and timber supply but losses in nursery areas of commercially important fish and shrimp, coastal erosion and land accretion.

The coastal zones of most nations in the Association of Southeast Asian Nations (ASEAN) are subjected to increasing population and economic pressures manifested by a variety of coastal activities, notably, fishing, coastal aquaculture, waste disposal, salt-making, tin mining, oil drilling, tanker traffic, rural construction and industrialization. This situation is aggravated by the expanding economic activities attempting to uplift the standard of living of coastal people, the majority of which live below the official poverty line.

Some ASEAN nations have formulated regulatory measures for their coastal resources management (CRM) such as the issuance of permits to fishing, logging, mangrove harvesting, etc. However, most of these measures have not proven effective due partly to enforcement failure and largely to lack of support for the communities concerned.

Experience in CRM in developed nations suggest the need for an integrated, interdisciplinary and multisectoral approach in developing management plans providing a course of action usable for daily management of the coastal areas.

The ASEAN-United States (US) Coastal Resources Management Project (CRMP) arose from the existing CRM problems. Its goal is to increase existing capabilities within ASEAN nations for developing and implementing CRM strategies. The project, which is funded by USAID and executed by the International Center for Living Aquatic Resources Management (ICLARM), attempts to attain its goals through these activities:

- analyzing, documenting and disseminating information on trends in coastal resources development;
- increasing awareness of the importance of CRM policies and identifying, and where possible, strengthening existing management capabilities;
- providing technical solutions to coastal resources use conflicts; and
- promoting institutional arrangements that bring multisectoral planning to coastal resources development.

In addition to implementing training and information dissemination programs, CRMP also attempts to develop site-specific CRM plans to formulate integrated strategies that could be implemented in the prevailing conditions in each nation.

The coastal zone of Singapore is densely populated. The coastal waters are under the jurisdiction of the Port of Singapore Authority (PSA). Most of the coastal waters are already heavily utilized, mainly for shipping and transportation. There is limited area for domestic and recreational purposes. The coastal lands are already well-planned for housing and industrial development.

Singapore places considerable emphasis in keeping its marine environment clean as exemplified by government efforts to rehabilitate the Singapore River. There are also efforts being attempted by the Singapore National Team of the ASEAN-US CRMP to improve, develop and restore appropriate fish habitats by installing artificial reefs or restocking inshore waters. These efforts are part of a dualistic management approach adopted by the project, aside from the regulatory measures.

The Singapore subproject consists of three components, two of which are experimental and developmental in nature. These two are the development of netcage culture (floating and submersible) and artificial reefs. The third component involves the management aspects and the production of the country environmental profile as well as undertaking surveys of households and users of the coastal zone on their perception of the area.

This profile is the product of an exhaustive search for relevant secondary data from published and grey literature. The enormous data uncovered will form the basis of the formulation of guidelines for marine space allocation in this island state.

The hard work of the national team, in particular, Drs. Chia Lin Sien, Habibullah Khan and Chou Loke Ming, in accomplishing this profile is acknowledged and greatly appreciated.

Chua Thia-Eng
Project Coordinator
ASEAN-US Coastal Resources
Management Project

Chapter 1
Introduction

Singapore is situated between latitudes 1°09'N and 1°29'N and longitudes 103°38'E and 104°06'E. The Republic is located to the south of Peninsular Malaysia and is separated from its northern neighbor by Johor Strait. To the south are scattered the islands of the Indonesian Riau (also Rhiau, Rhio or Rio) archipelago (Fig. 1.1). The only clear view of the open sea is from Horsburgh Lighthouse at the eastern end of the Singapore Strait looking towards the South China Sea.

The main island of Singapore (henceforth referred to as Singapore Island) is 41.8 km long and 22.5 km wide. The total area of Singapore stands at 621 km^2, which includes about 60 islets (referred to as the "offshore islands") having a total area of 46 km^2. Land from foreshore reclamation has added some 40 km^2 as of 1985. The offshore islands are found mostly to the southwest of the main island although the largest two islands, Pulau (P. throughout this text, and which means island) Tekong Besar and P. Ubin, are respectively located to the east and northeast of the main island.

As an island nation in a region dominated by water, Singapore is by its very nature highly maritime. The country is heavily dependent on its marine resources including its strategic location on a major international sealane for commercial shipping, which perhaps may be considered the country's most important marine resource. Dependence on marine resources arises also as a result of the small physical size of the country, requiring it to be outward-looking in terms of international relations and its *laissez faire* policies on trade, manufacturing and services.

The economic and social foundation of Singapore lies in its being an *entrepôt* center, providing the trading links between the surrounding region and the developed nations of the West and Japan. Singapore's strategy has been to build up its internal infrastructure such as a well-developed system of port and road network, planned industrial estates and other essential facilities and to create an administrative and legal system that will ensure efficient services to sustain the vital linkages with the rest of the world. This strategy has led to Singapore being called the "global city". The development momentum beginning from the 1960s together with the increase in population has resulted in very great pressures on the marine or coastal resources with consequent impacts on the coastal environment of the country.

Singapore's territorial waters are limited in area as they are circumscribed by the waters of its neighboring countries. For this reason, the country is referred to as a "Geographically Disadvantaged State" (GDS) in the language of the United Nations Conference on the Law of the Sea (UNCLOS). However, the limited coastal area has played an important role in Singapore's economic growth and prosperity. Singapore has taken advantage of its strategic location between the economically powerful European states and the rapidly growing countries of the Arabian Gulf to the west and the expanding East Asian markets. Singapore is also the transportation hub for the Southeast Asian region to develop its external trade; to produce manufactured goods and provide services for the international community; and to become what is popularly known as one of the "Newly Industrializing Countries" (NICs). Its deepwater harbor

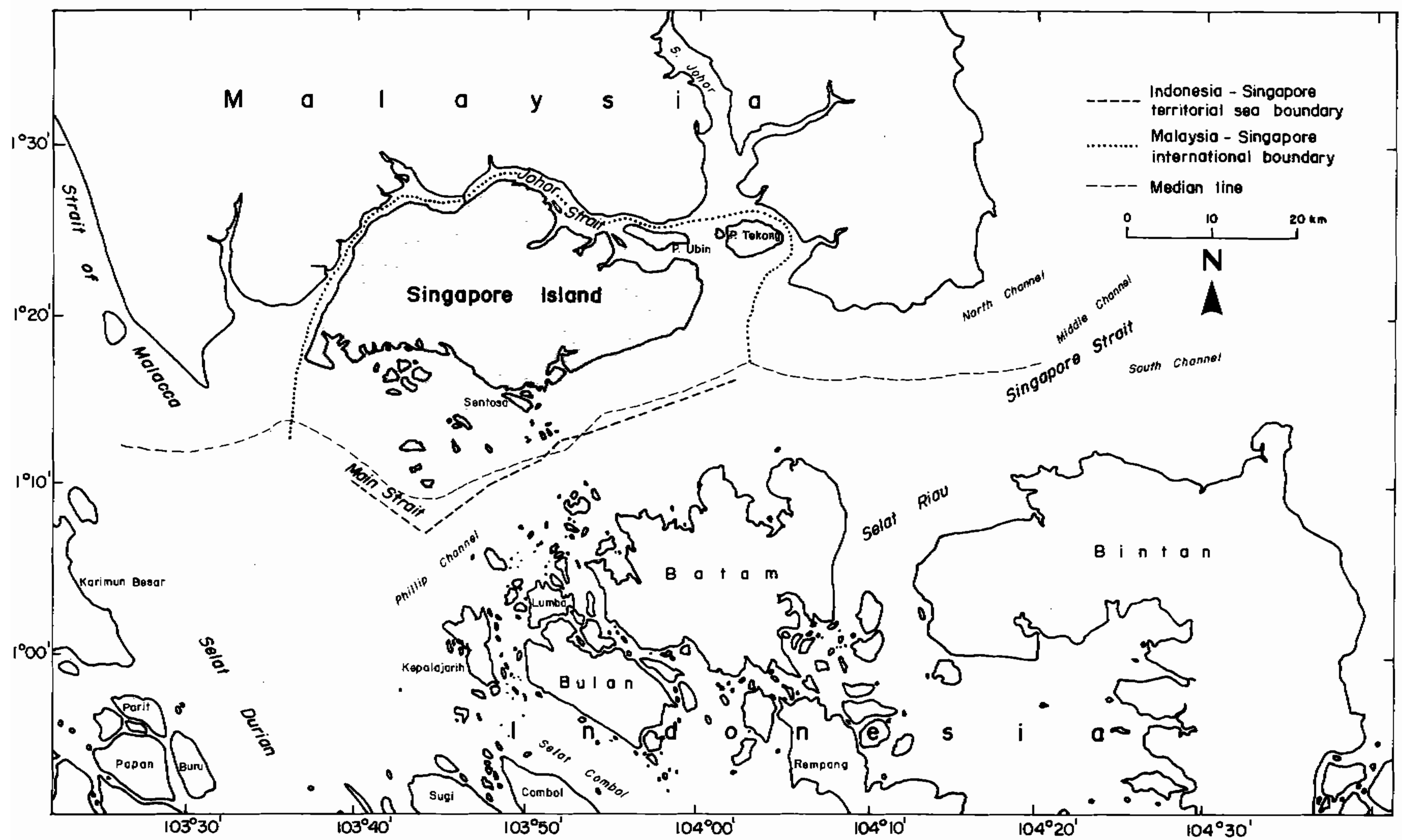

Fig. 1.1. Singapore and its surrounding areas.

and centrally located position have also made Singapore the second largest oil refining center in the world. The large flow of merchant ships including modern container vessels, oil tankers and other specialized bulk carriers further accentuated the growth of port facilities and led to the emergence of various supporting industries such as shipbuilding and shiprepairing and ancillary services such as banking and insurance.

Definitions

Coastal resources. The term "marine resources" refers to all kinds of resources found in or around the seas and under the seabed. Stowe (1979) classified these resources into three: biological, mineral and energy. Biological resources include all forms of plants and animals found in the seas such as seaweeds, corals, microorganisms, fish, mollusks, crustaceans and aquatic mammals. Examples of mineral resources found in the sea are petroleum, natural gas, sulfur, magnesium, salt, manganese nodules, sand and gravel, freshwater and various deepsea minerals. Energy resources available in the sea include thermal energy, wave energy and tidal energy. For Singapore, the entire territorial seas may be considered to be coastal waters.

Coastal zone or coastal area. The coastal zone may be broadly defined as an area on either side of the coast of any land mass where land, water (especially seawater) and air interact. The seaward limit of the coastal zone includes the coastal sea influenced by natural or man-made processes on land or the continental shelf. Under the UNCLOS, national maritime jurisdiction is extended to a maximum distance of 370 km (200 nautical miles or nm) (called the "Exclusive Economic Zone" or EEZ) from the baselines from which the breadth of the territorial sea is measured. In the zone, the coastal state has sovereign rights for exploring, exploiting, conserving and managing all marine resources. The conference also made a provision for continental shelf rights beyond 370 nm (Jayakumar 1981).

Definition of the landward limit of the coastal zone may be based on physical arguments on the landward effects of marine influences such as tidal penetration or salt intrusion. In Malaysia, for example, the limit is given as 20 km from the coastline as reported by Lee et al. (1982). Since no part of the main island of Singapore is more than 15 km from the sea, the country in many ways may be regarded as entirely coastal in nature. However, the operational definition of coastal zone in Singapore may be different from the above. Krausse (1983) considered all the reclaimed areas as well as the locations within 4.8 km of the shore as being "coastal". At present, there is no waterfront zoning, special districting or other official definitions of coastal areas in Singapore. There are, however, several government agencies which control the various uses of the limited coastal zone in the country. Singapore's coastal land may be considered to comprise a narrow strip of land along the coast extending inland to include all reclaimed land and properties that have a waterfrontage as well as uses which in some ways are marine-dependent. Because of the bias in favor of an operational definition, the more neutral term "coastal area" is preferred over "coastal zone".

Having defined the term "coastal area" in the Singapore context, coastal resources then refers to all the natural resources found within the coastal area. Any economic activity within the coastal area may be considered to be forms of "coastal resource utilization". While marine resources include all of the resources found in or under the sea, coastal resources include only those found within the boundary of the coastal area of a particular country. No strict and unvarying definition can be applied as the landward limit has been arbitrarily determined.

Primary versus secondary marine resources. By applying the concepts of Ricardo goods and Heckscher-Ohlin goods, which are often used by economists in international trade theories (Hirsch 1974), the various kinds of marine resources can be usefully classified into "primary" and "secondary" commodities. Ricardo goods are those which rely upon an important specific natural resource, and Heckscher-Ohlin goods use standard technology with constant returns to scale in capital and labor. In other words, Ricardo goods are predominantly gifts of nature and are indeed "primary" commodities such as oil, natural gas, copper, tin and fish. Heckscher-Ohlin goods or services, on the other hand, are "secondary" or manufactured products such as refined petroleum products, petrochemicals, ships, oil rigs and processed fish products. Here we consider only those coastal area-dependent goods produced.

Primary marine goods (or services) can be transformed into secondary products through the application of technology. For example, a small natural harbor can be transformed into a modern port such as Singapore's which provides a wide range of navigational facilities and shipping services. Similarly, simple fishing villages can be transformed into international tourist resorts such as those in Phuket in Thailand or Bali in Indonesia. A country need not produce primary marine resources in order to specialize in secondary processing activities. For instance, Singapore has become the largest "marine manufacturing and service center" with excellent facilities for oil refining, shipping services and related activities, and fish processing and distribution in the region although it possesses few primary marine resources.

Marine sector. It is difficult to identify the marine sector of a country because the sea is virtually related to everything, directly or indirectly through backward and forward linkages. Backward linkages refer to establishments that supply the ocean sector with goods and services that are used as inputs to its production process. Examples are shipbuilding and shiprepairing; marine construction, engineering and technical services; marine research and marine science institutions; pipe manufacturing; and other various supporting services to water transport.

Forward linkages refer to establishments that utilize the ocean sector outputs as inputs to their activities, e.g., petroleum for refineries, fish for food production, and sand and gravel for construction. There are a number of other establishments--those on tourism and on manufacturing sporting and recreational goods--which do not exploit the oceans directly but do benefit from the sea for their development.

From the above, Singapore's marine sector would include reclaimed land, mangroves, aquaculture, marine fisheries, beaches, coral reefs, offshore islets; contributions from petroleum and petrochemical plants, shipping, shipbuilding and shiprepairing; oil rig construction; marine-related tourism and recreation activities; and others.

Population

Singapore has a small population base. In June 1985, the Republic had a population of 2.558 million, with Chinese accounting for 76.4%; Malays, 14.9 %; Indians, 6.4%; and others, 2.3%. The sex ratio was fairly well-balanced with 1,037 men/1,000 women, indicating a settled population rather than a migrant one which has characterized Singapore's population from its foundation in the early 19th century.

Rising standards of living and better health facilities have reduced the infant mortality rate from 13.9 in 1975 to 9.3 in 1985 for every 1,000 live births. Crude death rate has, however, remained more or less stable during the last decade (5.1 in 1975 versus 5.2 in 1985 per 1,000). Life expectancy increased from 67.3 years in 1970 to 71.2 years in 1980.

The population growth rate has shown a downward trend, from 1.4% in 1975 to 1.1% in 1985. Projections of future population show that the rate will further decline to 0.6% during the period 1995-2000. In the year 2000, the population is expected to be just under 2.93 million.

The proportion of younger persons has been declining while that of older ones has been increasing. The index of aging (persons aged 65 and over divided by persons under 15) has increased from 12.3 in 1975 to 21.4 in 1985; and it is projected to increase further.

As a result of the aging problem and the slow population growth, the growth rate of the indigenous labor force has been gradually declining. Annual growth rate of the latter was 1.9% in 1985 which is projected to decline to 1.1% in 1990 and to 0.5% in the year 2000. Labor force participation rate (labor force as a proportion of the working age population) increased from 59.7% in 1975 to 65.6% in 1985, and it will be difficult to raise this rate further in the future.

The standard of living in Singapore has improved significantly. Per capita indigenous gross national product (GNP) (at current market prices) increased from $5,089 (Singapore $, unless otherwise indicated) in 1975 to $12,865 in 1985. The literacy rate (for 10 years and above) increased from 78.2% in 1975 to 86% in 1985. Other social indicators also show that Singaporeans continue to enjoy a high standard of living. For example, every two persons had a telephone, and every five owned a television set in 1985.

Coastal population

In the absence of any generally agreed-upon definition of the coastal zone, researchers usually set arbitrary landward limits for operational purposes. The difficulty in setting such a landward limit for analyzing coastal population is that the coastal areas so determined may not correspond with actual census divisions. In utilizing the available census data in 1980, 42 census divisions (comprising 450 km^2 of land), out of a total of 70, were selected on the basis of proximity to the coastline (Figs. 1.2 and 1.3).

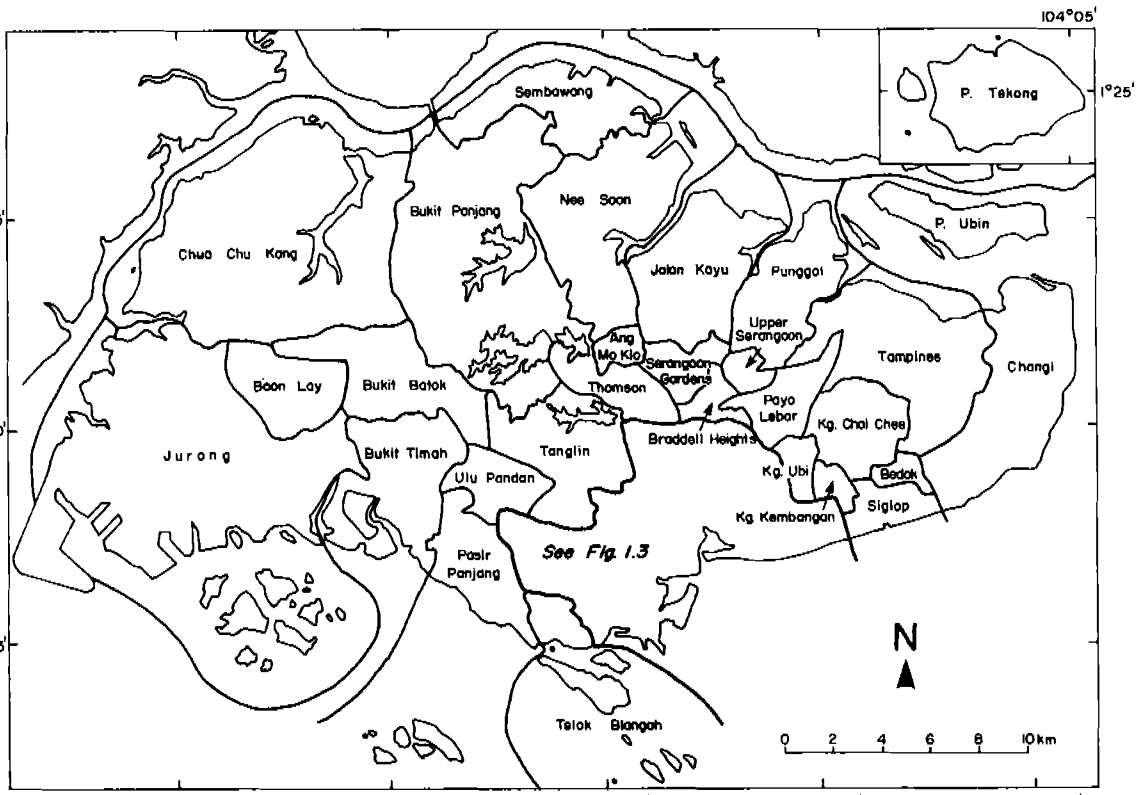

Fig. 1.2. Singapore's census districts, 1980.

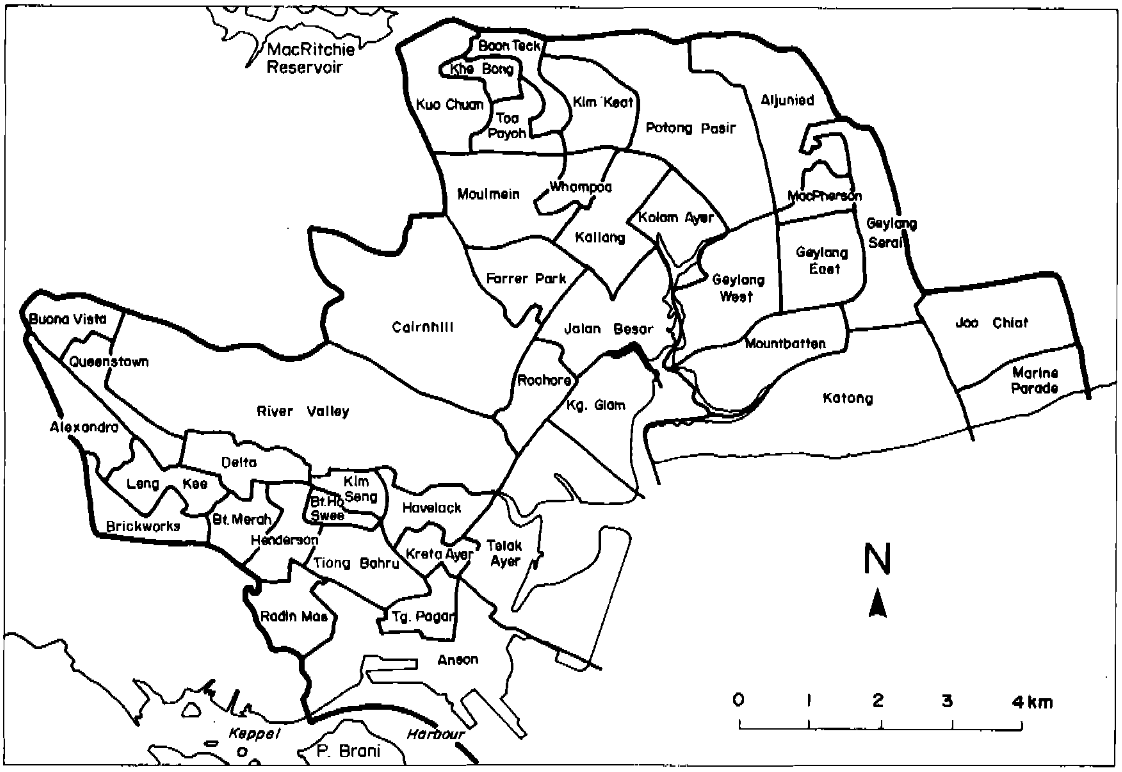

Fig. 1.3. Singapore's census districts in city center.

Table 1.1. Coastal population in 1980.

Alexandra	33,273	Kampong Ubi	30,697
Anson	20,903	Katong	22,915
Bedok	86,909	Kim Seng	25,133
Brickworks	25,887	Kreta Ayer	17,235
Bukit Ho Swee	20,773	Leng Kee	27,078
Bukit Merah	34,977	Marine Parade	38,699
Bukit Panjang	49,038	Mountbatten	23,462
Bukit Timah	124,117	Nee Soon	37,641
Changi	36,443	Pasir Panjang	38,423
Chua Chu Kang	46,703	Punggol	47,308
Geylang East	21,657	Radin Mas	34,125
Geylang Serai	17,656	Rochore	23,547
Geylang West	41,134	Sembawang	39,029
Havelock	21,274	Siglap	31,272
Henderson	32,125	Tanjong Pagar	21,551
Jalan Besar	25,954	Tampines	36,616
Jalan Kayu	43,679	Telok Ayer	16,702
Joo Chiat	22,445	Telok Blangah	43,502
Jurong	50,974	Tiong Bahru	31,539
Kampong Chai Chee	80,174	Port Limits	130
Kampong Glam	28,553		
Kampong Kembangan	22,381	Total	1,485,596

Source: DOS (1980).

Table 1.2. Occupational structure of the coastal population, 1980.

Occupation	Percentage of total	Occupation	Percentage of total
Manufacturing	27.57	Construction	6.77
Commerce	22.25	Agriculture and fishing	1.99
Other services	19.80	Utilities	0.73
Transportation and communications	13.57	Quarrying	0.11
Financial and business services	7.17	Unclassified	0.04

Table 1.1 presents the 1980 population; coastal population accounted for 61.5% of the total of 2,413,945. Table 1.2 shows the occupational structure of the coastal population (employed persons only) in 1980. The distribution pattern reflects the overall employment trend in the country.

Table 1.3. Population in offshore islands, 1957.

Southern Islands		P. Seraya	311
		P. Meskol	2
P. Blakang Mati	2,153	P. Shoal	7
P. Brani	3,607	P. Samulun	393
P. Selegu	10	P. Damar Laut	118
St. John's Island	518	P. Semakau	322
Lazarus Island	251	P. Sakeng	217
Peak Island	5	P. Sebarok	126
P. Bukum	4,817		
P. Bukum Kechil	719	Subtotal	14,300
P. Pawai	87		
P. Senang	5	Northern Islands	
P. Sudong	368		
P. Saturun	7	P. Tekong	4,169
P. Ayer Chawan	41	P. Ubin	1,942
P. Ayer Merbau	84		
P. Merlimau	111	Subtotal	5,111
P. Pesek	13		
P. Sakra	8	Total	20,411

Source: Statistics from SDC.

Population in the offshore islands

Although Singapore has some 60 offshore islands, only a few of them are now inhabited. With the increasing use of the islands for industrial purposes, the population had to be removed gradually to the main island. In 1957, the total population of these islands was 20,411 (Table 1.3) and in 1980 was 4,781 (Table 1.4).

The two biggest islands, P. Tekong and P. Ubin, contained the bulk of the population in 1980. However, the entire population from P. Tekong and P. Tekong Kechil had been removed by the end of 1986 as the islands were used for military purposes. P. Ubin and P. Sakeng still retain their rural character but definite plans regarding their use are not yet known. Most of the residents there are engaged in fishing or other primary activities, and lead a *kampong* (village) life-style. The population is predominantly Malay, followed by Chinese and Indians (Table 1.4).

Table 1.4. Population in offshore islands, 1980.

Island	Total			Chinese			Malays			Indians			Others		
	Persons	Males	Females	Persons	Males	Females	Persons	Males	Females	Persons	Males	Females	Persons	Males	Females
P. Ayer Merbau	2	2	–	–	–	–	–	–	–	2	2	–	–	–	–
P. Bukom Besar	376	258	118	139	92	47	124	77	47	71	67	4	42	22	20
P. Sakeng	525	263	262	3	3	–	522	260	262	–	–	–	–	–	–
P. Sakijang Bendara	30	14	16	–	–	–	30	14	16	–	–	–	–	–	–
P. Sentosa	3	3	–	–	–	–	–	–	–	–	–	–	3	3	–
P. Tekong	2,570	1,372	1,198	1,168	624	544	1,391	738	653	11	10	1	–	–	–
P. Tekong Kechil	30	19	11	24	13	11	6	6	–	–	–	–	–	–	–
P. Tembakul	3	2	1	3	2	1	–	–	–	–	–	–	–	–	–
P. Ubin	1,242	685	557	889	494	395	349	187	162	4	4	–	–	–	–
Total	4,781	2,618	2,163	2,226	1,228	998	2,422	1,282	1,140	88	83	5	45	25	20

Source: DOS (1980).

Table 1.5. Percentage distribution of GDP by industry at 1968 factor cost.

Industry \ Year	1960	1970	1980	1984	1985
Manufacturing	13.0	19.3	22.7	20.2	19.0
Trade	33.0	29.5	24.5	23.3	23.4
Financial and business services	13.8	11.4	15.4	22.2	22.3
Transport and communications	11.5	13.7	17.7	21.3	23.2
Others	28.7	26.1	19.7	13.1	12.1

Source: MOTI (1985).

There is a preponderance of males over females except in P. Sakeng where there is a settled population of Malays. The population of P. Bukom comprises mostly employees of Shell Oil Company and their families who live in modern accommodation with a range of facilities and services on the island. See Chia and Khan (1987) for more discussion on utilization of offshore islands.

Development Background

Singapore achieved self-rule in 1959 and for a period, 1963 to 1965, was part of the Malaysian Federation. After breaking away from the Federation, Singapore became a sovereign state on 9 August 1965. The People's Action Party has been the dominant political party since self-rule and has been an important factor in providing strong leadership required to effect rapid development for the city-state.

Initial problems of unemployment, housing shortage, road congestion and poor urban conditions were solved through sound economic policies and planning. Since the early 1960s, a series of effective statutory boards (quasi-government bodies) was established to provide solutions to these problems. The two main thrusts of the early socioeconomic program were public housing and industrial development. It was feared that the traditional *entrepôt* trade on which the economy has depended upon for so long would not be able to provide the necessary growth to sustain it and to provide employment for the rapidly growing population.

However, the Singapore economy started expanding rapidly in 1960 (Table 1.5) and now enjoys a standard of living close to that of some of the advanced European nations. A combination of external and internal factors contributed towards the success. Among the external factors are the favorable booming world trade and offshore oil exploration and exploitation within the region; and expanding economies of the fellow member states of ASEAN and good foreign relations. Internally, there is the stable political climate; successful educational and industrial programs supported by a buildup of good infrastructure and appropriate institutions; burgeoning construction activities; and from the 1970s, successful programs to promote various service industries.

The rapid expansion of population and economy resulted in intensive development affecting all corners of the land, transforming it beyond recognition. Large-scale foreshore reclamation; construction of public housing and planned industrial estates; and buildup of infrastructure (air- and seaports and road network) all have an immense impact on the coastal land. There are also clear evidences of maritime change brought about by the construction of industrial complexes and recreational facilities on offshore islands, and the ever increasing number of ships calling at the port, requiring augmented facilities and services. These momentous changes affecting the entire coastal scene strongly suggest an assessment of past changes, present situations and future trends as well as the need for management.

Chapter 2
Coastal Land and Offshore Islands

Climate

The climate of Singapore is, according to Thornthwaite's classification, of the hot and wet equatorial type with high average temperatures, humidity and rainfall throughout the year. The local climate is modified strongly by the Asian monsoon regime with its annual change in prevailing northeast and southerly winds. Hence, the climatological year is divided into the northeast monsoon (November to March); first intermonsoon period (April/May); southwest monsoon (June to September); and second intermonsoon period (October/November) (Chia 1979a).

Wind

Wind conditions can be seen from the windroses for each of the seasons (Fig. 2.1) and except for the northeast monsoon when average wind speeds can exceed 8 m/s, winds are generally light; and during the intermonsoon periods, are highly variable. Again except for the northeast monsoon, the percentage of observations shown as "calm" is high, being above 30% (Chia and Wong 1977).

Wind speeds are generally higher over the sea and small islands than on the mainland where they are reduced rapidly by frictional effects from the coast inland. The highest recorded wind speed is just over 40 m/s (April 1984) during a squall. Such squalls occur during the early morning hours from the direction of the Strait of Malacca and are locally called "Sumatras". The generally calm wind conditions in Singapore are due to the absence of tropical storms or typhoons which are restricted polewards of about 6^{o} latitude on either side of the equator.

There is a distinct diurnal pattern of change of wind speeds as shown in Fig. 2.2. There has been no investigation into the occurrence of land and sea breezes, although it is likely that they are not well-developed because of the presence of the many islands to the south of Singapore. During most of the day, there is a general drift northwards and, during the night, a general southward drift of air. The more vigorous wind movement along the coast add a pleasant quality to the environment there.

Air temperature and humidity

As for solar radiation, Chia (1969) noted that it appears to be higher along the southern coast and over the Southern Islands than further inland. Due to the cooler air arriving over Singapore and more overcast skies during the end of the year and in January, air temperatures

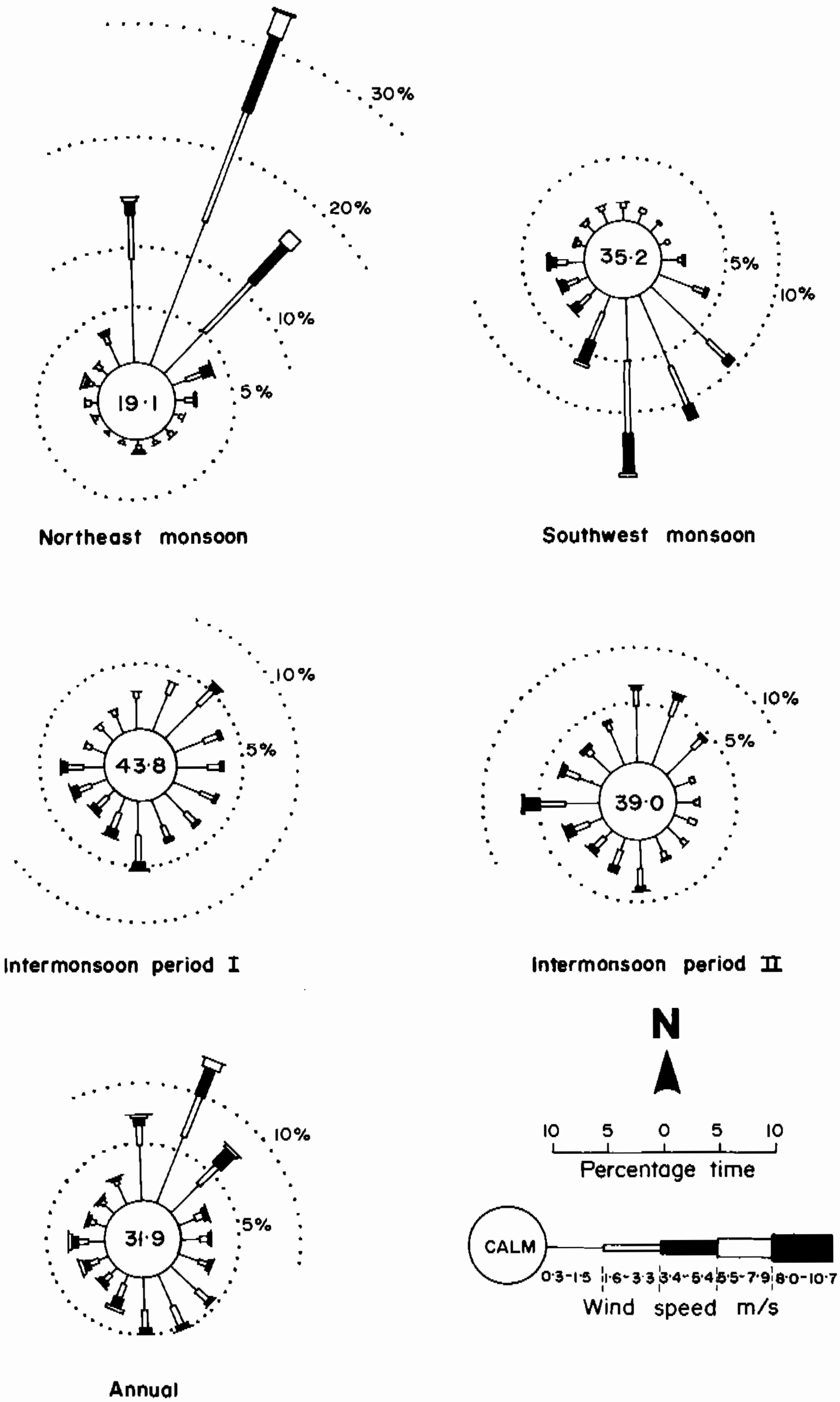

Fig. 2.1. Annual and seasonal windroses, Singapore.

are lower and mean values are at 25.5°C in December and January. Mean monthly temperatures rise to 27.3°C in May and June, giving an annual range of only 1.8°C. Nieuwolt (1966) found that humidity is high on the coast and that the marine influence does not affect conditions more than a few tens of meters from the shoreline.

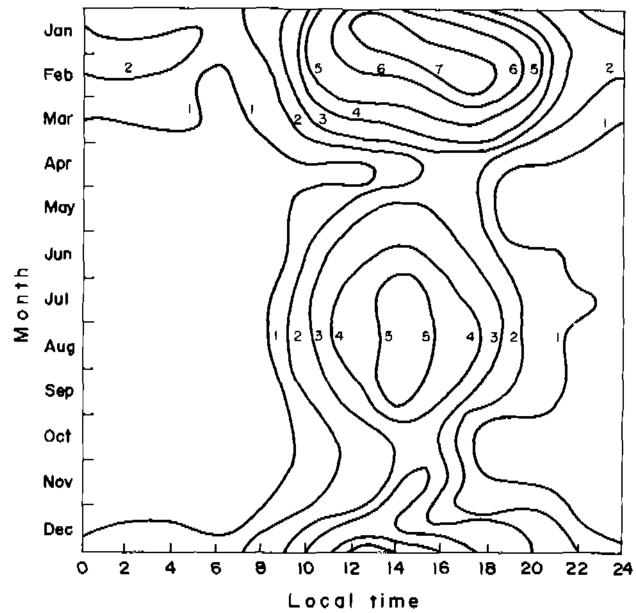

Fig. 2.2. Diurnal and seasonal variations of wind speeds, Singapore.

Precipitation

While rainfall is high in Singapore, the mean amounts vary from over 230 cm within the north central area to below 200 cm along the south coast. There are also significant differences in the annual variation of rainfall over the main island (Fig. 2.3). Runoff from streams in the various water catchment would therefore also be affected by the rainfall regime. There are occasional floods mainly during the early period of the northeast monsoon, resulting from heavy rainfall coinciding with high tide levels (Chia and Chang 1971).

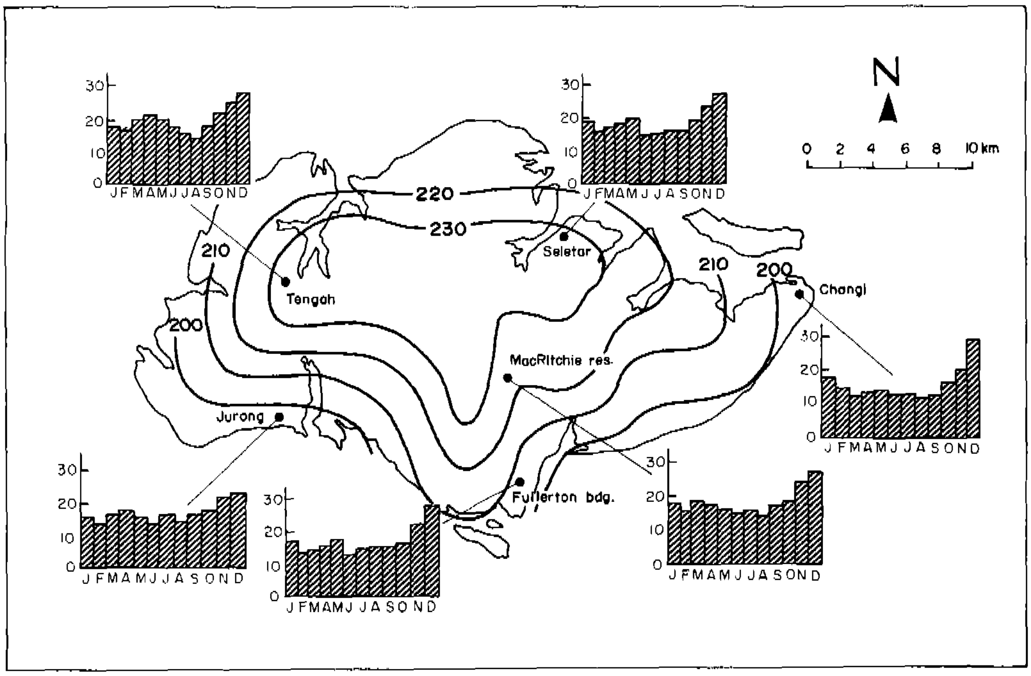

Fig. 2.3. Mean annual rainfall (cm) of Singapore.

Coastal Landforms

There is a fortunate lack of natural hazards in Singapore. The enclosed shallow shelf areas of the South China Sea form a stable block or plate called Sundaland. Thus, Singapore only experiences slight tremors when there are major earthquakes in nearby Sumatra. A concise description of the geology of the Republic is given in Anon. (1982), while Hill (1973) and Thomas (in press) provide detailed discussion. The basic geology of the country is represented by a central core of granites and sedimentary rocks underlying the area to the west and southwest of the main island, while over the eastern parts, there is a thick layer of semi-consolidated alluvial material referred to as the "Old Alluvium" (Fig. 2.4). More recent alluvial materials are found along the river basins and the coasts (Thomas, in press; Anon. 1982).

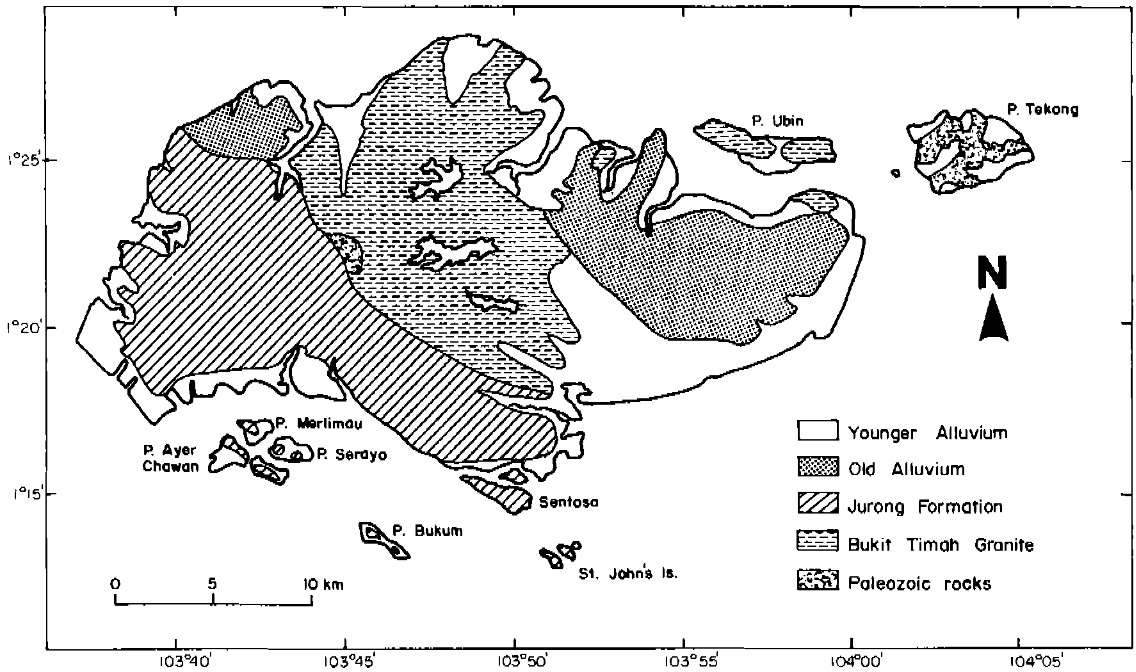

Fig. 2.4. Geology of Singapore.

Effects of sea level changes

The coastal areas have clearly been affected by changes in the sea level. According to Batchelor (1979), a lowering of sea level by around 1,000 m in the Middle Miocene (19-12 million years ago) created an emergent Sundaland continent some 2,000 km wide and extending from western Sumatra to eastern Kalimantan. Subsequently, sea level rose and by the Lower Pleistocene (about 1.5 million years ago), had risen above the continental shelf break to flood the Sunda Shelf. Evidence of sea level changes can be shown by the occurrence of fluviatile, organic and other terrestrial sediments, including laterites, at depths up to 90 m in the South China Sea and the Strait of Malacca as well as the existence of extensive drowned valley systems cut in the floor of the Sunda Shelf (Hill 1968; Biswas 1973, 1976).

In Singapore, two extensive suites of deposits, the Old Alluvium and the Holocene Formations (younger of the two), record some of these changes. The former comprises an extensive semiconsolidated deposit of sand, pebbles and gravels. It is exposed to a height of 46 m on the flanks of the central granitic area and up to 70 m and possibly 138 m in Southern Johor

(Gupta et al. 1980). With the end of the last Ice Age around 12,000 years ago, world sea level rose. The rising sea level resulted in extensive marine clays, beach deposits and associated sediments being deposited around the island.

The Holocene Formations suite comprises two major divisions: the Tekong Formation which is a thin sequence of sands and gravels with estuarine muds and peats; and the Kallang Formation which consists of various sediments including sands, silts, clays and peats found along most of the coastline and filling the often deeply incised lower parts of river valleys draining the main island. These sediments are found on P. Ubin as offshore reef deposits.

The Kallang Formation is further divided into five members (subtypes) giving variation to the natural coastline of Singapore. Starting with the oldest, the Marine Member consists of blue-grey silty clay with sandy, peaty and shelly layers and shell fragments and is largely restricted to the river valleys and estuarine areas below 2 m. It underlies almost one quarter of Singapore and is also found as an extensive offshore mud blanket. The Lower Marine Member was deposited to heights of 2 m above the present sea level. The Alluvial Member consists of pebble beds, sands, clays and peats and is found as valley fill throughout the Island and as thin veneer across the floor of the Kallang and Jurong River Basins. The Transitional Member which consists of a series of unconsolidated black or blue-grey organic muds up to 13 m thick is found in river mouths and tidal swamps surrounding Singapore. This member represents former mangrove swamp sedimentation and may be found both under and intercalated with the Marine Member. The Littoral Member forms a series of coastal beach sands and gravels, offshore sands and tidal sand banks. It is found in the Southern Islands and in shoals south of P. Tekong and east of P. Ubin and P. Seletar. On the south coast of St. John's and elsewhere on several neighboring islands, the Littoral Member includes cemented beach rocks up to 2 m below present sea level. Finally, in the Southern and Southwestern Islands, the active coral reefs and calcareous sands are grouped as the Reef Member and are probably contemporaneous with the Littoral Member. Much of the coastal formations can now no longer be seen as a result of extensive foreshore reclamation.

Relief

The relief features of Singapore are shown in Fig. 2.5. The Republic has a moderately low relief, with more than 60% of the land surface below 30 m above mean sea level (msl) and only 10% above 100 m. The highest point on the island, Bukit (Bt. throughout this text, and which means mountain or hill) Timah, is 165 m. Along the coast of the main island and on some offshore islands, flat reclaimed land characterizes the coastal relief.

To the west and southwest of the main island, including the Southern Islands, the sedimentary rocks give rise to a series of narrow ridges including Pasir Laba Ridge and Mt. Faber-Kent Ridge which runs along a good part of the southwest coast (Fig. 2.5). To the east, the edges of the Old Alluvium have been dissected by a number of small streams and gullies to produce steepsided valleys and cliffs which may be seen as more prominent features along short stretches of the southeastern coast.

For Singapore, a new soil type for reclaimed land along most parts of the coast needs to be included. Soil composition varies according to the original source of the fill material. Soil structure is poor and nutrient levels are low. Initial establishment of a vegetation cover is difficult due to poor drainage. Special management of reclaimed land, including proper drainage and landscaping, needs to be carried out (Rahman, in press).

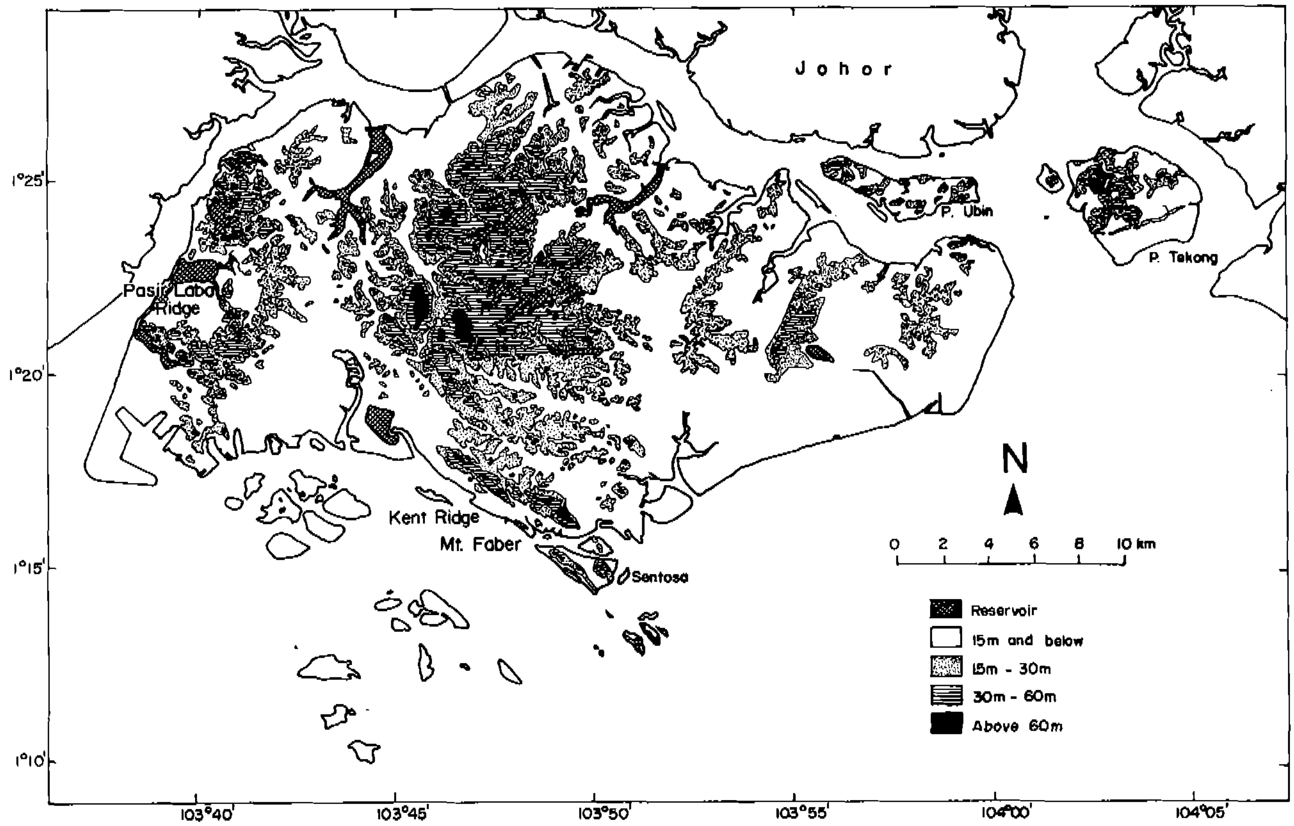

Fig. 2.5. Relief map of Singapore.

Drainage

The complex pattern of drainage on Singapore Island is the result of heavy perennial rainfall acting on the weathered rocks of a varied terrain. The Island is divided into 40 drainage basins, the largest of which is Sungei (S. throughout this text, and which means river) Kranji-Pang Sua Basin which is 68.12 km^2 and covers 12.5% of the total drainage area. The other large basins--S. Seletar, S. Jurong, S. Kallang, S. Rochore, S. Serangoon and S. Geylang --individually drain more than 16 km^2. Together, these seven basins cover 27% of the total drainage area. Eight basins, each less than 2.6 km^2, cover only 2.5% of the drainage area. The average basin size is 12.38 km^2, and the median size is 6.37 km^2 (Fig. 2.6).

Over a quarter of the Island drains southwards to the city area via the Kallang, Geylang and Singapore Rivers. The concentration has resulted in floods. Historically, measures to control them have been effected through interference with the drainage lines (Thomas, in press). Thus, a quarter of the original stream channels have been altered beyond recognition by diversion or artificial channeling, with the remainder much modified (Wong 1969). Further changes in recent years have taken place and are still taking place, especially with the construction of the underground mass rapid railway system and in the central city area.

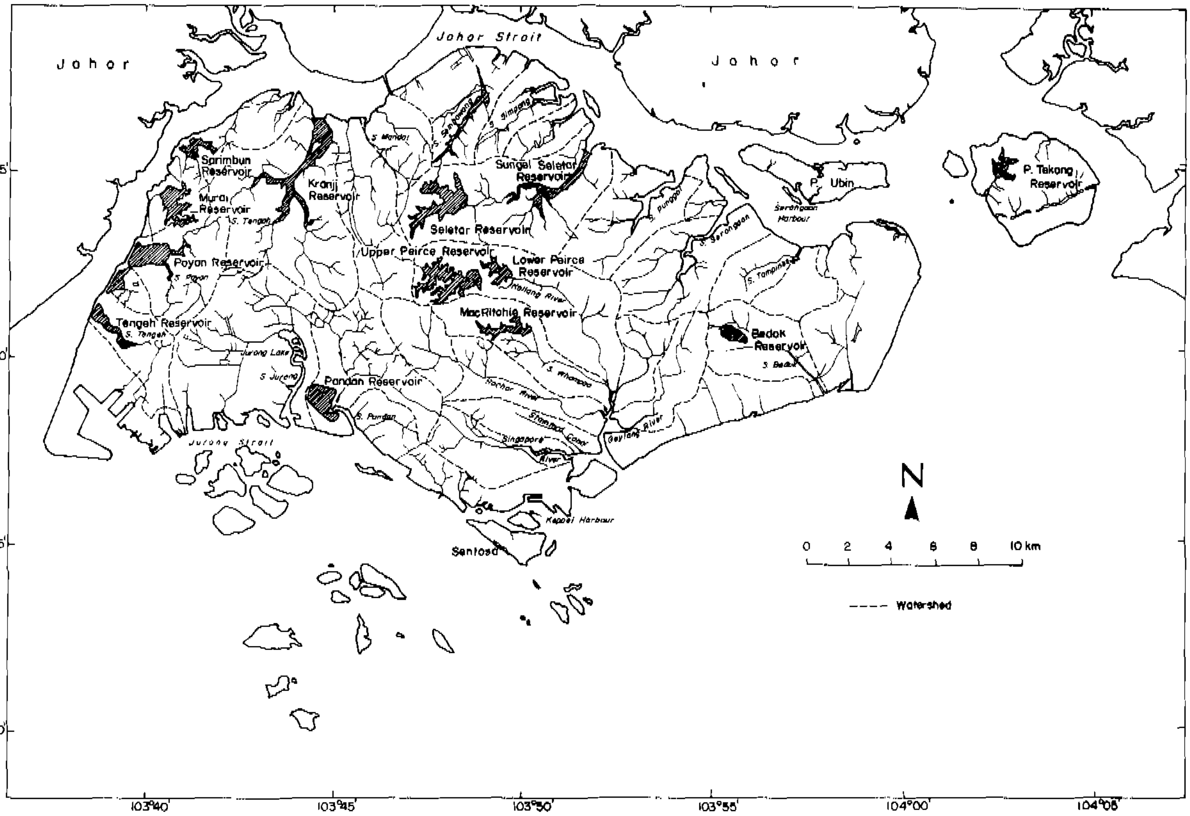

Fig. 2.6. Drainage (rivers, boundaries of catchment areas and reservoirs) of Singapore.

Coastal Features

The lengths of the coast of the main island of Singapore and that of the combined offshore islands are about 131.5 km and about 150 km, respectively. The total length of the coasts of the main island has increased from about 106 km around the early 1970s (Hill 1973) as a result of foreshore reclamation. The disappearance of the original and much more interesting coastline was accompanied by a good deal of straightening and the introduction of vegetation and new soil.

The original coast of the main island was low-lying, with few cliffs and of no great elevation. The most prominent features of the coast on the main island were the ridges along the southwest and west coasts and the granite outcrops at Changi. Many of the hills along the coast, including the cliff along the eastern end of the southeast coast, have been removed to provide fill material for land reclamation. In general, the fill material is highly variable over short distances and consists of fine sand and mud. Pebble beaches are uncommon except close to cliffs. Rivers normally supply the finer sediments.

The coasts of many of the offshore islands, such as P. Senang, P. Sudong, P Ubin and Sentosa, are steep. Details of Singapore's coasts are given by Bird and Schwartz (1985) and Swan (1971). Several coastal types have been identified by Wong (1966) as follows:

1. Cliffs - defined as slopes of more than 40^{o} but often are vertical with no vegetation on them. They are bordered with beaches and are mainly found along the southeast and west coasts of Sentosa, St. John's Island, P. Brani, along Tanah Merah, Changi Creek (all have since

been obliterated), P. Ubin, Tanjong (Tg. throughout this text, and which means headland) Punggol, Labrador and near Tg. Gedong.

2. Steep coasts - with slopes between 20° and 40° and usually are covered with vegetation and bordered by beaches. They are common in the northwest near Tg. Gedong and in isolated sections at Tg. Pasir Laba, Tg. Gul, Ayer Gemuruh and P. Tekong.

3. Sandy coasts - comprise materials of less than 4 mm in diameter. The longest stretch of sandy beaches is found along the southeast of the main island stretching from Tg. Rhu to Batu Puteh. Other stretches are found along Pasir Panjang, Pasir Ris, Punggol and Tg. Irau. Reclamation along most of these coastal stretches has changed the characteristics of the coasts drastically.

4. Pebbly or stony coasts - have sand grains of more than 4 mm in diameter. The more common stony beaches are found in isolated short stretches at Tg. Gul, Tg. Chenting and Tg. Murai where they are underlain by sedimentary rocks. Two other segments are found at Tg. Punggol and Changi.

5. Mangrove swamp coasts - are in estuaries and are colonized by mangroves. Recent deposits of fine sand, mud and humus are found along such coasts.

6. Coral coasts - are fringed by coral formation and are found mainly in the southwestern coasts from Tg. Tuas to P. Semulun (now reclaimed) and the yet unreclaimed Southern Islands.

7. Seawalls and artificial coasts - are created by reclamation and seaport and airport construction. Such coasts first appeared soon after the arrival of the British in the early 1800s. Today, this type of coast stretches along the stretch of the southern coast from Pasir Panjang Wharves to Tg. Rhu and along the Jurong seafront.

Beaches

Beaches in Singapore are generally intertidal and narrow. Cemented beach and conglomerate sand are found on some of the Southern Islands. Beaches comprise the backshore, foreshore and offshore zones. These zones are associated with dynamic processes which shape their physiographic features. Details on the beaches in Singapore were given by Ang (1979), while Wong (1981, 1985) reported results of studies on artificial beaches in Singapore.

Main Island Beaches. On the main island, the reclaimed land of the southeastern coast forms the only beach of substantial length which stretches from Tg. Rhu to Changi Airport and consists of some 53 cells. Each cell is part of the shore between a pair of breakwaters, irrespective of the actual shape of the shore (Wong 1973).

The artificial beaches are known as the East Coast reclaimed beaches and are exposed to the refracted swell from the South China Sea (Chew et al. 1975). The predominant wave action is from the southeast, and there is a westward littoral drift. Beach development here is influenced by structures such as seawalls, large drains and jetties. Accretions occur on the upcoast side of each structure while erosion occurs on the downcoast side. Details of the features, processes involved and interaction between the beach and the man-made structures were given by Wong (1973) and Chew et al. (1975).

Elsewhere on the main island coast, beaches are isolated and of limited length. The only other group of reclaimed beaches is that along Pasir Panjang. The reclaimed material is derived from sedimentary fill taken from the nearby Telok Blangah Hills. The beach of P. Terumu Laut is made up of fill taken from the Sisters Shoal and is mainly of calcareous, shelly material. Coastal vegetation, including *Casuarina equistifolia,* has colonized the berm.

The natural beaches on the main island are limited to the north-northeastern coast and the western coast. These beaches are in a very sheltered situation. The Changi beaches are found along an igneous coast, and the material is derived from granodiorite. The beaches on the sandpit extend westwards. Here, wide foreshores and developed berms are characteristic features. Except for the beaches on Changi, the west coast beaches are poorly developed.

On the Pasir Ris beaches, the sand has been removed in some areas to expose the underlying Old Alluvium. At Punggol, the end of the foreshore is marked by a line of pebbles. Young mangroves are found on the foreshore of the beach at Seletar, and below the sand deposit is a layer of peat indicating a former swamp area. The formation of the beach at Sembawang is disrupted by the presence of a jetty, slipway and drain. In addition, the western coast beaches are washed by polluted discharge from the nearby swamps at ebb tide. Land reclamation has been carried out along the northwestern coast.

Offshore Island Beaches. On the offshore islands, the largest group of artificial beaches is found on the relatively exposed Southern and Southwestern Islands. These islands have been reclaimed using fill material transported from the nearby Sisters Shoal and Beting Kapal. Rock bunds are built round these reef-fringed islands to contain the fill. Gaps are provided to encourage the beach to form. The beaches of the Southern Islands are at various stages of development. Those exposed to strong wave action, such as Kusu and Sisters Islands, are well-developed. The beach along the southeastern tip of St. John's is well-developed as are the beaches on Lazarus Island which have a wide and well-developed berm. On P. Brani, a beach has formed behind a break in the rock bund. The best and longest beach among the Southern Islands is on the southern shores of Sentosa Island. On other islands, beaches are less well developed.

To the northeast, there are reclaimed beaches on the sheltered Coney Island and P. Seletar. The beach material is derived from that transported from the Alang Perimbi Shoal off Punggol and is mainly of quartzose sand. However, the beaches are as yet not well-developed due to the limited exposure to wave action and insufficient duration from the time the material was brought in.

Natural but poorly developed beaches are found on the offshore islands to the northeast, i.e., Ubin and Tekong, and the islands of Semakau, Pawai and Senang to the southwest. The berms are usually narrow or absent. Typically, a narrow linear foreshore is succeeded seawards by a low-tide terrace consisting either of sand and mud or of lines of pebbles. These natural beaches are found alongside mangrove coasts.

The beach material on the northeastern islands of Ubin, Tekong and Tekong Kechil is derived from locally weathered rocks. These beaches are relatively sheltered from wave action. Small pocket beaches are found on this group of islands where rocky headlands are closely spaced and there is a limited supply of sediments.

Finally, the natural beaches on the southwestern group of islands of Semakau, Pawai and Senang are exposed to long swells and strong wave action. However, beach development is hampered by the presence of mangroves and limited sediment to form beach material.

Vegetation

The original forest cover was already largely removed by the latter part of the 19th century as a result of land clearance for commercial crop agriculture and later for market gardening and urban expansion. The freshwater swamp forest in Nee Soon (Yishun), for example, was only removed in the present decade. Riparian forest is found only in small patches along rivers on the northern part of the island which have now been dammed to create reservoirs. Similarly only remnants of the mangrove forest are found in Jurong-Pandan, Kranji, Seletar-Tampines, P. Hantu and P. Ubin. Some beach vegetations are still left in Labrador Park and Raffles Lighthouse.

Mangrove Forests. Mangroves are found inside tidal river mouths and may spread along the coast. *Api-api, Avicennia* spp., can withstand the effects of the tide even under extreme conditions. When there is a high percentage of humus mixed with silt, *perepat, Sonneratia* spp., will establish itself. Other species can then colonize readily. Most of the tree flora is confined to four families: *Rhizophoraceae* (the most important), *Lythraceae, Verbanaceae* and *Meliaceae.*

The filling of swampy land and the removal of mangroves began early in the settlement history of Singapore. Land reclamation and construction of estuarine reservoirs have left only a few patches of the mangroves, mainly in the estuaries on the northeastern coast of the main island and on a few offshore islands,including P. Ubin and P. Tekong.

Beach Vegetation. Sandy beaches support a distinctive flora of species particularly adapted to conditions of the seashore. The upper parts of the sand may become invaded by grasses and sedges which act as sand binders and help to consolidate the substratum. Further inland, *ru, Casuarina equsetifolia,* and the screw pine, *Pandanus* spp., form a coastal fringe of trees on consolidated soil. This narrow band of sandy beach forest includes such trees as *Hibiscus tiliaceus* (sea hibiscus)*; penaga laut, Calophyllum inophyllum; ambong ambong, Scaevola frutescens; Cocos nucifera* (coconut)*;* and *pong pong, Cerbera odollam.* The last two have water-dispersed seeds.

Sandy beaches have little or no seaweed flora but usually, especially where there is some mud, the higher plant tapegrass, *Enhalus acoroides,* forms extensive beds at LWST.

Another higher plant, *Halophila* spp., also occurs in low-level pools. Sheltered beaches on Johor Strait may have sporadic outbursts of *Ulva* and various *Siphonales.* The true seaweed flora is well-developed on reefs, particularly in Southern Islands. On the beaches, the distinct zones of different seaweed species areas somewhat intermingle, and there is considerable mixing between the regions. Teo and Wee (1983) provided a description of the seaweeds found in Singapore waters, although they did not give spatial descriptions of the occurrence or abundance of the seaweeds.

Bird life

Of some interest mainly as a form of recreation is the bird life found along the less developed coasts. The bird life of Singapore is comprehensively described by Johnson (1973) and Briffet (1986). Compared with the other tropical countries, Singapore has poor bird life. Of over 280 species, less than 25% are resident species; the rest are vagrants or migrants occurring only at certain times of the year.

Human activities such as reclamation are the main reasons behind the reduction of habitats for bird life. The creation of urban parks and gardens and the planting of roadside trees have helped alleviate the pressures of advancing concrete development, but the most important and productive habitats for birds are still the protected nature reserves, water catchment areas and some of the rural coastal strips. Since about 1985, the Parks and Recreation Department (PRD) has begun creating small bird sanctuaries in coastal parks to encourage a large bird population.

The migrants which overwinter include the wading birds from the northern parts of East Asia; various egrets from Malaysia and Southeast Asia; durian starling , *Sturnus sturninus;* eastern swallow, *Hirundo rustica;* and brown-breasted bee-eater, *Merops superciliosus.* Many of these migrants are attracted to towns and cultivated areas, but others tend to avoid densely populated estates. Mangrove swamps and similar areas form gathering grounds for many small birds, waders and ducks (Johnson 1973).

In the mangroves around Kranji Dam, at low tides, herons, egrets and wading birds including several species of curlews, snipe and related forms often gather at the mudflat.

Mangroves attract many insects and birds. The latter include the flyeater, *Gerygone sulphurea*; common iora, *Aeqithina tiphia*; pied triller, *Lalage nigra*; and some migrant warblers such as the greenish, tree-dwelling leaf warblers of the genus *Phylloscopus*.

Around S. Sembawang (Senoko) area, water birds and waders are the more conspicuous species. The area is principally a river estuary which has been partly reclaimed. During migration periods, large flocks of waders seek this area as a gathering ground. The commonest waders are sandpipers; plovers, *Charadrius* spp.; and common redshank, *Tringa totanus*. Ducks are occasionally seen with flocks; they include the common teal, *Anas crecca* and the Indian whistling duck, *Dendrocygna javanicus*. The uncommon great knot, ruff and godwits are sometimes present. The moorhen, *Gillinula chloropus*, can usually be spotted also. Grey heron, *Ardea cinera*, and the purple heron, *A. purpurea*, are conspicuous. Up to five species of egrets (*Egretta* spp.) are conspicuous during winter.

In St. John's Island, the lush tree growth provides suitable habitat for bird life, besides rocky shoreline and muddy foreshore at low tide. Species occurring here are the white parrots (called little corellas), sulphur-crested cockatoos, mynas, coppersmith barbets, sunbirds, bulbuls, flowerpeckers, pipits, fishing reef egrets, common sandpipers, kingfishers, brahminy kites, eagles and ospreys.

Chapter 3
Coastal Waters

Territorial Waters

Since the signing of UNCLOS at the end of 1984, the Republic of Singapore no longer enjoys absolute freedom of the high seas. Over the last three decades, coastal states have one after another declared unilaterally the 22 km (12 nm) territorial sea limit and added the 370 km (200 nm) EEZ and placed the control of the coastal waters under their jurisdiction. In effect, Singapore became a GDS as it became shelf-locked as a result of the enlargement of the territorial waters of the neighboring states of Malaysia and Indonesia.

While the southern sea boundary of the Republic with Indonesia has been agreed upon, the northern boundary in Johor Strait is currently under negotiation as with the triple-point eastern and western distal end of the boundaries. No official estimates have been given for the size of the territorial waters of Singapore, but it would be about 300 km^2. The boundaries of Singapore's territorial waters (Fig. 1.1) coincide closely with the port limits, and the port waters are under the management of PSA and the Land Office of the Ministry of National Development (MOND).

Seabed Configuration

The seabed of the waters surrounding Singapore is highly irregular, being strewn with numerous islands and shoals. Most of the coastal waters are not more than 30 m deep. For navigation, sufficiently deep waters which come close to the shoreline, as shown by the 10-m isobath (Fig. 3.1), together with the sheltering effect of the surrounding islands, have provided Singapore with its well-known, excellent natural harbor. Thus, deep waters are found along the southern coast, especially the southwestern coast along Keppel Harbour, with channels of over 20 m deep running through the western, southwestern and southern groups of islands which form the Southern Islands. A large stretch of deeper waters of over 20 m is found off the southeastern coast. Sections of Main Strait have very deep waters, exceeding 50 m, and a trench is found off St. John's Island. The greatest depth here is 714 m (Hill 1968). The axis of the trench lies in an east-west direction, and there are other areas below 60 m. These trenches were probably part of the channels of the valleys of the ancient river system which used to flow across Sundaland.

Within Johor Strait, the western portion, though narrower, is deeper than the eastern portion. From the western entrance, some three-fifths of western Johor Strait is over 10 m in depth. The deeper waters are restricted to a narrow strip around Changi Point at the eastern

Fig. 3.1. Seabed configuration of the coastal waters of Singapore. (Numbers in fathom.)

end of the main island. The shallow depth in eastern Johor Strait is due to the large S. Tebrau which disgorges near the causeway and the very large S. Johor which emerges north of P. Tekong. These rivers carry very large sediment loads.

The seafloor is covered with unconsolidated sand and mud, some deposited at the end of the Pleistocene Era after the sea level rose. But the seafloor may be swept clear of sediments along channels where the velocity of tidal currents is high. This appears to be the case along parts of the channel across the main island and P. Seraya where an underwater tunnel has recently been constructed.

Characteristics of Coastal Waters

Tides and currents

The Singapore coast, as elsewhere in the humid tropics, is characterized by accumulation rather than erosion. This arises primarily because of the low wave and tidal energy conditions (Swan 1971). During the various periods of lower sea level in the Pleistocene Era, there was deep weathering of the exposed continental shelf which generated large quantities of sediments. Subsequently, when sea level rose, this material was reworked by the transgressing shore zone and redeposited as extensive plain of coastal accumulation (Thomas, in press). The eroded land surface during the period of low sea level and the subsequent rise in sea level since the Pleistocene Era, which drowned the land masses, also explain the uneven coastal seafloor around Singapore.

Singapore's low-energy marine and coastal environment is due to the protection by the surrounding land masses. Wave fetch is generally short, and the directions of maximum fetch rarely coincide with those of the strongest winds. In addition, wave power is dissipated through refraction and obstruction by the shallow waters, islands and reefs. Thus, the average breaker height is less than 20 cm (Chew 1974; Swan 1971). Meter-high openwater waves may be generated by the Sumatran squalls during the southwest monsoon and by swell from the South China Sea, but again refraction and obstruction reduce their effects at the shore (Wong 1985; Chew et al. 1975).

Tides. The Singapore tide is a direct result of the tides generated in the South China Sea and to a lesser extent those produced in the Indian Ocean. Generally, the tide in this region is semidiurnal with a mean range of 2.2 m and a spring maximum of 3.0 m. It is characterized by two occurrences of both high and low waters within a lunar day. The second high and low waters are of a lower range, and the difference in the heights of successive high and low waters is referred to as diurnal inequality. The rising tide moves westward, and the ebb tide, eastward. The time of the turn of the tide is coincident with the time of high and low waters at certain points only (Khoo 1966). Tide observations are made at Sembawang Dock, Sultan Shoal Lighthouse, Raffles Lighthouse, Keppel Harbour, Jurong Wharf and Horsburgh Lighthouse (Fig. 3.2).

Tides at different periods of a lunar month and at different positions of the sun were studied by Lim (1983, 1984) and Chua and Lim (1986). The latter noted that the tides in the vicinity of Jurong, Raffles and Sultan Lighthouses show similarity in the magnitude of diurnal inequalities between successive high and low waters. It is also usual for the lower of the two low waters to occur after the higher high water. As for the waters between Keppel Harbour and Horsburgh Lighthouse, and in the vicinity of Sembawang, the two heights of successive low waters differ appreciably whereas the difference in the height of the two high waters is small (Fig. 3.3).

Range of Tide. Observations reveal that spring or neap tides in Singapore Strait occur two days after the new/full moon or first/last quarter of the moon. The range of tide decreases

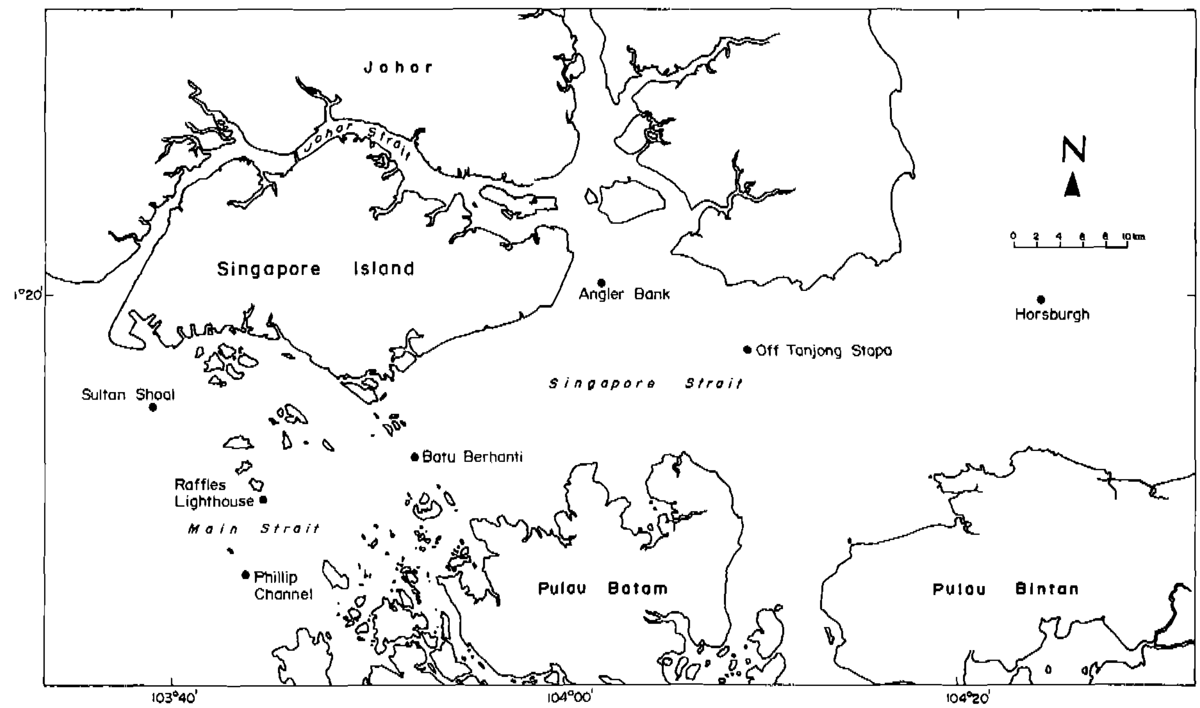

Fig. 3.2. Tide observation stations.

gradually as movement progresses further eastward away from the Singapore Island (Table 3.1). Diurnal range reaches a peak when the moon is farthest from the equator, and the tides occurring at such times (twice in a lunar month) are known as tropic tides (Table 3.2).

Mean Sea Level. The msl varies from day to day due to changes in water density, wind and atmospheric pressure. The monthly mean also fluctuates, but the variation of yearly means in Singapore is marginal (Fig. 3.4). The monthly msl is lower than the yearly one in April to September, mainly as a result of the prevailing southwesterly winds when the water mass is moved away from the land mass towards the South China Sea. On the other hand, the monthly msl is higher in November to January during the northeast monsoon when winds pile up the water at the southwestern portion of the South China Sea (Chua and Lim 1986).

Tidal Streams/Currents. Tidal streams or currents circulating around Singapore are known as monsoon currents because they are generated by the prevailing winds during the monsoons (Tham 1973a). The general pattern of current movements around Singapore is shown in Fig. 3.5. In general, tidal streams at the western entrance of Singapore Strait flow in a south-south-west or north-north-west direction, while those at the eastern end flow in west-south-west or east-north-east direction. In places such as Keppel Harbour and Selat Jurong, owing to the constriction of land masses to the north and south, the pattern of flow of tidal streams is rectilinear, i.e., in an east-west direction. During the day, there is generally only one strong eastgoing stream accompanied by two westgoing streams. The former occurs at about the time of high water prior to lower water, and becomes strongest about two hours before the time of lower low water. The westgoing stream occurs about halfway between the time of the lower low water and its consecutive high water. It becomes strongest twice and is interrupted by a pause of weaker stream. After attaining its first maximum velocity, the westgoing stream decreases in velocity to become weak, or may even slacken to become a weak easterly flow before resuming its high velocity. The westgoing stream flows for a longer period of more than 15 hours; then it turns to become an eastgoing stream (Chua and Lim 1986).

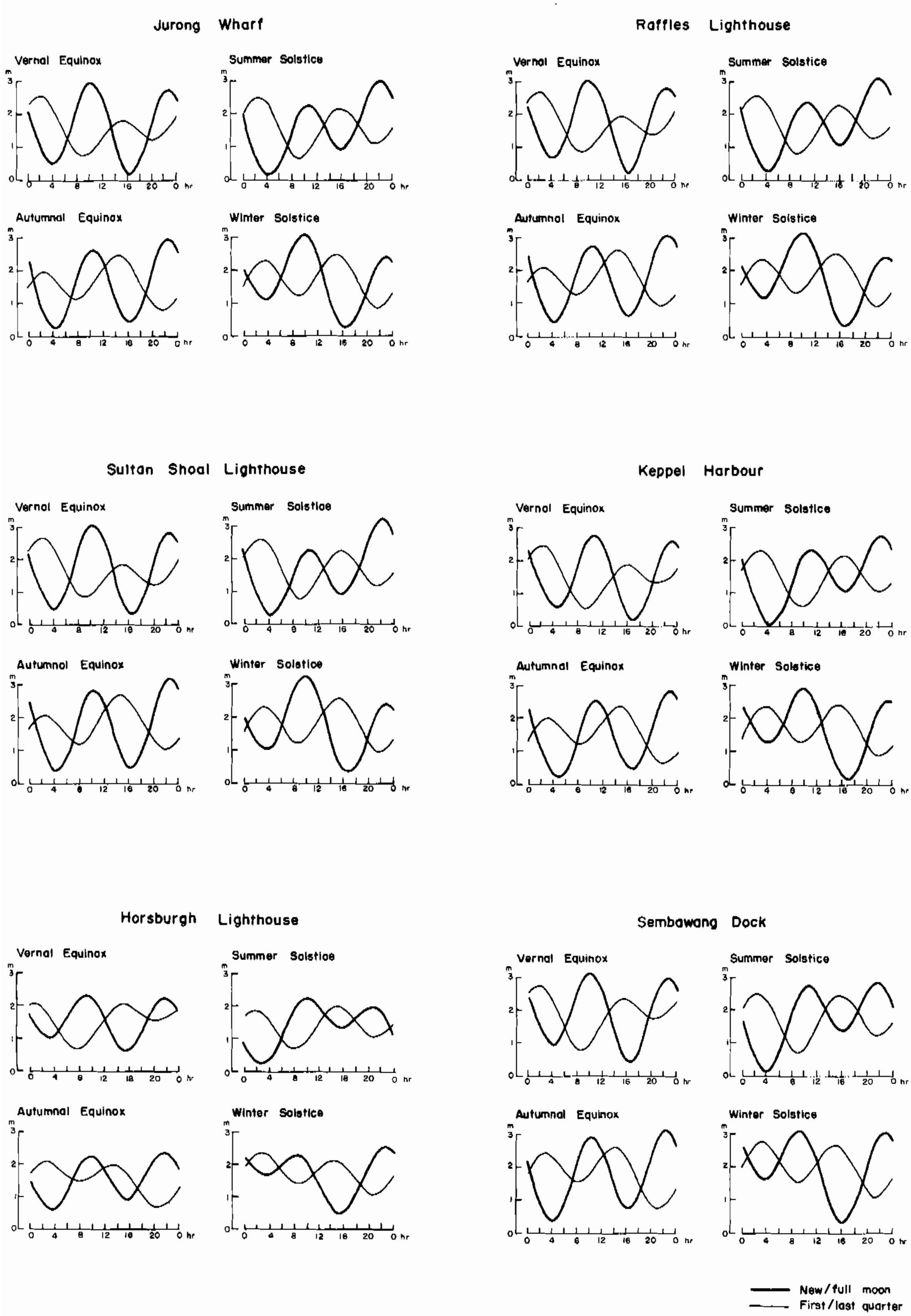

Fig. 3.3. Tides at various stations in Singapore.

Table 3.1. Tidal range of spring and neap tides (m).

Station	Spring range	Neap range
Sembawang	2.5	1.1
Sultan Shoal Lighthouse	2.5	0.9
Raffles Lighthouse	2.4	0.9
Jurong	2.4	0.9
Keppel Harbour	2.3	0.9
Angler Bank (off Changi)	2.1	0.9
Horsburgh Lighthouse	1.5	0.7

Source: Chua and Lim (1986).

Table 3.2. Diurnal range of tropic tide (m).

Station	Range
Sembawang	1.2
Sultan Shoal Lighthouse	1.0
Raffles Lighthouse	1.0
Jurong	1.0
Keppel Harbour	1.1
Angler Bank (off Changi)	1.2
Horsburgh Lighthouse	1.1

Source: Chua and Lim (1986).

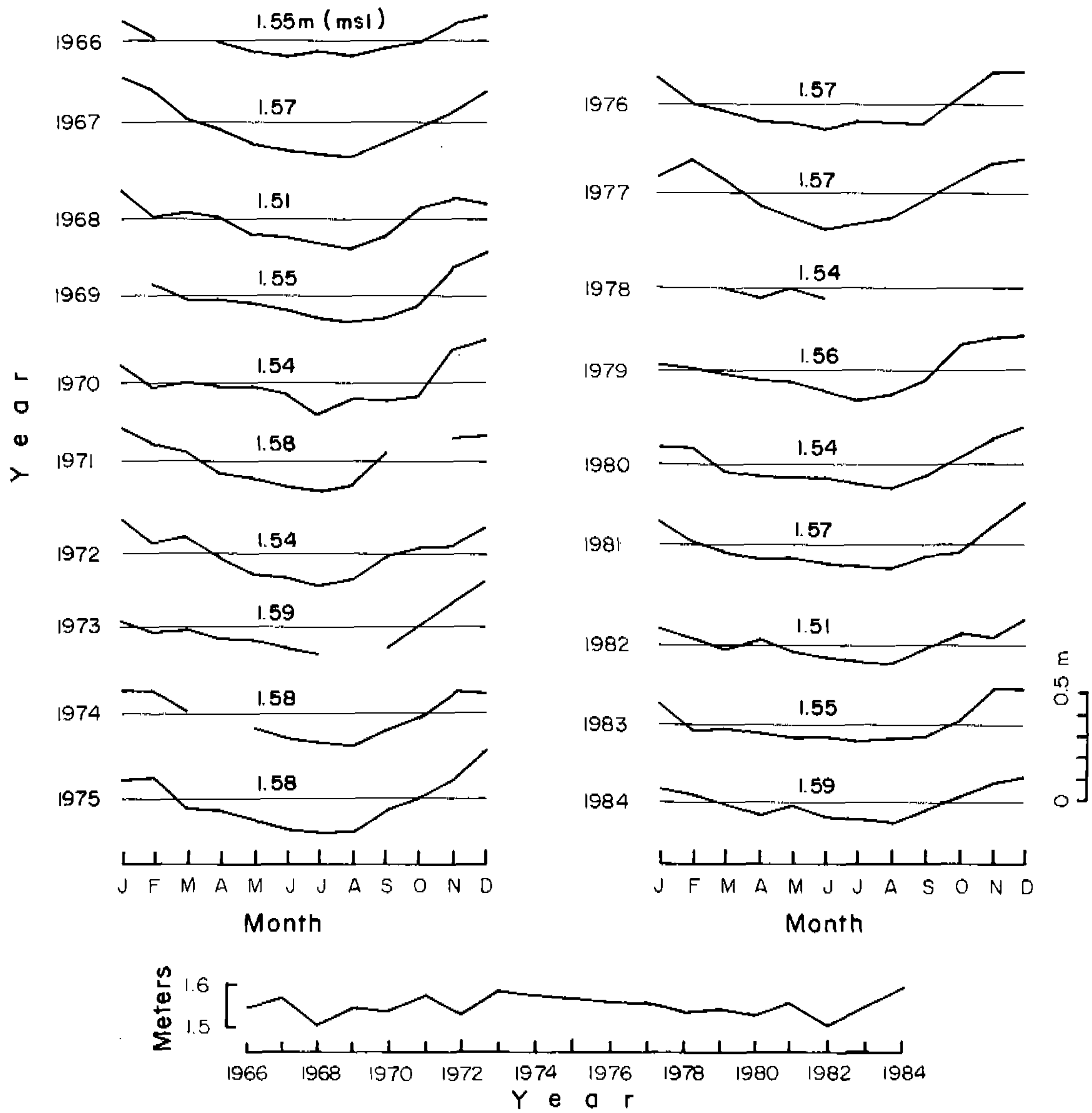

Fig. 3.4. Seasonal and annual changes of sea level at Keppel Harbour, Singapore, 1966-1984.

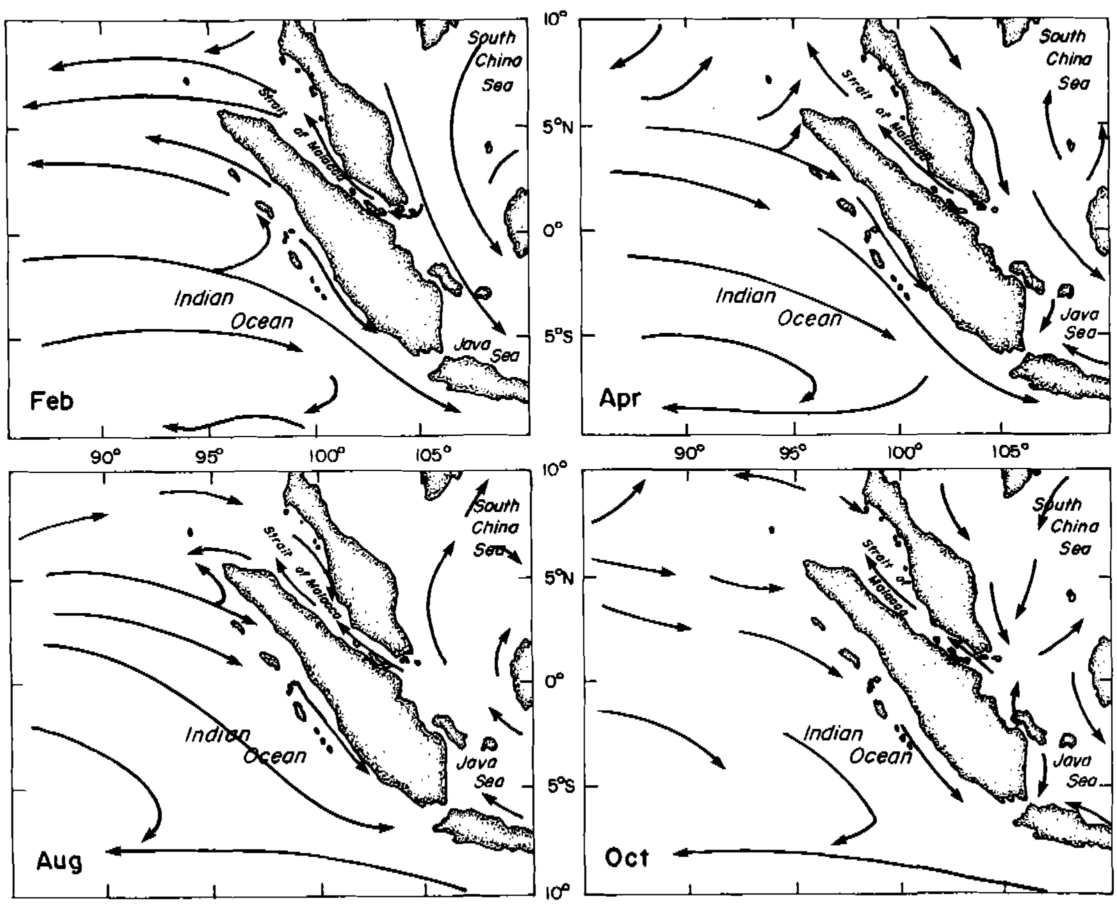

Fig. 3.5. General ocean surface currents of the waters around Singapore.

Studies by Lim (1983) on current movement in East Johor Strait and adjacent waters showed that the patterns of tidal current at the surface and near bottom were very similar. During flood tide, water enters East Johor Strait from Kuala Johor, and the direction is reversed during ebb tide. Both the surface and near bottom tidal currents in Kuala Johor are stronger than those in East Johor Strait. Also, in both areas, the ebb flows were observed to be stronger, and the surface currents were stronger than the near bottom currents. Kuala Johor has a stronger residual current than East Johor Strait where the net current moves seawards at the upper layer and towards Johor Causeway near the bottom. This is in contrast to the surface and near bottom water in Kuala Johor which flows into Singapore Strait.

In Singapore Strait and West Johor Strait, the monsoon currents are superimposed on the tidal currents (Tham 1953). Lim's (1984) investigation on the hydrological conditions in West Johor Strait showed that during the northeast monsoon, a branch of the southerly current in the South China Sea moves along the east coast of Peninsular Malaysia and turns round the southern tip of the peninsula to move through Singapore Strait before entering the Strait of Malacca. During the southwest monsoon, a northerly current from Java Sea passes into Singapore Strait and into the Strait of Malacca through the east coast of Sumatra and into the South China Sea (Fig. 3.5). Thus, Singapore Strait receive water from South China Sea during the northeast monsoon and from the Java Sea during the southwest monsoon (Lim 1984; Rahman and Chia 1977).

Tidal streams within Singapore Strait attain maximum speed first at the eastern entrance and then progressively farther westwards. The mean time difference between the maximum tidal streams at Phillip Channel and the eastern entrance at the spring tide is approximately 1.8 hours. The time difference is, however, much shorter when the tidal current is diurnal.

The maximum rates of tidal currents recorded for a number of stations, eastgoing and westgoing, respectively, are: Phillip Channel, 6.8 km/hour and 4.6 km/hour; Keppel Harbour, 5.2 km/hour and 4.4 km/hour; off Tg. Stapa, 6.5 km/hour and 4.6 km/hour; and Batu Berhanti, which has the strongest, 12 km/hour and 7.6 km/hour.

Nontidal Currents. Those currents arising from the prevailing winds can attain a maximum speed of 0.5 kt in the eastern and southern part of Singapore waters during the southwest monsoon. The speed reaches a maximum velocity of 0.3 kt in Main Strait. During the northeast monsoon, nontidal currents are westgoing in all waters of Singapore and reach a maximum rate of 0.7 kt (Chua and Lim 1986).

Biological Aspects

As a result of the interaction among the various environmental factors and the organisms of differing physiology, adaptations and behavior, it is not surprising that the community of animals varies in composition from one place to another horizontally and vertically along the coast. Environmental factors such as climate, bottom topography of the sea, tides and currents, water salinity, turbidity and temperature affect the distribution of organisms along the coast and in the sea. Tham (1973a) provided a useful review; Lim (1983, 1984) dealt with the hydrological conditions in Johor Strait; and Lee (1966) gave details of the shore flora and fauna off Tg. Teratip.

Plankton

The data on monthly variations in the distribution of plankton, such as the diatoms of the genus *Coscinodiscus* and copepods, in the three sectors of Singapore waters were gathered by the following: (1) Singapore Strait, Tham (1953); (2) Serangoon Harbour and Johor Strait, Khoo (1966); and (3) Punggol Estuary which drains into Johor Strait, regarding observations on the changes in the environmental conditions, Chua (1966) and Tham et al. (1968).

Phytoplankton. Phytoplankton are primary producers and thus determine and affect the other trophic levels in the marine ecosystem. The results of plankton surveys by Tham (1953) on Singapore Strait and Khoo (1966) on Johor Strait was similar. This is because the bulk of the water in Johor Strait, and therefore the phytoplankton, came from Singapore Strait.

The results showed that diatoms dominated the phytoplankton flora in Singapore waters, and there were five peaks of abundance in a year: July, September (only in Johor Strait), November, January and April. Here, the phytoplankton in the waters not only fluctuated constantly but also sharply, and there was no prolonged period of "bloom". The plankton count in Johor Strait obtained by Khoo (1966) was found to be very much lower than that in Singapore Strait (Tham 1953). It was possible that the lower count was due to grazing by plankton-feeding fish as later it was shown by Khoo (1966) that the fish catch in Johor Strait was much higher than that in Singapore Strait. Also, the fish in this area were mainly plankton-feeders (Table 3.3).

The relative amounts of each species or genus were seen to vary from month to month. Usually, only one or two species of diatoms were markedly abundant at any month and the dominant species changed in the course of the year. Many species were observed to be present each month but only a few were predominant. Changes in the planktonic community occurred

Table 3.3. Abundance of the main fish groups (expressed as percentage of total sample) in Johor Strait.[a]

Fish groups / Period	1965 Jul	Aug	Sep	Oct	Nov	Dec	1966 Jan	Feb	Mar	Apr	May	Jun
Plankton feeders	77.98	83.81	65.88	36.55	73.27	93.55	71.71	82.56	49.93	42.58	92.63	87.00
Stolephorus spp.	44.60	63.62	59.27	9.05	51.92	82.48	42.07	35.99	16.87	7.89	6.51	38.52
Clupea spp.	32.57	19.11	5.78	22.56	18.36	8.76	25.24	40.23	19.77	28.04	79.31	41.73
Predators	6.34	2.40	4.96	4.60	6.15	4.12	15.46	10.29	5.79	4.80	1.96	4.55
Benthos feeders	1.55	0.59	5.27	4.60	4.49	0.48	2.79	3.14	0.74	3.34	2.13	2.28
Crustaceans	–	–	1.95	1.94	1.63	0.65	2.16	1.32	0.66	0.90	0.07	0.06
Other low-quality fish and invertebrates (trash fish)	13.30	12.93	10.62	44.62	1.63	0.65	3.45	0.67	41.32	46.32	1.94	4.39
Total sample (g)	12,171	29,741	16,868	8,798	4,722	6,972	4,687	5,963	5,303	5,572	4,460	6,405

[a]"Fish" is used here to include both aquatic vertebrates and invertebrates of fishery values.

Source: Khoo (1966).

rapidly in Singapore waters, taking as short a time as two weeks. In the periods of investigation by Tham (1953) and Khoo (1966) in Singapore Strait and Johor Strait, respectively, there seemed to be a certain pattern in the variation of phytoplankton, zooplankton, temperature, salinity and dissolved phosphate in Singapore waters. The predominant species in both straits were also recorded by the two (Tables 3.4 and 3.5).

These results showed that certain phytoplankters such as *Thalassiothrix, Hemidiscus, Rhizosolenia, Biddulphia, Bacteriastrium* and *Dictylum,* were present in Singapore Strait throughout the year but bloomed only during certain periods (Table 3.4). They were not common and bloomed only very occasionally in the other two sectors. On the other hand, phytoplankton such as *Nitzschia, Lauderia, Guinardia* and *Leptocylindrus* were present in Johor Strait during the greater part of the year and bloomed for short periods during certain months (Table 3.5); but

Table 3.4. Diatom cell counts expressed as percentages of monthly averages (1965/1966) in Johor Strait.

Species / Month	1965 Jul	Aug	Sep	Oct	Nov	Dec	1966 Jan	Feb	Mar	Apr	May	Jun
Coscinodiscus	61.56	63.42	23.50	79.32	16.20	28.83	16.81	83.89	79.00	90.86	34.04	46.14
Biddulphia	0.34	0.99	0.53	1.29	0.90	1.32	0.33	0.76	0.49	0.06	0.25	0.47
Ditylum	0.93	0.66	12.32	3.86	1.87	1.13	0.36	0.57	–[a]	0.07	0.08	1.11
Chaetoceros	17.22	13.68	17.48	0.88	51.17	13.49	3.91	3.38	12.89	2.67	3.18	22.04
Bacteriastrum	0.04	–	11.19	0.60	2.86	0.07	0.31	0.13	–	–	–	–
Thalassiothrix	0.63	4.20	1.48	4.65	–	3.10	0.48	5.90	1.23	1.27	–	1.75
Rhizosolenia	–	0.66	–	0.40	1.35	6.66	0.34	1.12	2.30	0.21	–	1.18
Navicula	0.42	–	0.67	–	0.02	–	–	–	–	0.03	0.33	0.20
Staurastrum	0.13	–	–	–	0.23	0.49	–	0.21	0.49	0.32	0.08	–
Nitzschia	15.79	5.93	14.16	–	0.18	41.59	19.52	–	1.32	–	–	0.74
Lauderia	–	8.28	14.17	5.24	14.86	–	0.22	0.31	–	–	–	2.30
Guinardia	–	–	–	0.69	4.01	0.33	0.03	0.31	–	0.13	–	5.37
Leptocylindricus	2.63	0.96	0.72	1.89	0.13	1.19	57.85	2.21	–	1.31	0.41	1.36
Hemidiscus	–	–	0.16	–	–	–	–	–	–	0.07	59.37	16.40
Average monthly cell counts	213,800	66,400	192,100	86,900	451,600	301,550	554,050	209,250	54,550	492,600	159,500	86,700

[a]A dash (–) signifies absence.

Table 3.5. Diatom cell counts expressed as percentages of monthly totals in Singapore Strait.

Diatom genera / Period	1936 Jan	1947 Feb					1935					
			Mar[a]	Apr	May	Jun	Jul[b]	Aug	Sep[b]	Oct	Nov	Dec
Coscinodiscus	26	12	—[c]	20	p[d]	6	p	9	p	14	13	15
Chaetoceros	2	18	—	12	97	26	—	p	—	6	17	8
Biddulphia	6	14	—	12	—	11	—	79	—	p	20	10
Rhizosolenia	12	14	—	32	2	13	—	—	—	56	41	31
Thalassiothrix	50	20	—	—	—	p	—	—	—	—	—	11
Bacteriastrum	2	8	—	—	p	p	—	p	—	6	7	18
Ditylum	2	7	—	—	—	—	—	3	—	—	—	7
Other diatoms	—	7	—	24	1	44	p	9	p	18	2	—

[a]No samples for March.
[b]July and September catches were extremely poor.
[c]A dash (—) signifies absence.
[d]p signifies presence in very low numbers.

these species were extremely rare in Singapore Strait. Hence, the peaks of abundance for Singapore Strait and Johor Strait in July, September, November, January and April were due to blooms of different species of diatoms. The sharp decline of these dominant species was often followed by a new peak of the third or fourth species.

Margalef (1958) noted that a general pattern of phytoplankton succession usually began with small-celled diatoms, succeeded by medium-size species and finally by motile forms such as dinoflagellates which were also characterized by a high level of toxic metabolites. In Johor Strait, there seemed to be an inverse relation between the dinoflagellates and the diatom counts. The dinoflagellate abundance in August, December and June coincided with the months of low diatom counts. The only exception was April which had counts of both diatoms and dinoflagellates. This is because the dominant diatom for April was *Coscinodiscus* spp., a hardy species which might not be inhibited by the toxic metabolites of the dinoflagellates (Khoo 1966).

Zooplankton. The majority of the smaller zooplankton consists of copepod nauplii, followed by dinoflagellates and bivalve larvae. Tham (1953), Khoo (1966) and Chua (1966) showed that certain zooplankters such as the chaetognaths, siphonophores, decapod larvae and *Oikopleura* were extremely rare in Johor Strait but were fairly common in Singapore Strait. On the other hand, planktonic organisms such as *Ceratium,* tintinnids and bivalve larvae were fairly common in Johor Strait during the year, but extremely rare in Singapore Strait. The total count of larger zooplankton done by Khoo in 1966 and 1967 showed that there were two peaks of abundance, in October and April. He suggested that these peaks probably indicated the months of intensive breeding by some of the constituent organisms.

Nekton

Nekton data gathered from fishermen and recorded by Tham (1953) and Khoo (1966) included the edible fish and the mixed or manure fish usually used as duck feed or plant manure. There was an inverse relation between the nekton count and the plankton count, attributed to grazing. The abundance of nekton in a particular month was dependent not only on nutrient availability but also on other physical and chemical factors such as rain, wind velocity, tides and currents, water salinity, turbidity and chemical composition of the seawater.

Tham (1953) and Khoo (1966) reported that the number of species found in Singapore Strait and Johor Strait was large. The eastern portion of the latter was not a spawning area for most of the species caught as no fish fry had been caught in the plankton samples. Khoo (1966) suggested that most of the juveniles caught were carried into Johor Strait which might have also acted as a feeding ground and shelter for smaller fish. Tham (1953) showed that Singapore Strait was not a spawning ground but a feeding ground, and the fish were probably brought in by monsoon currents from the South China Sea.

Since Singapore and Johor Strait are semi-enclosed waters surrounding Singapore, the rapid increase in population and port and industrial activities causes immense increase in turbidity. Tham (1973) stated that phosphate levels had doubled in 20 years. The phytoplankton and zooplankton count showed that there had not been much change over the same period, but the fish catch had declined. These changes could be due to increased volume of shipping activity in Singapore waters. Oil discharge from and noise generated by ships rendered the environment less attractive to fish. Dredging to deepen ships' channels and to obtain landfill for coastal reclamation has also been a major cause of increased turbidity in recent decades (Chua 1983; Chia 1982). Another cause could be the increased fishing intensity over the last 30 years, not only in Singapore waters but also in the surrounding waters of Malaysia and Indonesia.

Coral reefs

Ecology. The reefs around Singapore are mainly of the fringing type, with some patch reefs (Fig. 3.6). Fringing reefs occur in shallow water near the shore and extend out to sea, with a sloping front where coral growth is most active. Between this front and the shore is a reef flat, the substratum of which comprises coral sand or mud, coral debris, coral rocks and living coral colonies (Chuang 1961). Patch reefs occur in areas where the seafloor is raised. They are totally submerged by high tides, and the top reef flat areas are exposed only at low tides.

Knowledge of the ecology of Singapore coral reefs has gained momentum with the advent of scuba diving. Reef studies and research were made by Chuang (1977) and Teo (1982) at P. Salu; Wong (1983) and P.F. Chong (1985), on the ecology of the fringing reef

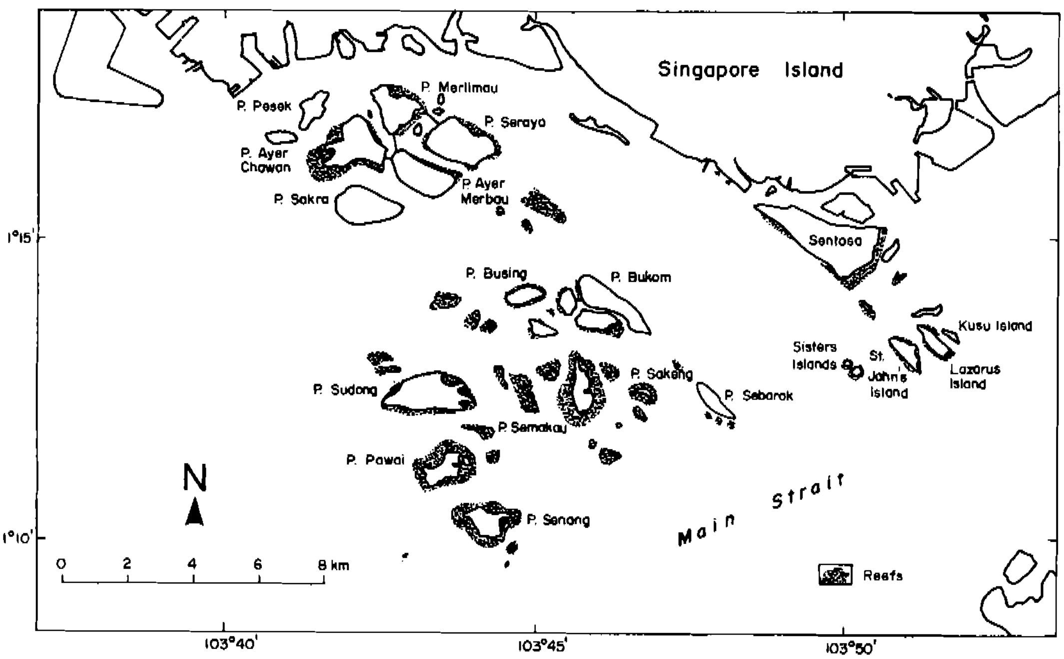

Fig. 3.6. Fringing and patch reefs in the Southern Islands of Singapore.

community at P. Hantu; Chan (1980), on the effects of land reclamation on the marine fauna of Singapore; and P.C. Chong (1985), on the recruitment of hermatypic corals to submerged vertical pillars and the adjacent reef slope at P. Hantu. This last study revealed that the coral community on the artificial substrate was significantly richer than on the natural slope. All these studies showed that coral reefs in Singapore are still thriving within limited zones (e.g., around the offshore islands lying south of Singapore mainland).

Studies on the scleractinian corals of P. Salu by Chou and Teo (1985) and Chou and Wong (1985) revealed 57 species of corals: *Porites lutea, Favia speciosa* and *Goniastrea retiformis* are the dominant ones on the reef flat; *Symphyllia nobilis, Diploastrea heliopora* and various *Montipora* species, on the reef edge; and *Pachyseris speciosa, Psammocora contigua* and *Pavona frondifera*, on the reef slope. The flora of the reef flat of P. Salu is dominated by the brown algae, *Sargassum, Padina* and *Turbinaria,* and the green algae *Enteromorpha* (Chou and Wong 1984).

At P. Hantu, P.F. Chong (1985) listed 86 species of hard corals. The dominant coral species (in terms of percentage cover) on the reef flat of this island include *Montastrea magnistellata, Montipora undata, Pectinia lactuca, Platygyra sinensis* and *Porites lutea.* The reef crests are mainly dominated by *Acropora divaricata, Merulina ampliata, Montipora undata, Pachyseris speciosa, Pavona frondifera* and *Porites lutea;* while the dominant species on the reef slope are *Echinopora lamellosa, Fungia repanda, Galaxea fascicularis, Merulina ampliata, Montipora informis, Pachyseris speciosa, Pavona frondifera* and *Pectinia lactuca.*

Threats. Snorkelling and scuba diving have become increasingly popular recreations of Singaporeans. Through these activities, corals, shells, fish and invertebrates for marine aquariums are collected. This poses a threat to the biota of the reef community although Chou (1986) reported that there has been vigorous regrowth of the corals in the islands. Also, due to industrial development and land reclamation, Singapore's coral reefs are not as attractive to tourists as those of the neighboring countries.

Chapter 4
Physical Resource Endowments

Location and Space as Resources

Strategic location

Certainly, for a small country like Singapore, the lack of the usually acknowledged natural resources, such as forests, agricultural land and minerals, would suggest that space and location are critical for economic growth and success.

The strategic location of Singapore within a resource-rich and fast-growing region is what must count as the fundamental resource of the country. In addition, the island republic stands at the southern entrance of Strait of Malacca which is the major artery of shipping between Europe and the Far East. The significance of this fact was well-appreciated by Sir Stamford Raffles who established the original trading post on the southern side of Singapore River. Today, the straits are also important because of the movement of the vital energy resources of crude oil and refined petroleum products between the Middle East and East Asia. However, the opportunities which this seaborne trade has given to Singapore also bring with them problems and obligations such as ensuring maritime safety and avoidance of marine oil pollution, details of which were given in Rahman and Chia (1977), Rahman et al. (1980) and Chia (1981). To accommodate the maritime traffic, Singapore's fine-sheltered and deepwater harbor has been highly developed through the construction of a wide range of facilities including wharves, cargo handling equipment, navigational aids, suitably deepened navigational and other ancillary facilities and services.

Land and seaspace

Land. Table 4.1 shows the change in the overall land use in Singapore in the last two decades. The increase in total land area from 581.5 km^2 in 1965 to 620.5 km^2 in 1985 is due to land reclamation which has added nearly 10% to the original land area. It is technically and economically feasible to add another 15% to 20% to the land area, the limits to what can be won from the sea being determined by the configuration of the seabed. Table 4.1 also shows the rapid increase in built-up area which now accounts for just under half of the total land area. The less economically valuable land uses have also given way to uses which provide higher economic returns as in the case of the reduction of farmlands. Fig. 4.1 shows the expansion of the built-up areas from 1819 to 1985 and indicates the increasing intensity in which land is being used and the consequent transformation of the landscape of Singapore.

Seaspace. Singapore's seaspace, being contiguous with the waters of the neighboring countries and the international waters, enables the country to be linked to the rest of the world

Table 4.1. Land use in Singapore, 1965-1985 (in km²).

Year	Total	Built-up area[a]	Farm holding area[b]	Cultivable waste	Forest	Marsh and tidal waste	Others[c]
1965	581.5	177.4	131.6	110.1	35.0	35.0	92.4
1970	586.4	189.9	134.0[d]	95.8	32.4	32.4	101.9
1975	596.8	228.4	105.9	95.8	32.4	32.4	101.9
1980	617.8	275.1	80.9	95.0	30.0	26.0	110.8
1985	620.5	298.8	47.1	—[e]	28.6	18.5	227.5

[a]Includes new industrial sites.
[b]Refers to farm holding area of licensed farms, excluding land occupied by pure rubber and coconut plantations.
[c]Include inland water, open spaces, public gardens, cemeteries, nonbuilt-up areas in military establishments, quarries and rubber and coconut plantations.
[d]Previously referred to as "agriculture" and area differently classified.
[e]Included under "others" from 1981.

Source: DOS (1965-1986).

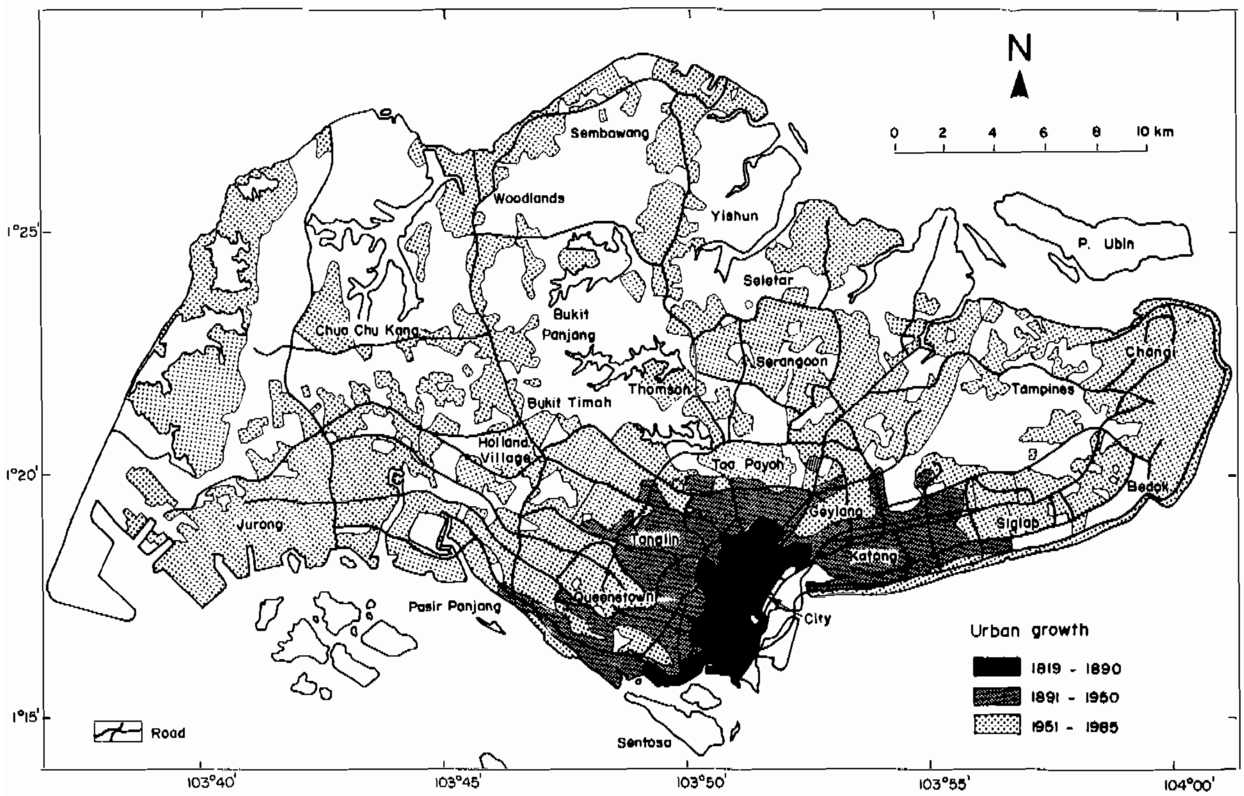

Fig. 4.1. Expansion of built-up areas in Singapore, 1819-1985.

by marine transport. Technology has long been available for overcoming constraints of water as a barrier. Vessels, undersea pipes, cables and tunnels for transport and communication have been used between the main island and the offshore islands as well as with the neighboring countries and further afield.

The use of floating platforms for shipbuilding and shiprepairing has already been tried. There is also the exciting prospect of creating large underwater and floating structures to be used as runways for aircraft and recreational facilities as well as for human habitation. Other potential uses of seaspace have been suggested in Singapore.

The control of the coastal waters is primarily with PSA. The first priority for the use of coastal seaspace is for navigation and port-related uses (Fig. 4.2) which are important for Singapore's trade and export-oriented manufacturing industries. However, the expansion of port and navigational facilities and activities has resulted in the reduction of the traditional use of seaspace for fishing and related activities and the removal of coastal settlements (see later sections and Chia 1985).

Freshwater

The limited availability of potable water is a problem in small islands and must be regarded as an aspect of the coastal zone broadly defined. The small catchment area and the large built-up area mean that there is limited freshwater that can be derived from precipitation in spite of the high average precipitation over Singapore. There is the additional problem of long-term fluctuation of rainfall (Chia and Foong, in press). As a result of a combination of population and economic growth, freshwater consumption has been increasing at a very high rate. Singapore currently imports more than half of its water from Johor in Peninsular Malaysia.

Potential Yield of Freshwater. Available water based on an average of 2,200 mm of annual rainfall gives 12.1 x 10^8 m^3 of water falling over the main island of Singapore. About half of this would be lost through evaporation and transpiration. Rough estimates give the total available water from existing catchment area to be about 1.6 x 10^8 m^3 per year. This may be compared with the amount of water consumed per year which is around 2.5 x 10^8 m^3, indicating a water deficit of 0.9 x 10^8 m^3 per year.

Investigations on drought in Singapore (Nieuwolt 1966; Chia and Foong, in press) indicated that it can occur any time of the year. Historically, there were periods when rainfall was lower than the long-term average when droughts were more frequent. Also, during periods of unusually heavy rainfall, reservoirs are limited in their capacity to receive exceptionally high flows and the excess water has to be discharged. This occurred, for instance, during the December 1969 floods (Chia and Chang 1971).

Impoundment of Water. Creating reservoirs to receive and store freshwater for domestic, commercial, industrial and other uses has become an important building up of the country's infrastructure. MacRitchie Reservoir was the first to be constructed in the latter part of the 19th century; since then, the Upper and Lower Peirce and Seletar Reservoirs were added as the need for water expanded. By the end of the 1960s, there was no longer available space in the center of the main island for additional reservoirs.

Subsequently, major reservoirs could only be constructed by damming the mouth of rivers. These include the Murai, Poyan, Sarimbun and Tengah and, more recently, Bedok and S. Seletar (Fig. 2.6). Thus, the use of river for creating reservoirs has also become an important use of coastal land and resources. The total maximum storage capacity of these reservoirs is about 108 million m^3 (Table 4.2). As reported by Singapore's *Straits Times* (17 October 1986), with the completion of these reservoirs, the Singapore has exhausted the more obvious possibilities for impounding water.

The completion of the cleaning up of the Singapore and Kallang River Basins and the creation of Marina Bay at the mouth of the Singapore River offer another possibility of impounding freshwater. Other options such as recycling of water (already adopted in limited ways) and desalination of water remain feasible options.

The extent to which major rivers in Singapore can be dammed at their mouths (e.g., as suggested in Marina Bay) is limited by the fact that these rivers drain southward passing through the heavily built-up urban center, and thus only their upper reaches can be utilized as catchment

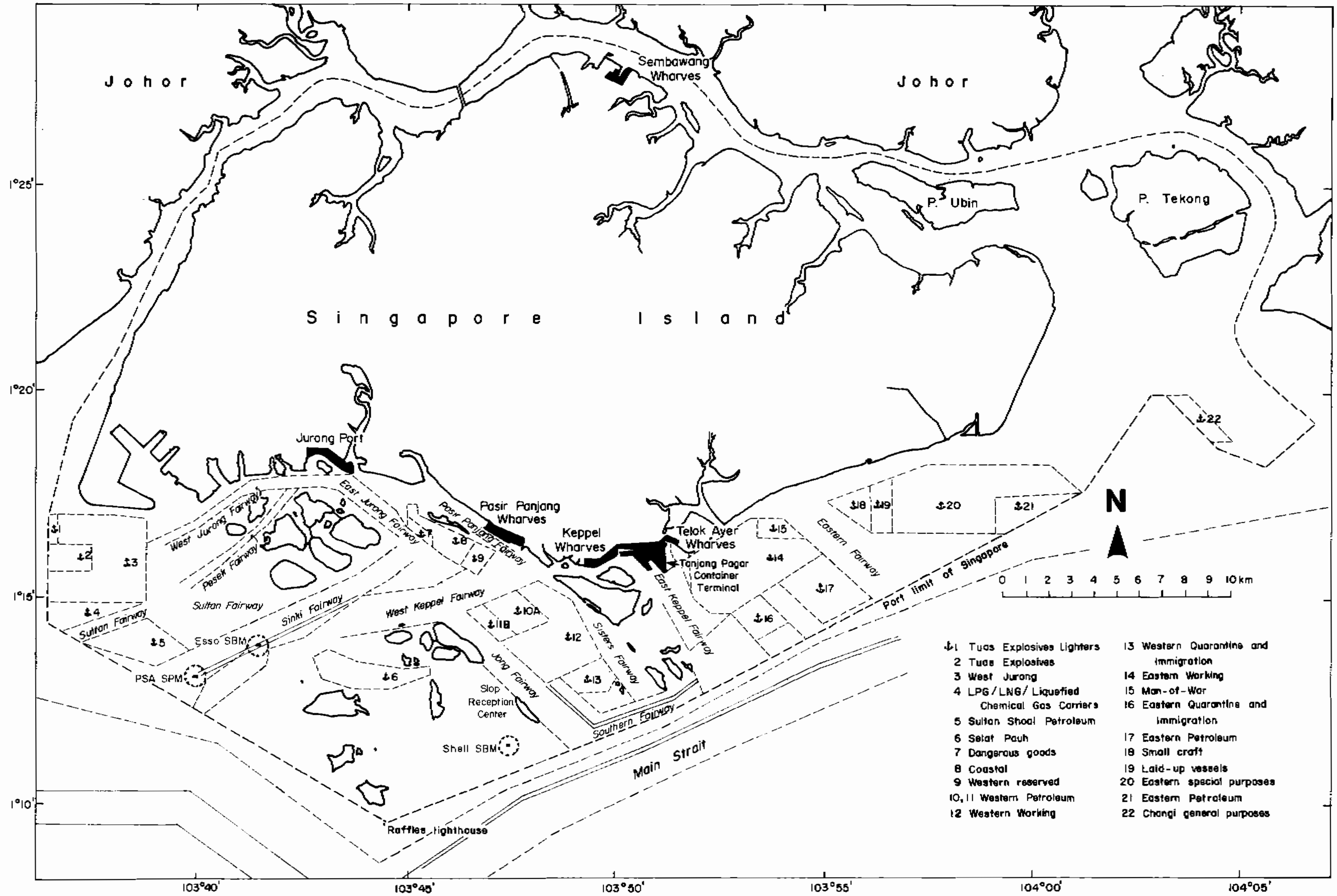

Fig. 4.2. Seaports and use of seaspace for port and navigational purposes in Singapore.

Table 4.2. Maximum storage capacity of reservoirs in Singapore.

Period of construction	Reservoir	Maximum storage capacity ($m^3 \times 10^6$)
1890-1894	MacRitchie	3.7
1900-1912	Lower Peirce	2.8
1941-1969	Seletar	24.4
	Upper Peirce	27.8
1971-1975	Kranji	15.0
	Pandan	6.0
1977-1981	Western Catchment Scheme Murai Poyan Sarimbun Tengah	28.4
1981-	Bedok Sungei Seletar	20
	Total	128.1

Source: PUB (1977, 1980).

areas. The exception is Pandan River which drains to the east of Jurong Town. Thus, only rivers that flow to the west and northwest, which comprise the Western Catchment Area, have been dammed. Progressively, rivers to the northeast will also be dammed to form reservoirs. The Bedok Reservoir near the southeastern coast was constructed in a hollowed-out area in the Old Alluvium.

The implication of coastal reservoirs is that within their catchments, there must be stringent controls on water pollution. Large farming areas, particularly for pig farming, have been moved out of the northwestern part of the mainland. The decision has been made to completely phase out pig farming there by 1991. In order to utilize built-up areas as well, more stringent measures will have to be taken to reduce water pollution from sources such as industries.

Underground Water Supply. Investigations by Pfeiffer (1975) on potential underground water indicated that the central, eastern and western parts of the Island have little groundwater. Among the Mesozoic sediments and granites, only the sandstones could be considered as possible aquifers; these, however, are generally very thin and interbedded with impermeable materials. Moreover, these Mesozoic sediments have been folded, and in some places, quite strongly. It is unlikely that any substantial yield of water could be obtained from them. The unweathered igneous rocks (granites and the like) are quite impermeable, but it may be possible that small supplies will be found in fissures and faults in the rock masses.

The Quaternary deposits of sand and gravel along the coast could provide good porous aquifers, but the beds of peat, clay and sandy clay have low permeability. On the islands, the marine sands on the coast provided an important source of freshwater for the previous resident islanders, although saline intrusion occurs during the drier periods of the year. The only area which offers any reasonable possibility of an underground source of water is the so-called Old Alluvium on the eastern part of the Island. There, a substantial thickness of older fluviatile terrace deposits is developed, with "younger Quaternary" deposited in the present stream valleys cut in the terrace deposits.

Alternative Sources. There are two other local sources of freshwater: recycled water and desalinized seawater. Both have implications for CRM. Water in Pandan Reservoir is treated and supplied to industrial users, primarily for cooling. Even here, the quantity of silt and salts in the water may be a problem. At present, the cost of desalination is still much higher than treating freshwater. There is also the possibility of damming the two ends of a nearby offshore island, joining it with the main island, then draining the impounded area of saline water and gradually allowing the soil to be leached of the salt. This process has been considered for one or two islands in western Johor Strait.

Economic Resources

Mineral resources

Clay. According to Wong (1969), some of the clays in the sedimentary rocks were found suitable for making bricks. A number of pits were opened for clay production and several small hills were partly removed for this purpose. At present, there are no clay pits in operation.

Sand and Gravel. Over the eastern portion of the main island, the material in the Old Alluvium is washed to obtain sand for construction purposes. Sand washing became a major activity from the late 1950s to the 1970s during the housing and construction boom. Old abandoned rubber and coconut plantations were converted into sand pits. There were about 150 sites, 20 of which involved S. Api Api. Runoff from washing the sand is held in sedimentation ponds (Wong 1969).

Wong (1969) noted that sand washing was haphazard and indiscriminate, which resulted in badly scarred landscapes and silting of streams and drains. This led to the passing of the Sand Quarries Ordinance at the end of 1962 to prevent operators from damaging adjacent properties or interferring with drainage channels. Licenses were issued, which in 1963 totaled 61. By the end of 1966, there were 58 licensed operators working in Tampines and Ulu Bedok areas. Sand washing left some 3 km^2 of wasteland. Nearly 5.2 km^2 of vegetation along a belt of land around the sand pits were denuded, leading to severe soil erosion.

Desilting Bedok Canal cost some $5.4 million. To control the situation, the government set up an operation on a 113-ha site in Tampines, using modern quarrying and excavation methods, and also took responsibility to discharge slurry into the sea for which a 7,500-m pipeline was constructed. Much of this wasteland has now been built over with the government's low-cost housing as in the Tampines New Town area.

Granite. Quarrying for granite for construction materials began in Singapore in the early part of the 20th century. According to Scrivenor (1924), granite was used as a ballast for the railway line which opened in 1903. In P. Ubin, granite quarrying was carried out to supply material for the seawall, Johor Causeway and roads in Singapore. In the postwar years, several quarries were opened around the fringes of B. Timah Reserve, B. Gombak, B. Panjang and B. Mandai and in P. Ubin. In 1963, there were 20 quarries, but three years later, with the closure of the smaller ones, only 13 were in operation. The land alienated for quarrying was about 101 ha (Wong 1969; Tok 1966). According to an estimate, outside of B. Timah Reserve, the main island could economically yield about 137 million m of granite (Alexander 1950).

Fill Material. Filling low-lying swampy land along Singapore River and the seafront began a long time ago. Fill material was obtained by demolishing nearby hills which also resulted in level land. Major land reclamation began in the 1960s. For East Coast Park, for instance, the materials were derived from removing the upper layers of the Old Alluvium and from excavating Bedok Reservoir. Fill material was also obtained from dredging shallow shoals within the territorial waters of Singapore and by importing it from Indonesia.

Noneconomic Resources

Most coastal resources utilized for recreation and tourism have no direct economic value but give rise to activities which have direct and indirect economic and noneconomic benefits. There is considerable need to develop coastal marine resources for these purposes to cater to the country's population which is still young. Added to this have been the increased leisure time and greater mobility accompanying rising affluence; more prevalent practice of the five-day week; emphasis on sports and other leisure activities in the school program; and apartment dwelling.

A more affluent and well-educated population tends also to be more sophisticated and more culturally aware. One effect of this is to want to preserve things of the past, including, among others, archaeological sites, buildings, monuments and artifacts, as well as old trades, crafts and practices.

Parks and open space

Considerable attention has been placed on the provision of open spaces in the Statutory Master Plan and in the Long-Range Comprehensive Concept Plan of Singapore. Among the physical criteria adopted by Singapore planners for choosing suitable recreation sites are coastal areas, beaches, offshore islands, seafront in central city area with harbor view, and riverbanks.

Planners have also sought to develop a coherent system of open spaces at several levels, i.e., national, district and local and to match these with appropriate facilities. The development of a corridor of open spaces along the seafront has proceeded well as in the case of the 12-km East Coast Park which will be linked with the Marine City seafront when the latter is completed.

The planning standards for open spaces are to be upgraded. In 1967, the amount of public open space was 0.39 ha per 1,000 people for the main island; 0.16 ha for city areas; 0.33 ha for urban areas; and 0.6 ha for the islands. The provision for housing estates was at 0.4 ha per 1,000. The aim for the country has been to provide 0.6 ha per 1,000 persons which generally compares well with western cities.

Historically, there was little attention given to the provision of open spaces in Singapore until the 1960s. Efforts were haphazard and piecemeal. In the 1960s, recreational parks developed were Mt. Faber Park, Toa Payoh Garden, Seletar Reservoir Park and the Chinese and Japanese Gardens in Jurong, several of which may be considered to be coastal parks. In the latter 1970s, the rapid development of several large national parks included the East Coast Park on 140 ha of reclaimed land. Three other large coastal parks (between 10 ha and 80 ha) at Pasir Ris, Sembawang and Kent Ridge Extension are being developed. Six new projects, all coastal, have been approved: the West Coast Park Extension, Kent Ridge Park, East Coast Park Extension, East Coast Parkway Strip, Sembawang Park and Marina Centre Park.

Recreation facilities in Singapore also include three main stretches of sandy beaches along the East Coast in the southeast; Pasir Ris in the northeast; and Tanjong (Tg. throughout this text, and which means cape) Irau in the north. East Coast Park is approximately 9 km in length and stretches from Tg. Rhu to Bedok. Apart from swimming, the sea off the beach is used for boating, sailing, windsurfing and fishing. Facilities include a golf driving range, tennis center, aquatic complex, cycling paths and holiday chalets, among others.

Pasir Ris along the northeast coast is suitable for swimming, skiing and yachting, but not well-patronized due to inaccessibility. However, when Pasir Ris New Town, now under development, is completed, residents there will form the main source of visitors to the adjoining park. Tg. Irau Beach is also poorly patronized due to public ignorance of its existence. Finally, the offshore islands, such as Sentosa and St. John's Island, are also eminently suitable for recreation.

Also of interest are private parks and open spaces owned by families and private organizations and in military areas. In the 1970s, they made up 40% of the total available parks and open spaces in Singapore. Haw Par Villa (formerly Tiger Balm Gardens) on the west coast is the only private park of substantial size. The facility has been donated to the government to be expanded and upgraded into a theme park. There are also several golf ranges on the coast, although these are restricted to members and their guests.

Protection for vegetation and amenities in parks are provided for in the Trees and Plants (Preservation and Improvement of Amenities) Act 1970. Under the act, streams are protected by prohibiting the construction of buildings too close to the banks; prohibiting factories from discharging effluents and sewage unless these are below specified levels of pollution; and keeping streams free of obstructions. Beaches and coasts are also protected by prohibiting indiscriminate erection of buildings along them, littering, taking away sand, destruction of plants, and by requiring sunken vessels and hidden poles to be cleared.

Reclaimed land

Foreshore reclamation in Singapore symbolizes the intensive development within the coastal area. In many ways, reclaimed land may be considered created resources which once acquired, are little different from natural resources except in characteristics.

Large-scale land reclamation schemes were carried out to solve the problem of shortage of land for development. Filling of swampy land along the city waterfront and the mouth of Singapore River was made very early after the establishment of the trading post by the British in 1819. Reclamation has since added some 40 km2 to the land (Table 4.3). Although the schemes

Table 4.3. Increase in the total land area as a result of reclamation in Singapore (including offshore islands) since 1965.

Year	Area (km^2)	% increase
1965	581.5	–
1966	581.5	–
1967	583.0	0.26
1968	584.3	0.48
1969	585.3	0.65
1970	586.4	0.84
1971	586.4	0.84
1972	586.4	0.84
1973	586.4	0.84
1974	587.6	1.05
1975	596.8	2.63
1976	602.0	3.32
1977	616.3	5.98
1978	616.3	5.98
1979	617.8	6.24
1980	617.8	6.24
1981	617.9	6.26
1982	618.1	6.29
1983	618.1	6.29
1984	620.2	6.65
1985	620.5	6.71

Source: DOS (1965-1986).

started in the mid-1960s, the activities were intensified only in the late 1970s when the need was strongly felt due to massive public housing development and rapid industrialization.

The three main statutory boards involved in reclamation are the Housing and Development Board (HDB), the Jurong Town Corporation (JTC) and the PSA. While JTC and PSA have been reclaiming land mostly for their respective purposes, land reclaimed by HDB has been almost solely for housing and recreational needs, with the major exception of Marina City which adjoins the Central City area.

The following are the major reclamation projects of Singapore (Fig. 4.3):

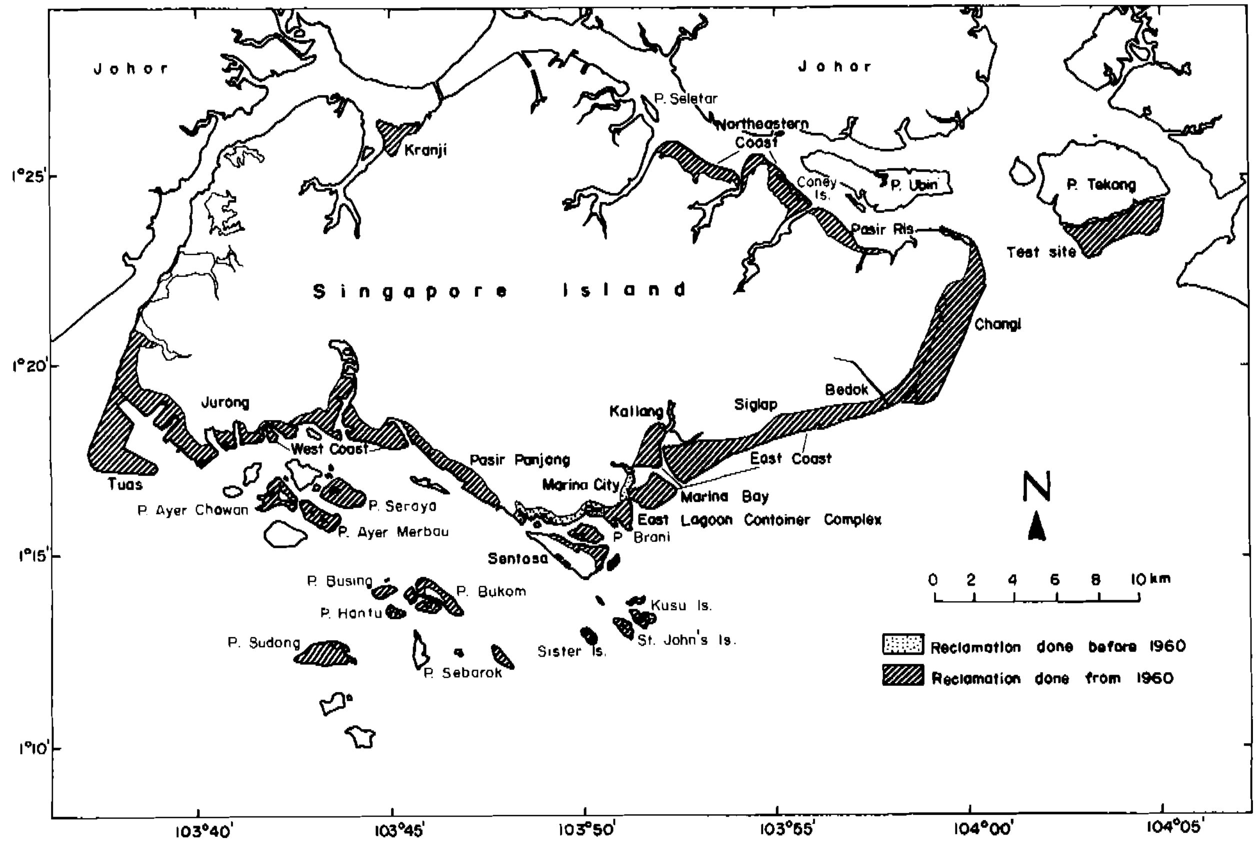

Fig. 4.3. Reclamation in Singapore.

East Coast Reclamation Scheme. Following a small project in 1963 to reclaim 19 ha of land at 14 km East Coast Road, the East Coast Reclamation Scheme was launched in April 1966. HDB, acting as the agent for the government, undertook the planning, design and supervision of construction. The whole scheme comprised seven phases and, until end of 1986, HDB had reclaimed 1,525 ha at a cost of $613 million. Phase 7, which involved the reclamation of 360 ha of land at Telok Ayer Basin and Tg. Rhu, had been completed in 1986 and added about 1,000 m of shoreline.

This scheme has provided additional land for residential, commercial and recreational purposes. The housing units on this reclaimed island include high-rise HDB-built apartment blocks in Marine Parade Estate (which is the first public housing scheme there) and privately developed apartments and condominiums. Due to the area's popularity and hence higher property prices, development for residential purposes has since been left to private enterprises.

Adjoining Marine Parade Estate is Marine Parade Centre which is provided with a range of shopping, entertainment and social facilities to serve the rapidly growing number of residents in the eastern part of the main island. Both East Coast Parkway (a large privately developed modern shopping and entertainment complex) and East Coast Park were also built on land reclaimed under the scheme. The $225 million and 19-km long East Coast Expressway links the Changi Airport to the city.

The East Coast Park has transformed the simple, newly created reclaimed waterfront land into a 140-ha parkland which provides wide-ranging food and recreational facilities. The 9-km stretch of stable, sandy beach, stretching from Tg. Rhu to Bedok, has been protected from wave erosion by the construction of a series of headland breakwaters along the reclaimed shoreline.

The Marina Centre is a 101-ha reclaimed land situated next to the present Central Business District (CBD). The planned mixed-use development, which comprises shopping centers, food and entertainment complexes, hotels, sports center, cultural center, residential apartments and open space along the seafront, is intended to form the link between Central Area and Orchard Road commercial-tourist corridor.

Flanking Marina Centre are Marina South and Marina East on two plots of land reclaimed off Telok Ayer Basin and Tg. Rhu. Together with land earlier reclaimed, the three areas which total 66 ha make up Marina City. The reclamation makes available much needed land for future expansion of Central Area, while creating new opportunities for urban planners to conserve the historic parts of the city.

Changi Airport Reclamation Project. The construction of Changi Airport was made possible through reclamation undertaken by Singapore Engineering and Consultancy Services Pte Ltd, a subsidiary of PSA, on behalf of the government. The project involved dredging 36 million m^3 of sand from the adjoining seabed, pumping it ashore and placing it hydraulically onto the filled land. The 663-ha reclamation work began in 1976 and was completed in 1978 at a cost of $230 million. An 8-km stretch of new coastline was also created. Today, about half of the airport sits on reclaimed land.

To cater for the long-term needs of Changi Airport, additional reclamation was launched in July 1982. The $118 million project was completed in mid-1986 and added 612 ha of land to Changi's northern bay and 120 ha to the southern bay. The land will be used temporarily as an extension to the East Coast Park until the need arises for future airport expansion. Required were about 12 million m^3 of material, which was derived from the dredging of offshore areas. The project also added about 4.5 km of new beaches to the existing 8-km stretch of coastline already developed.

East Lagoon Container Complex Reclamation Scheme. The Container Port, now known as the Tanjong Pagar Container Terminal, was developed to meet the ever-growing throughput of containerized cargo. The first phase of the 23-ha reclamation was completed in late 1967, which made possible the construction of three container berths commissioned in 1971. The second phase, completed in 1976, provided for two more berths. Another berth was constructed under the third phase.

Pasir Panjang Reclamation Scheme. This scheme was carried out for developing Pasir Panjang Wharves into a warehouse cum port terminal. Two phases were involved: Phase I, which lasted from February 1972 to October 1973, was the reclamation of 37 ha off Pasir Panjang coast. The project provided 1,300 berthing facilities for lighters and coastal vessels and some 223,000 m^2 of transit sheds and warehouses. Phase II involved the reclamation of 24 ha and was carried out between April 1977 and end of 1979.

West Coast Reclamation Scheme. This scheme was undertaken by JTC and HDB to complement the government's efforts to develop the relatively untouched west coast. Reclamation work by HDB was from 1975 to 1977, and yielded about 89 ha of land at approximately $6.4 million. The reclaimed land was then used for the development of Neighbourhood V and VII of Clementi New Town, and the section of the major arterial road, West Coast Expressway, linking the eastern and western coasts. JTC also undertook the development of an industrial estate on part of the land reclaimed by HDB.

Jurong Reclamation Scheme. This was carried out to develop the foreshore areas for Jurong Industrial Estate. A total of 1,416 ha was reclaimed from swamps and the foreshores to the west of Mobil Oil Refinery. Two other major reclamation projects in this scheme involved the construction of sea channels with 6 m minimum depth of water, Benoi Channel and Gul Channel. These channels provided extra waterfront land for marine industries (shipyards). This scheme also included doubling the size of P. Samulan into a modern thriving shipyard with a drydock capacity claimed to be the largest in Southeast Asia.

Tuas Reclamation Scheme. Tuas, located at the extreme western corner of Singapore Island, was formerly a fishing village set among a fringe of mangroves. It is being developed into an extension of Jurong Industrial Estate to accommodate marine-oriented and related industries. The project has reclaimed about 709 ha of seafront swampland off the west coast of Tuas village with JTC also dredging two channels, the Northern and Southern Tuas Channels.

Another project, which was launched in Tuas, yielded about 650 ha of land. The $602 million scheme commenced in March 1984 was completed in 1988. It has resulted in a "hockey stick-shaped" land with a perimeter of about 13 km. Included in the development are a 36-hole golf course, fishing village and park. This addition would also mean that Jurong will have a second "green lung" to provide relief from the harshness of an industrial area.

Northeastern Coast. This reclamation scheme covers about 685 ha of the shallow foreshore and swampland at the northeastern coast of Singapore, from Pasir Ris to Seletar. The project is estimated to cost $874 million and will be undertaken between 1985 and 1992. The project, undertaken by HDB, covers an area of about the size of a large Pasir Ris New Town. Portions of the area, adjacent to Serangoon sludge treatment works, will be used for refuse disposal and industrial and recreational purposes such as the Pasir Ris Park.

Offshore Island Reclamation Schemes. Since the mid-1970s, more than 1,695 ha of land have been added to 32 offshore islands (Table 4.4). The earliest of the offshore islands used for industries are P. Bukum and the neighboring islets (now linked) which were enlarged by Shell for a large oil refinery. The islands near Jurong coast are under the jurisdiction of JTC and are used for heavy industries requiring marine transport facilities. The industries are located there also because of their high potential for air and water pollution.

Table 4.4. Land (ha) reclamation on offshore islands in Singapore.

Island	Original	Area After reclamation	Increase	Island	Original	Area After reclamation	Increase
P. Tekong	1,792.4	2,337.4	545.0	P. Samulun	14.5	30.3	15.8
Coney Island	13.0	45.8	32.8	P. Damar Laut	15.6	24.1	8.5
P. Seletar	27.0	40.4	13.4	Terembu Retan Laut	-	24.6	24.6
Sentosa Island	284.4	335.0	50.6	P. Sebarok	9.6	59.1	49.5
Buran Darat	-	16.5	16.5	P. Bukom Kechil	30.0	62.5	32.5
P. Brani	74.0	105.5	31.5	P. Bukom	120.0	178.2	58.2
St. John's Island	33.2	39.3	6.1	P. Ular	0.4	31.7	31.3
Lazarus Island	26.0	32.7	6.7	P. Hantu	2.0	12.5	10.5
Kusu Island	1.2	8.0	6.8	P. Busing	4.4	55.5	51.1
P. Renggit	-	12.5	12.5	P. Satumu	0.3	1.4	1.1
Sisters Islands	2.5	7.9	5.4	P. Sudong	10.0	211.7	201.7
P. Seraya	97.7	193.3	95.6	Sultan Shoal	-	0.6	0.6
P. Ayer Chawan	90.2	164.8	74.6				
P. Ayer Merbau	96.0	179.7	83.7				
P. Sakra/Bakau	42.2	155.0	112.8	Total	2,786.6	4,366.0	1,579.4

Source: Chia and Khan (1987).

Reclamation to enlarge P. Seraya was done by JTC resulting in the merging of the island itself with P. Seburus Dalam and P. Seburus Laut. A total of 193 ha of valuable waterfront industrial land was reclaimed at a cost of $32.7 million. P. Seraya was later given over to the Public Utilities Board (PUB) for the development of a power station.

P. Ayer Merbau was the result of combining five small islets. Reclamation by JTC from 1976 to 1977 increased its total size to 123 ha. The island was then leased to Petrochemical Corporation of Singapore Pte Ltd (PCS) for the construction of a $2 billion petrochemical complex. The complex, officially opened in March 1985, occupies about 90 ha of the island.

About 59 ha of land was added to P. Busing by JTC from 1983 to 1984 at a cost of $28.9 million. About 35 ha have been allocated to Paktank Singapore Terminal Pte Ltd for setting up an oil storage facility with an initial capacity of 400,000 m^3, which will eventually be increased to 1 million m^3.

Two small islands, P. Sakra and P. Bakau, off the coast of southern Jurong were reclaimed at a cost of $33.5 million in 1984, yielding an enlarged island of 155 ha. Some 7.5 million m^3 of sand was dredged from Raffles Shoal, Sawa Remalang and Selat Sakra, and pumped onto the reef surrounding the two islands which have been earmarked for industrial development.

P. Sudong, rich in coral reefs and seagrass beds in the surrounding waters, is also reserved for industrial purposes. Reclamation and shore protection works by PSA from 1976 to 1979 added 174 ha of land at a cost of $39 million. Reclamation of P. Tekong Besar undertaken by PSA from 1981 to 1985 cost $620 million. About 540 ha of the southern foreshore of the island were reclaimed using 33 million m^3 of dredged fill material from offshore sources.

Terembu Pesek, an underwater reef located about 2 km off the coast of southern Jurong, underwent reclamation by JTC in 1985 at a cost of $11.2 million. The new 34-ha land will be used by PPD as a holding station for imported pigs.

Several islands near existing ports have been developed for port-related purposes. Reclamation work on the foreshores of the northern part of P. Brani commenced in 1975 to provide more space for a new container terminal. The project, completed the following year at a cost $6.3 million, added 28 ha of land. Terembu Retan Laut was reclaimed by PSA from 1975 to 1983 and yielded about 24 ha of land at $11.5 million. The purpose was to provide more land for recreation and sheltered mooring for some 800 lighters.

Reclamation work on Sentosa was carried out from 1979 to 1980 by PSA on behalf of the Sentosa Development Corporation (SDC) at a cost of $15.7 million. Added were 63 ha for tourist and recreational facilities such as the Maritime Museum (owned by PSA), a golf course, cycle tracks and a monorail system.

The islands farther from the main island are suitable for recreational purposes, too. Thus, St. John's Island, which for a long time was used as a leper colony, was enlarged by 4 ha at a cost of $1.5 million by PSA from 1975 to 1976. The island underwent intensive development which included the setting up of holiday camps, bungalows, chalets, cafeteria and sporting facilities. Regular ferry services by PSA are provided to St. John's Island and the adjacent Kusu Island. The PSA also undertook reclamation on the latter island to add 6.4 ha at a cost of $2.6 million in 1975. Improvements were made to the Chinese temple and the Malay holy place *(kramat)* on the island.

Other islands among the Southern Islands have been developed by PSA for recreation. These include Lazarus Island where about 4 ha were reclaimed in 1976 at $1.6 million; Sisters Island which was reclaimed with 5.4 ha between 1974 and 1975 at $1.7 million; P. Hantu where shore protection and filling were done on the foreshores from 1974 to 1975, yielding 12.2 ha of land at $4.1 million; Buran Laut which was reclaimed between 1975 and 1976, yielding about 15 ha of land at $5 million; and P. Renget which was enlarged by 12 ha of land in 1976 at $4.1 million.

In West Johor Strait, P. Serangoon/Coney Island, which is owned and developed by PSA, was enlarged by about 36 ha between 1974 and 1976 at a cost of $10.4 million. Facilities such as landing jetties and water supply were provided; and trees and shrubs planted. Finally, work on P. Seletar, which cost $4.6 million between 1975 and 1976, produced an additional 18 ha of land.

Archaeological sites and edifices

Little is known of the pre-colonial (before 1819) settlements in Singapore, although they were likely to be coastal in nature. At the excavating sites on Central Park, which overlooks the original settlement on the southern side of the mouth of Singapore River, were found interesting artifacts, pottery, ornaments and jewellery which showed a bit of the social and economic life of the early residents of Singapore. There was clear indication of a maritime trade. Unfortunately, the early settlers, some of whom were migratory, left little evidence of their existence on the island.

Relics of the early colonial past include such things as the fortification at Fort Canning within Central Park; the Temmengong's tomb along Pasir Panjang Road; and the first Christian (Armenian) Church. The Urban Redevelopment Authority (URA) has, since about 1985, begun a program to conserve religious and public edifices (as well as old trades and crafts) in the "ethnic centers," i.e., Kampong (Kg. throughout this text, and which means village) Glam, Chinatown, and Serangoon Road (Little India). The program has exhibited that the ethnic centers can be considered, in a broad sense, to be coastal in nature and that the early Malay residents were coastal and seafaring peoples, while the Chinese and Indians were migrants and dependent on seaborne trade and maritime commerce.

The designation of many of the old public and religious buildings and monuments as "conserved" under the Conservation of Monuments Act serves to safeguard important aspects of Singapore's past, many of which are coastal in nature. Finally, mention must be made of the Chinese temple and *kramat* on Kusu Island in Southern Islands where during October/ November, thousands of worshippers make a trip by ship to take part in religious rituals there.

Chapter 5
Coastal Resources Utilization and Development

Port and Shipping Services

Singapore is now rated as the world's busiest port in terms of shipping tonnage. In 1980, the total shipping tonnage of vessels arriving at and departing from the country's port was 528.8 million gross registered tons (GRT). About 30,000 vessels call yearly. Some 600 ships flying the flags of almost all the maritime nations in the world are in port at any one time. There are about 500 shipping lines linked to nearly all parts of the world.

PSA, a statutory board under the Ministry of Communications and Information (MOCI), replaced the Singapore Harbour Board (SHB) in 1964. The PSA is responsible for administering the port; managing some 583 km^2 of waters within the port limits, which cover the major portion of the territorial waters of Singapore; providing and maintaining port facilities and services; regulating traffic and navigation in port; supplying pilotage; and promoting the use and development of the port.

PSA at present operates five main gateways (Fig. 4.2) which have a total wharf length of 14 km. These provide berthing facilities to accommodate container ships, bulk carriers, cargo freighters, coasters, lighters and passenger lines with the capacity to handle over 80 million freight tons (ft) a year.

Performance of Singapore Port

The port activities have been gradually improving during the past decade as evident from the statistics presented in Tables 5.1 and 5.2. However, the activities suffered a setback in recent years due to economic slowdown.

The functions of the port of Singapore are not confined to cargo handling. It also has a comprehensive range of marine services such as providing bunker fuel and ship supplies; oil refining; pilotage and tug; freshwater services; gas-free inspection and fumigation; and slop reception for oil tankers. Environmental control services, such as cleaning oil and debris from the sea and firefighting services, are also provided.

In 1985, 17 tugs handled 52,200 jobs, an increase of 2% over 1984. The number of pilotage movements in 1984 was 56,000 but it decreased by 3% in 1985 to 54,500. Bunker throughput dropped marginally in 1985 by 3% to 1.3 million t. The number of vessels serviced also dropped from 1,370 to 1,150. Water sales at the wharves took a dip of 3% to 507 million l, while water sales from PSA's 8 waterboats dropped by 15% to 981 million l. In 1985, 2,200 ship inspections were done on vessels entering shipyards for repairs, a reduction of 8% over 1984.

Table 5.1. Cargo (in ft) handled by the port of Singapore.

Year	General and bulk cargo by PSA Wharves[a]	Mineral oil in bulk	Total
1975	17,900,400	37,317,900	55,218,300
1976	19,335,100	40,594,800	59,929,900
1977	20,503,600	45,314,200	65,817,800
1978	25,139,000	51,019,400	76,158,400
1979	29,832,000	53,305,500	83,137,500
1980	33,807,700	52,491,800	86,299,500
1981	35,759,300	56,803,700	92,563,000
1982	39,527,200	61,962,100	101,489,300
1983	42,787,900	63,560,500	106,348,400
1984	48,721,700	63,175,600	111,897,300
1985	42,225,200	63,610,600	105,835,800

[a]PSA Wharves include Tanjong Pagar Container Terminal, Keppel Wharves, Pasir Panjang Wharves, Sembawang Wharves and Jurong Port.

Source: PSA (1986).

Table 5.2. Arrivals and departures of vessels (over 75 GRT).

Year	No.	GRT (in millions)
1975	41,866	317.0
1976	43,367	351.6
1977	44,018	393.9
1978	44,403	386.0
1979	51,163	456.5
1980	54,061	474.1
1981	56,634	521.0
1982	60,973	554.0
1983	60,515	562.3
1984	57,442	527.5
1985	60,512	528.8

Source: PSA (1986).

The port of Singapore has the best facilities in the region for the reception and treatment of slop, sludge, dirty ballast and tank washings in P. Sebarok. Located 6 km from Keppel Wharves, the Slop and Sludge and Treatment Centre was established in 1972. Facilities at the center include 4 piers which can accommodate vessels up to 264 m long and 45,800 t replacement and 6 deslopping barges with capacities ranging from 1,200 m^3 to 2,000 m^3.

Storage facilities for all types of import, export and transshipment cargo are provided both within and outside the Free Trade Zone by PSA and private companies. In this zone, there are nearly 475,000 m^2 of covered storage space, while the open storage is about twice that. Outside the zone, there are some 400,000 m^2 of covered warehouse space at the Multi-Storey Complex and Pasir Panjang Complex. There is also a sophisticated multistorey cold storage complex at Keppel Wharves with a storage area of 12,000 m^2 for frozen and chilled meat, fish, fruit and vegetables. PSA is the largest warehouse owner in Singapore with a total of 486,000 m^2 of warehousing space.

Singapore is the salvage and towage center in the region due to its location astride the Europe-Asia shipping lines. The largest of the salvage companies operating out of Singapore are Smit International, Fukuda Salvage, Singapore Salvage Engineers and Sembawang Salvage. All companies keep tugs permanently at sea in the region's crowded waterways. These tugs are equipped with the latest in surveillance equipment and are in constant radio contact with their homebases. The companies compete for contractual salvage work, such as cargo retrieval and wreck removal, and for towage work with extensive services being offered to shipowners, rig owners and the offshore industry as a whole. PSA has a fleet of 17 tugs equipped with firefighting and anti-oil pollution capabilities. They performed 52,200 jobs in 1985 (PSA 1986).

Shipowning and management

Singapore's merchant fleet now ranks 16th in the world compared to its being 15th in 1984. As of end of 1985, there were 1,406 ships totaling 6,622,350 GRT on the Singapore Register (Table 5.3). General cargo ships constitute the largest percentage by number of vessels while bulk carriers provide the largest percentage by tonnage (Table 5.4).

Table 5.3. Ships registered in Singapore and their aggregate tonnage, 1975-1985.

Year	No. of vessels	GRT (x 10^3)
1975	1,356	6,225
1976	1,580	6,675
1977	1,780	7,514
1978	1,742	7,959
1979	1,583	7,690
1980	1,552	7,420
1981	1,682	7,777
1982	1,780	7,731
1983	1,743	7,140
1984	1,555	6,864
1985	1,406	6,622

Source: MD (1985).

Table 5.4. Type distribution of ships registered as of 31 December 1985.

Vessel type	No.	GRT
Oil tanker	105	1,606,086
Product tanker	1	19,832
Chemical tanker	8	52,572
Liquefied gas carrier	2	71,635
Bulk carrier	75	2,006,388
OBO carrier	3	150,881
Vehicle carrier	9	125,094
Livestock carrier	2	53,798
Container ship	48	627,101
General cargo ship	204	1,322,082
Cargo/passenger ship	1	2,319
Passenger ship	16	2,856
Ocean tug	156	32,643
Harbor tug	43	7,658
Motor-propelled barge	2	3,571
Dumb barge	630	469,676
Miscellaneous	101	68,157

Source: MD (1985).

Although Singapore's fleet ranks 16th in the world with over 7 million GRT, locally owned tonnage accounts for about a third of this total. This composition is a direct result of an open registry from 1969 to 1982. The indigenous component of the fleet tends to be older with about half beyond 15 years. Most of these vessels are below 6,000 deadweight tons (dwt) (Federation of ASEAN Shipowners' Association, Singapore 1984). The more modern tonnage belongs to Neptune Orient Lines and subsidiaries of the state-owned shipyard Keppel Management, Straits Steamship and Sembawang Johnson Ship Management. Their vessels participate actively in international conference shipping, tramping and worldwide chartering.

Most Singapore shipowners registered a drop in their profits in the first half of the 1980s. All of them have been writing down the book values of their ships in line with the depressed shipping market. The Keppel group reported a loss of around $173.9 million in 1983/1984, after it wrote $131 million off the value of its fleet in the preceding financial year. According to a report by the *Far Eastern Economic Review* (15 August 1985 issue), Neptune Orient Lines refused to trim down its fleet values, and was, therefore, able to declare some marginal profits. It was actually making losses in operational terms.

The number of seamen employed at sea continued to drop in recent years. As of end of 1985, there were 1,799 seamen employed at sea.

Manufacturing Industries

Marine industry

The marine industry comprises three sectors: shipbuilding, shiprepairing and oil-rig construction. The industry in Singapore has its roots in the early 19th century. The first commercial dry dock was built in 1859, fifty years after Sir Stamford Raffles founded Singapore. In the early years after World War II, Singapore had 6 dry docks, during which period, the

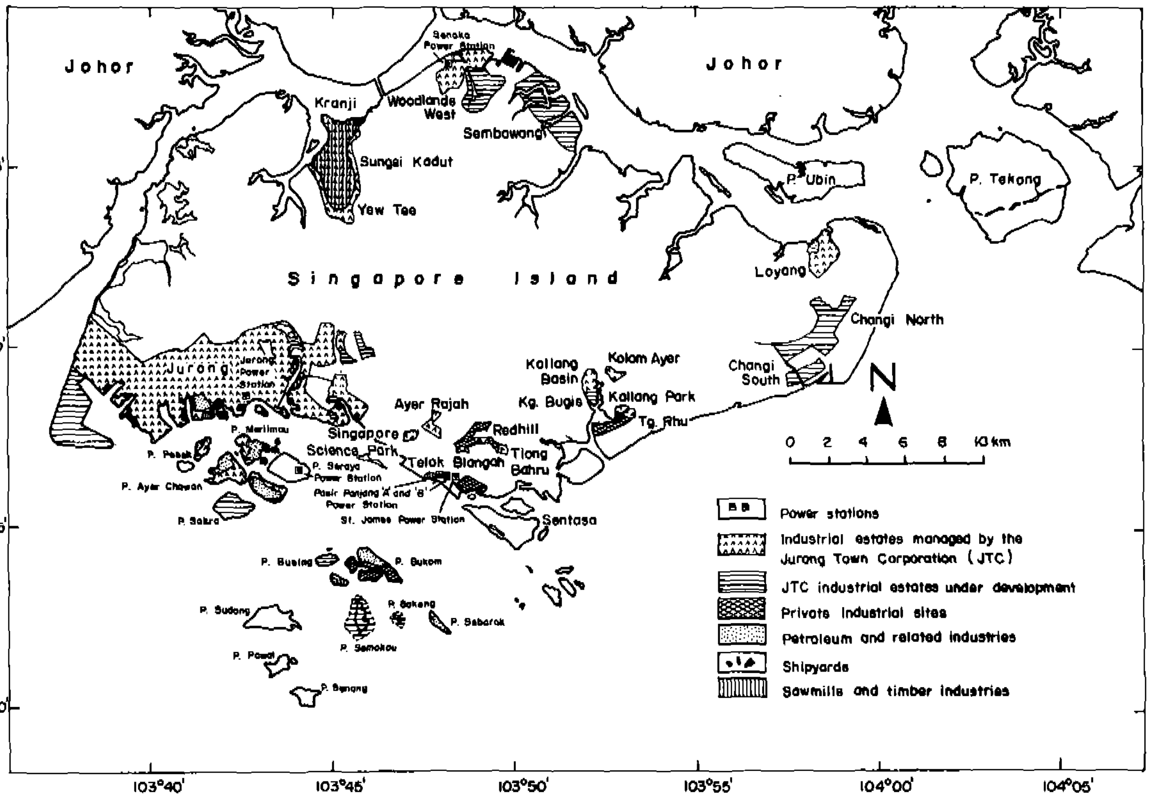

Fig. 5.1. Industries and power generation plants in Singapore.

industry grew as a by-product of the country's trade and *entrepôt* services. The shipyards used to service the merchant ships which called at the port and the naval ships which protected Britain's interest in the region.

The next phase of growth started in the late 1960s, after the attainment of self-rule. This phase saw the birth of the large Jurong, Sembawang and Keppel Shipyards. The marine industry began its greater role in the country's industrial development and performed quite well until the first half of 1980s. Today, Singapore has some 70 shipyards located in the southern and western parts (Fig. 5.1), offering a wide range of sophisticated marine services. The Singapore Association of Shipbuilders and Repairers (SASAR) which was formed in 1968 has the overall responsibility of developing the three sectors of the marine industry.

The industry grew at an average rate of 23% during the period 1972 to 1982 (Table 5.5). Revenue soared from $1 billion in 1978 to a peak of $2.4 billion in 1981. Unfortunately, the worldwide recession soon took its toll on the industry, causing a drop of about 6% in revenue, to $2.3 billion in 1982. The downward trend has continued until 1987 (Table 5.6).

The shiprepairing sector is the largest in the industry in terms of investment and revenue. Up to June 1983, the shiprepairers operated 21 dry docks, two of which were 400,000 dwt in size (Table 5.7). The aggregate capacity of 2.8 million dwt represented the heaviest concentration of repair facilities in any major port. Unfortunately, the performance of the industry in recent years has not been very encouraging. The revenue dropped by about 21% in 1982 and continued to decline through 1985 due to massive price erosion caused by sharp competition at home and abroad (Table 5.8).

In July 1985, one of Singapore's five major shipyards, Mitsubishi Singapore Heavy Industries, pulled out of shiprepairing because of poor business and the grim outlook for this industry in Singapore. This shipyard, established in 1976, is a joint venture among Mitsubishi Industries of Japan, Temasek Holdings and the Development Bank of Singapore. Its workforce

Table 5.5. Revenue breakdown of marine industry by sectors, 1972-1985 (in $ million).[a]

Sector	1972	1973	1974	1975	1976	1977	1978	Year 1979	1980	1981	1982	1983	1984	1985
Shiprepairing	350	413	435	460	465	537	541	725	685	1,088	860	673	668	457
Shipbuilding	87	103	145	272	525	530	374	387	537	540	643	430	277	142
Rig construction	-	-	140	248	260	158	130	281	499	790	781	392	183	52
Total	437	516	720	980	1,250	1,225	1,045	1,393	1,901	2,418	2,284	1,495	1,128	651

[a]In Singapore dollar, unless otherwise stated.

Source: SASAR (1979, 1983-1985).

Table 5.6. Yearly changes in marine industry revenue, 1972-1985.

Year	Revenue ($ million)	Percentage change over previous year
1972	437	-
1973	516	+18.1
1974	720	+39.5
1975	980	+36.1
1976	1,250	+27.6
1977	1,225	-2.0
1978	1,045	-14.7
1979	1,393	+33.3
1980	1,901	+36.5
1981	2,418	+27.2
1982	2,248	-5.5
1983	1,495	-34.5
1984	1,128	-24.6
1985	651	-42.3

Source: SASAR (1979, 1983-1985).

Table 5.7. Dry docks in Singapore as of 30 June 1983.

DWT	No.	Total DWT	Remarks
Below 5,000	1	4,000	
5,000- 29,999	6	43,000	One 10,000 DWT (F)[a] One 10,000 DWT (S)[b]
30,000- 49,999	4	140,000	One 30,000 DWT (F) One 40,000 DWT (F)
50,000- 99,999	1	90,000	
100,000-149,999	1	100,000	
150,000-199,999	3	470,000	One 150,000 DWT (F)
200,000-399,999	4	1,180,000	
400,000 and above	2	800,000	
Total	22	2,827,000	

[a]Floating dock.
[b]Syncrolift.

Source: SASAR (1983-1985).

Table 5.8. Yearly changes in shiprepairing revenue, 1972-1985.

Year	Shiprepairing revenue ($ million)	% change over previous year	Shiprepairing revenue as % of marine industry revenue
1972	350	-	80.09
1973	413	+18.00	80.03
1974	435	+5.33	60.41
1975	460	+5.75	46.94
1976	465	+1.08	37.20
1977	537	+15.48	43.84
1978	541	+0.74	51.77
1979	725	+34.01	52.04
1980	865	+19.31	45.50
1981	1,088	+25.78	44.99
1982	860	-20.95	37.65
1983	673	-21.74	45.01
1984	668	-0.74	59.20
1985	457	-31.59	70.19

Source: SASAR (1979, 1983-1985).

was reduced from 560 to less than 100. With the closure of the 400,000 dwt dry dock, Mitsubishi will focus on plant engineering.

The repair industry's capacity was also reduced by the voluntary agreement among the four local yards (Hitahi Zosen Robin Dockyard, Jurong Shipyard, Keppel Shipyard and Sembawang Shipyard) and Malaysia Shipyard and Engineering in Johor to collectively reduce dock capacity by 20% by utilizing their docks 24 days a month.

Singapore's modern shipbuilding history can be traced back to the early 1970s. The main impetus was provided by active offshore exploration activities in the region, the Middle East and the North Sea, which generated a demand for vessels. The Republic's shipbuilders now offer a wide range of vessels such as LPG tankers, cellular containerships, general cargo ships, jack-up derrick barges, fast missile naval craft, tugs, seismic vessels, mining dredges, pipe-laying barges and various other boats and crafts. Table 5.9 shows the different types of vessels built in Singapore during 1978 to 1982. Like the other sectors of the marine industry,

Table 5.9. Vessels launched from Singapore shipyards, 1978-1982.

	1978		1979		1980		1981		1982	
Type of vessel	No.	Total GRT	No.	Total GRT	No.	Total GRT	No.	Total GRT	No.	Total GRT
Barges	98	71,753	125	69,943	317	172,604	315	211,226	229	163,298
Tugs	40	3,603	24	2,419	32	6,716	40	9,054	41	9,925
Cargo vessels	21	41,786	9	20,172	6	13,619	10	13,848	6	16,629
Tankers	3	31,080	2	1,087	3	1,854	2	4,487	–	–
Supply/utility vessels	15	3,006	9	3,096	14	5,830	17	9,441	29	16,965
Patrol craft	4	700	5	291	3	274	1	–	1	492
Landing craft and dredgers	17	10,422	8	4,902	12	2,233	6	3,400	13	5,231
Ferries/launches, others	15	1,674	12	2,248	18	9,047	11	6,086	12	2,762
Total	213	164,024	194	104,158	405	212,177	402	257,542	331	215,302

Source: SASAR (1983-1985).

shipbuilding revenue also fell significantly in recent years (Table 5.10). The industry, however, is trying to increase its profitability through diversification and restructuring of activities.

Located in the center of the Asia-Pacific offshore exploration region, Singapore has developed into a major center for the construction of oil rigs and other offshore structures. Five major rig builders offer a complete range of drilling and production structures. Table 5.11 shows the numbers and types of oil rigs constructed in Singapore during 1970 to 1985. The industry is also adversely affected by the economic recession, and revenues fell by more than 50% from 1984 to 1985 (Table 5.12).

Despite depressed market conditions, several of Singapore's shipyards are in the process of expanding their facilities or are planning to in the near future. Some have invested in yards in other ASEAN countries and a few more will also be lending their expertise to their neighbors to develop their marine industries. Businesses in the shipyards have picked up from 1986 due to higher Japanese yen and relatively weaker Singapore dollar (Singapore's *Straits Times,* 15 May 1986). There has also been a pickup in demand for dry docking, with shipowners sending ships for repairs which they had delayed because they had to cut costs. There has, however, been no improvement in the rigbuilding business, and the rig yards are now moving to ship construction and other businesses. Shiprepair prices have been significantly lowered, and therefore overall profitability of the industry has fallen despite some short-term business gains.

Table 5.10. Yearly changes in shipbuilding revenue, 1972-1985.

Year	Shipbuilding revenue ($ million)	% change over previous year	Shipbuilding revenue as % of marine industry revenue
1972	87	-	19.9
1973	103	+18.4	20.0
1974	145	+40.8	20.1
1975	272	+87.6	27.8
1976	525	+93.0	42.0
1977	530	+1.0	43.3
1978	374	-29.4	35.8
1979	387	+3.5	26.9
1980	537	+38.8	28.2
1981	540	+5.6	22.3
1982	643	+19.1	28.2
1983	430	-33.1	28.8
1984	277	-35.6	24.6
1985	142	-48.7	21.8

Source: SASAR (1979, 1983-1985).

Table 5.11. Rigs completed by Singapore rigbuilders, 1970-1985.

Type	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Total
Jack-up	1	1	3	2	4	7	8	4	2	9	11	15	16	3	2	-	88
Drilling tender	-	1	1	-	1	2	1	-	1	-	1	3	2	1	-	-	14
Drill barge	-	-	-	1	-	1	-	-	-	-	-	-	-	1	-	1	4
Submersible	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Semi-submersible	-	-	-	-	2	-	-	1	-	-	-	-	-	3	-	-	6
Drillship	-	-	-	-	-	1	2	1	-	-	-	-	1[a]	1	-	-	6
Semi-submersible	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Accommodation unit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jack-up accommodation barge	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Total	1	2	4	4	7	11	11	6	3	9	12	18	20	10	2	1	121

[a]Conversion from a bulk carrier to a drillship.

Source: SASAR (1983-1985).

Table 5.12. Yearly changes in rigbuilding revenue, 1974-1985.

Year	Rigbuilding revenue ($ million)	% change over previous year	Rigbuilding revenue as % of marine industry revenue
1974	140	-	19.44
1975	248	+77.14	25.31
1976	260	+4.84	20.80
1977	158	-39.23	12.90
1978	130	-17.72	12.44
1979	281	+116.15	20.17
1980	499	+77.58	26.25
1981	790	+58.32	32.67
1982	781	-1.14	34.19
1983	392	-49.81	26.22
1984	183	-53.32	16.22
1985	52	-71.58	7.98

Source: SASAR (1979, 1983-1985).

Petroleum Industry

This industry includes activities such as refining, storage, transshipment of petroleum products and petrochemical manufacturing. It plays an important role in Singapore's foreign trade, port activities, maritime industry and the overall economic growth. To make a correct assessment of its present economic significance, it is necessary to identify the factors which led to the emergence of Singapore as a major oil refining center in the world in the late 1960s and early 1970s. After World War II, the multinational oil companies (MNOCs) began to search for refining bases for their Middle Eastern crude oil. Singapore presented an ideal choice due to its strategic location.

The first refinery in Singapore was officially opened on 26 July 1961. The $30 million refinery set up in offshore P. Bukom by Shell Company had an initial refining capacity of 20,000 barrels per day (bpd), and it catered for the markets of Singapore and the Federation of Malaya.

After the attainment of self-rule in 1965, the government of Singapore embarked upon a rapid export-led industrialization program and promoted the high value-added industries to accelerate its growth rate. Foreign investment was very much encouraged from the beginning. The world economy at that time was booming, and there was a rising expectation that the demand for oil products in the Asia-Pacific region would further increase. The world trade was fast expanding, and the importance of Singapore's port increased significantly. The emergence of super oil tankers such as the very large crude carriers (VLCCs) made possible the transport of massive amounts of oil closer to the market for refinery at extremely low cost. All these factors, combined with Singapore's continued political stability and open-door policy, led to the phenomenal growth of the petroleum industry in the late 1960s and early 1970s.

There are five major oil refineries located in the coastal areas of Singapore (Fig. 5.1), and their total refining capacity is more than 1 million bpd (Table 5.13). This makes Singapore the second largest refinery in the world after Houston. The refineries have been processing

Table 5.13. Refineries in Singapore: ownership, capacity, sources of crude and major products as of 1978.

Refinery	Ownership	Capacity (bpd) 1978	Source of crude	Major products (including alternatives)
Shell, P. Bukom	100% Shell	500,000	70% Middle East (ME); 30% Far East (FE)	Fuel oil, diesel fuel, aviation fuel
Exxon, P. Ayer Chawan	100% Esso	213,000	Nearly 100% ME with some Pertamina and spot market terms	Fuel oil, diesel fuel, aviation fuel, gasoline
Mobil, Jurong	100% Mobil	180,000	90% ME; 10% FE	Fuel oil, diesel fuel, aviation fuel, gasoline
BP, Keppel	100% BP	28,000	50% ME; 30% Indonesia; and 20% Malaysia	Fuel oil, kerosene, gasoline
Singapore Refining Corp. (SRC), P. Merlimau	30% BP; 30% Caltex; and 40% SRC (31.33% SRC; 31.33% Development Bank of Singapore; 31.33% Amocco; and 6% C. Itoh)	65,000 and adding 100,000	Nearly 100% ME but takes special crude for Pertamina	55.5% fuel oil; 11.0% diesel fuel; 7.7% aviation oil; 4.6% gasoline (average for all Singapore refining)

Source: Far Eastern Economic Review (26 January 1979).

crude oil into various types of products, and the composition of output has been gradually adjusted to meet the demand. The refineries now give relatively less emphasis to bunker fuels and more to petroleum products such as kerosene and diesel fuel. Fuel oils still account for an overwhelming proportion of the output amounting to about 25% of the total product.

Contribution to the Country's Economy. The percentage composition of GDP by industry of Singapore for the years 1960, 1970, 1980, 1984 and 1985 is given in Table 1.5. The manufacturing industry increased its share of the GDP to 19% in 1985 from 13% in 1960, while the contribution by the trade sector decreased from 33% in 1960 to 23.4% in 1985. The petroleum industry contributes a major share to both sectors.

The contribution of the petroleum industry to total manufacturing output during 1974 to 1985 (Table 5.14) has been substantial although in value terms, has fallen from 40% in 1974 to 27.3% in 1985. In terms of gross value added (Table 5.15), the contribution is similarly substantial, averaging about 17% of the total output of the manufacturing sector. The industry is the second largest contributor to the industrial sector, after electronic products and components industry, although the share dropped recently due to recession.

Table 5.14. Contribution of petroleum industry to Singapore's manufacturing output, 1974-1985 ($ million).

Year	(1) Petroleum refineries and petroleum products	(2) Total manufacturing output	(3) (1) expressed as % of (2)
1974	5,705.5	14,237.0	40.1
1975	4,753.3	13,197.4	36.0
1976	6,118.8	16,175.0	37.8
1977	7,022.4	18,293.5	38.4
1978	7,498.3	20,492.3	36.6
1979	9,308.1	26,331.0	35.3
1980	11,520.5	32,805.8	35.1
1981	14,453.8	37,694.0	38.3
1982	14,641.2	37,141.1	39.4
1983	13,163.6	37,888.3	34.7
1984	12,448.8	41,704.1	29.9
1985	10,642.5	38,937.8	27.3

Source: DOS (1965-1986).

Table 5.15. Value added by the petroleum industry as compared to the manufacturing sector, 1974-1985 ($ million).

Year	(1) Petroleum refineries and petroleum products	(2) Total manufacturing output	(3) (1) expressed as % of (2)
1974	864.6	3,596.8	24.0
1975	605.0	3,463.8	17.5
1976	698.5	4,041.1	17.3
1977	774.2	4,539.6	17.1
1978	787.0	5,220.0	15.1
1979	916.0	6,523.9	14.0
1980	1,470.4	8,652.8	16.9
1981	1,707.2	9,866.9	17.3
1982	1,617.7	9,505.8	17.0
1983	1,382.6	10,012.4	13.8
1984	955.6	11,268.9	8.5
1985	845.8	10,657.4	7.9

Source: DOS (1965-1986).

As far as its structure is concerned, the petroleum industry is highly capital-intensive. The industry's capital expenditure accounted for about 17% of the total by that of the manufacturing sector on an average during 1975 to 1984. The petroleum industry is not a major employer of labor. In 1984, it had 3,575 workers, only 1.4% of the total employment in the manufacturing sector. The industry had the lowest ratio of personnel to total employment, reflecting its high degree of automation and mechanization.

The personnel have obtained relatively higher level of skills and expertise through various training programs. The average gross value added and remuneration per person far exceeds those in other industries. In 1984, the value added per person in the industry was $265,000 compared to an average of $40,400 for the total manufacturing sector. Average remuneration in the refining industry was $42,500 thousand in 1984, which was three times more than the average for the entire manufacturing sector. (See DOS 1985 for details on employment and remuneration figures.)

Capital investment in the petroleum industry has been steadily rising over the years, and as the figures in Table 5.16 suggest, the industry attracted substantial investments during 1975 to 1985. In 1975, about 44% of the total manufacturing investment went to the petroleum industry, but the proportion of investment gradually declined as the industry reached "optimal" size and its profitability was reduced. The bulk of the investment came from overseas (for example, in 1984, foreign investment accounted for about 75% of the total manufacturing investment), mainly from the US, Japan and the United Kingdom.

Table 5.16. Net investment commitments in petroleum industry ($ million), 1975-1985 (excluding petrochemicals).

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Petroleum	135.0	16.0	66.2	330.0	224.5	200.0	162.0	387.7	367.1	358.8	190.0
As % of total manufacturing investment	44.1	5.3	16.7	40.6	23.8	14.0	8.6	22.5	20.5	19.8	16.6

Source: DOS (1965-1986).

The petroleum industry plays a very important role in the country's foreign trade. In 1985, the export of petroleum and petroleum products accounted for 27% of the total exports, and the percentage share of the commodity in total imports was 29% (Table 5.17). In 1985, 11.5% of the

Table 5.17. Trade statistics for petroleum and petroleum products ($ million), 1974-1985.

Year	Export	% of total exports	Import	% of total imports
1974	3,654.1	26	4,891.3	24
1975	3,407.6	27	4,730.5	25
1976	3,743.7	23	6,136.6	27
1977	4,834.6	24	6,519.5	26
1978	5,279.1	23	7,074.5	24
1979	7,337.2	24	9,668.0	25
1980	11,828.0	29	14,879.5	29
1981	13,980.6	32	19,819.2	34
1982	14,437.3	33	20,471.4	34
1983	12,761.9	28	18,601.4	31
1984	12,992.3	25	16,949.4	28
1985	13,456.1	27	17,019.9	29

Source: DOS (1965-1986).

total crude oil imports came from Saudi Arabia. This country was Singapore's largest supplier of crude oil until 1984. The other major traditional suppliers are Kuwait, Iran and the United Arab Emirates.

In 1985, the People's Republic of China (PROC) ranked first as a supplier of petroleum and petroleum products to Singapore (Table 5.18). In previous years, PROC's contribution was only marginal, but it is hoped that it will remain the major customer of Singapore's refineries. Table 5.19 lists the major countries which import Singapore's petroleum, 1980 to 1985. Japan has always been the largest buyer, and with its recent major liberalization, Singapore can expect to penetrate the Japanese petroleum market even more. However, the penetration may be faced with intense competition from the US, Saudi Arabia and PROC.

Table 5.18. Percentage share of Singapore's main sources of petroleum imports, 1980-1985.

1980		1981		1982		1983		1984		1985	
Saudi Arabia	43	Saudi Arabia	54	Saudi Arabia	46	Saudi Arabia	35	Saudi Arabia	33	China	22.7
Kuwait	19	Kuwait	10	Penin. Malaysia	11	Penin. Malaysia	11	Kuwait	11	Iran	14.5
Penin. Malaysia	8	Penin. Malaysia	9	Iran	9	Kuwait	8	Penin. Malaysia	10	UAE	9
Bahrain	4	UAE	4	Kuwait	5	UAE	8	PROC	9	Saudi Arabia	11.5
Iran	3	Iran	4	Bahrain	4	Iran	6	UAE	8	Penin Malaysia	8.6
UAE	3			Sabah	4	Sabah	4	Iran	4	Kuwait	5.7
						Oman	4	Sarawak	4	USA	3.3
						Sarawak	4			Sarawak	3
										Brunei	3
										Sabah	2.9

Source: DOS (1965-1986).

Table 5.19. Major importers of Singapore's petroleum products, 1980-1985 (%).

1980		1981		1982		1983		1984		1985	
Japan	18	Japan	22	Japan	22	Japan	20	Japan	22	Japan	21
Hongkong	18	Hongkong	19	Hongkong	17	Penin. Malaysia	17	Penin. Malaysia	15	Penin. Malaysia	16
Penin. Malaysia	10	Penin. Malaysia	12	Penin. Malaysia	16	Hongkong	14	Hongkong	13	Hongkong	12
Australia	8	Australia	7	Australia	7	Thailand	8	Thailand	10	USA	8
Thailand	8	Thailand	7	Thailand	6	Iran	5	Australia	6	Thailand	8
New Zealand	6	India	5	India	5	Australia	5	India	6	Iran	6
India	4	New Zealand	3	New Zealand	4	Philippines	4	USA	5	Australia	5
Bangladesh	3	Bangladesh	3	Iran	3	S. Korea	3	Iran	4	New Zealand	3
Sabah	2	USA	2			USA	3			India	3
Taiwan	2										

Source: DOS (1965-1986).

Petrochemical Industry. The Petrochemical Complex of Singapore is the largest single investment, $2 billion project in Singapore. Mainly export-oriented, the upstream company of PCS supplies high-quality ethylene, propylene and acetylene gases to downstream companies. The latter produce high-quality petrochemical products for Southeast Asia and Japan.

The end products of the petrochemical industry are mainly plastics and resins, which are used as raw materials in the plastics industry. It had been estimated that the availability of stock for the plastics industry in Singapore would save close to half a million dollars in the cost of raw materials if local users buy from PCS. Such savings should increase the international competitiveness of the plastics industry (Singapore's *Economic Bulletin,* March 1984).

Perhaps the most important contribution of PCS is the transfer of advanced technology and skills from the investing countries. The management and operations of the sophisticated plants will help in upgrading the skills of local employers at both technical and managerial levels. More downstream industries may, in the future, be attracted to Singapore because of the available by-products of the petrochemical plants and savings on shipping costs. This can, therefore, stimulate the growth of related industries such as those of detergents, synthetic fibers, plastic parts of electrical appliances and automobiles in the region. The complex is a major user of electricity and other utilities, and a large purchaser of various goods and services from local industries.

Another reason for setting up PCS, as pointed out by the Economic Development Board (EDB), is that it is making use of abundant by-products (naphtha in particular) of Singapore's oil refineries which would have been wasted otherwise. Though the complex is a costly undertaking due to a large "minimum efficient scale," it offers one of the highest returns on capital invested in the petroleum industry.

Prospects for the Petroleum Industry. The oil industry in Singapore is mainly export oriented. Its export potential depends on Singapore's export of petroleum products which is affected by the total domestic demand and the total supply of the goods produced locally. The future export target can be realized only if there is a matching import demand from overseas, which again depends on the total demand for petroleum products in the rest of the world (particularly Singapore's traditional export markets) and the total world supply.

Domestic demand for oil products in Singapore is quite small, although the growth in domestic oil consumption in the past has been quite substantial. In 1983, the total demand for petroleum and petroleum products in Singapore was 76.4 million barrels (SICC Annual Report 1983-1984) as against the total refining capacity of 365 million barrels (at the rate of 1 million bpd) in that year. Local demand can be expressed in value terms by taking the differences between the export and import figures in Table 5.17. The differences are computed for 1974 to 1985 and shown in Table 5.20. It is clear from the table that local petroleum consumption was always above 30% of the petroleum exports, and that there has been significant growth in demand in the past decade although the demand sharply fell in 1983 to 1985.

Looking at the structure of domestic demand, the bulk of petroleum goes to ship bunkering, and the rest to PUB, aviation and the transport sector. Since the demand for public utilities (electricity, gas, etc.) in Singapore has been rising, it is expected that PUB's consumption of petroleum will continue to rise in the future despite the fact that it (PUB) has

Table 5.20. Domestic demand for petroleum and petroleum products ($ million), 1974-1985.

Year	Domestic consumption	Domestic consumption as % of exports
1974	1,237.2	33.8
1975	1,322.9	38.8
1976	2,392.9	63.9
1977	1,684.9	34.8
1978	1,795.4	34.0
1979	2,330.8	31.8
1980	3,051.5	25.7
1981	5,838.6	41.7
1982	6,034.1	41.7
1983	5,839.5	45.7
1984	3,957.1	30.4
1985	3,563.8	26.5

Source: DOS (1965-1986).

already taken some measures to conserve energy. The growth of motor vehicles in Singapore has been moderated from the 1970s and, so their demand for petroleum will grow gradually.

Apart from factors endemic to the refining industry as a whole (e.g., oil glut, decreased demand), Singapore has other problems due to losing refining orders from Indonesia and Malaysia, which have recently developed their own refineries to attain self-sufficiency in petroleum products. Other countries, such as Thailand and India, are also developing their own refining facilities.

Besides searching for new outlets for its products, the Singapore petroleum industry is now trying to improve and restructure its products towards secondary processing to upgrade heavier products, such as residual fuel oil (the demand for which fell sharply during 1973 to 1983), into lighter and more marketable products such as gasoline and middle distillates. If the demand for oil products gradually shifts towards lighter products, as projected by international energy experts, Singapore oil refineries will regain their profitability towards the latter part of the 1980s.

Other manufacturing industries

Industrial promotion in Singapore was carried out by setting up a number of satellite towns throughout the coastal zone. JTC played a pioneering role in the country's industrialization program, specifically, the development and management of industrial estates or parks. There are some 3,300 factories, employing 208,600 workers (JTC 1986) in these industrial estates. Besides port- and marine-related industries, there are various types of light manufacturing, furniture, cement, paper, metal and food processing industries in Jurong. There is no other industrial estate in the country of comparable size, as can be seen from Fig. 5.1.

JTC has drawn up development programs to promote new investments by high-technology and skill-intensive industries and to upgrade producton methods of existing industries. These programs include a 125-ha Science Park at Kent Ridge which aims to stimulate research, development and innovation in the manufacturing sector; the reservation of new reclaimed land for high value-added industry; the development of warehousing facilities near heavy industries; and an increase in the number of technological institutes to import modern technology to local workers.

Since Jurong has reached more or less a saturation point in spatial development, JTC is currently promoting seafront property development in other locations to achieve a more equal distribution of industrial activities in the country. The industrial towns outside Jurong are not only decentralized but also exhibit a certain degree of specialization. The two nearby estates of Sg. Kadut and Kranji are the country's centers of raw timber and wood products. About 60% of the companies in the two estates are engaged in furniture manufacturing. Along the northeastern coast of Singapore, Loyang and Changi Estates have specialized in aviation-related activities. At Loyang, four major companies are in manufacturing, overhauling and maintenance of aircraft parts. Servicing of aircraft is done at Seletar, a former airforce base.

Power Generation

PUB, formed in May 1963 as a statutory authority to take over the function of utility supply from the former City Council, is responsible for the production and distribution of public utilities in Singapore. All power stations are located in the coastal area (Fig. 5.1).

Production and consumption

Electricity is generated mainly at three oil-fired power stations at Senoko, Pasir Panjang and Jurong. The gas turbines at these areas are used primarily for emergency and supplement in peak periods. Table 5.21 shows the production and sales figures for electricity during 1975 to 1985. Production has been increasing over the years, and in 1985, a total of 9,876 million kilowatt hours (KWH) was generated by the country's power stations. An additional 41 million KWH was produced in 1985 by the Ministry of the Environment's (MOE) Refuse Incineration Plant.

The total number of consumers was 716,848 in 1985, 85% of which were domestic consumers. However, domestic consumption formed only 16% of the total consumption (Table 5.21). Electricity sales in 1985 were 8,871 million KWH. The manufacturing sector has always been the largest consumer of electricity, and in 1985, it accounted for 45% of the total consumption. At the end of 1985, PUB employed 7,929 personnel.

Table 5.21. Electricity production and sales, 1975-1985.

Year	Production	Sales						No. of
		Total	Domestic	Lighting	Manufacturing	Industries	Export	consumers
		KWH (million)						(end of period)
1975	4,176.0	3,673.3	643.3	43.9	1,783.3	1,202.9	–	404,898
1976	4,604.9	4,038.0	703.4	46.6	1,980.5	1,307.5	–	433,784
1977	5,114.7	4,506.4	779.0	49.1	2,246.2	1,432.1	–	467,295
1978	5,898.0	5,213.7	887.5	51.5	2,606.8	1,619.5	48.4	504,327
1979	6,447.9	5,743.7	945.2	50.4	2,803.3	1,851.6	93.2	531,596
1980	6,940.4	6,198.0	1,014.3	56.7	2,947.2	2,087.8	92.0	561,708
1981	7,442.0	6,660.4	1,092.8	60.5	3,156.2	2,277.0	73.9	579,868
1982	7,859.6	7,000.1	1,166.9	64.5	3,217.6	2,499.6	51.5	593,975
1983	8,625.9	7,697.6	1,313.0	65.3	3,504.9	2,759.6	54.8	616,402
1984	9,420.7	8,398.8	1,336.2	68.3	3,926.7	2,994.6	73.0	678,626
1985	9,876.3	8,871.2	1,461.8	70.3	4,018.6	3,270.1	50.4	716,848

Source: DOS (1965-1986).

Singapore's electricity supply depends entirely on imported oil as energy source. The uncertainty of oil supply and high oil prices have led PUB to consider alternative energy sources. The most feasible alternative fuels for electricity generation in Singapore are natural gas and coal; other sources such as nuclear energy, tidal energy, hydroenergy and wind power are not feasible options. For instance, nuclear energy is not suitable because nuclear plants present many problems including safety, siting of reactors and waste disposal. Besides, the country's need for electricity until the year 2000 would be too small to make nuclear energy feasible.

PUB's existing power stations do not have coal-firing capabilities. One of the main considerations against the use of coal for power generation, though, was that it causes more pollution than other fuels. Coal burnt at coal-fired stations was found to produce an ash content 100 to 200 times higher than the oil-fired ones. As a result, there is no firm plan yet to construct a coal-fired power station in Singapore, although coal will remain a long-term option.

Negotiations on piping natural gas in Singapore began in 1983 between Malaysia's natural oil company, Petronas, and PUB. The proposed project involves piping of gas from Malaysia's offshore fields in Trengganu to Johor Bahru and then to Singapore. The natural gas will be used as an alternative to fuel oil to fire the Senoko Power Station, which has been designed to take in gas and fuel oil, and the P. Seraya Power Station which has similar provisions under its second phase. However, the current oil glut and weak prices appear to have diminished the urgency for Singapore to look for an alternative fuel oil. The plan to pipe the gas from Trengganu to Singapore was still being negotiated in 1988.

On 4 February 1986, a $4 million electricity project between Singapore and Malaysia was launched. The project involved the new power link between the Senoko Power Station and the Sultan Iskandar Power Station in Pasir Gudang, Johor. Each of the two 230 KV circuits linking the two power stations is capable of transmitting 200 MW of electricity either way. This project will mean fewer blackouts on both sides of the causeway and a quicker recovery if there should be large-scale power failures.

Fisheries and Aquaculture

Singapore obtains its annual fish supply of approximately 126,000 t mainly through fish importation from Thailand, Malaysia and Indonesia. Local supply contributes 12%, largely from capture fisheries along the coastal waters and partially from aquaculture. There are no inland fisheries resources in Singapore.

Coastal fisheries

There has been no systematic survey of the fisheries resources in Singapore waters. The amount of fish caught in local waters reached a maximum of about 40,000 t annually in the late 1940s and early 1950s. A number of fishing gears were used: otter trawls, trolling, gill nets, long lines in offshore waters and fish traps such as palisade traps (locally known as *kelong*) and fish pot *(bubu)* in inshore waters. Most of the fish caught were demersal species which made up two-thirds of the total catch (Aoyama 1973). Fish catch declined from its peak in the 1940s and 1950s to about 15,000-20,000 t in the 1970s and 1980s. The catch appeared to be static since 1974 (Table 5.22) while the fishing efforts underwent drastic readjustments. The number of fishing vessels dropped from 737 (499 powered) in 1975 to 446 (415 powered) in 1985. The 300 *kelong* in 1952 in Singapore waters was also reduced to about 270 by 1958, and further reduced in the 1960s (Fig. 5.2); only a few were left in the 1980s (Chia 1982). The number of fishermen also decreased at a fast rate, too. In 1980, there were 2,025 fishermen while in 1985, only 1,321 were left.

Table 5.22. Fresh fish supply and auctioned (t).

Year	Supply				Fish auctioned
	Total	Local production[a]	Imports	Exports	
1974	63,443	18,556	51,057	6,170	64,200
1975	59,610	16,928	50,559	7,877	65,803
1976	60,751	15,775	53,286	8,310	65,976
1977	59,450	14,350	69,729	24,629	67,478
1978	54,017	15,634	68,781	30,398	66,883
1979	51,266	16,015	73,524	38,273	68,299
1980	47,268	15,532	80,440	48,704	74,244
1981	64,501	15,620	99,707	50,826	85,016
1982	56,939	18,830	89,104	50,995	93,430
1983	62,152	19,099	99,099	56,046	102,573
1984	71,586	25,041	107,784	61,239	117,638

[a]Figures exclude pond fish production.

Source: DOS (1965-1986).

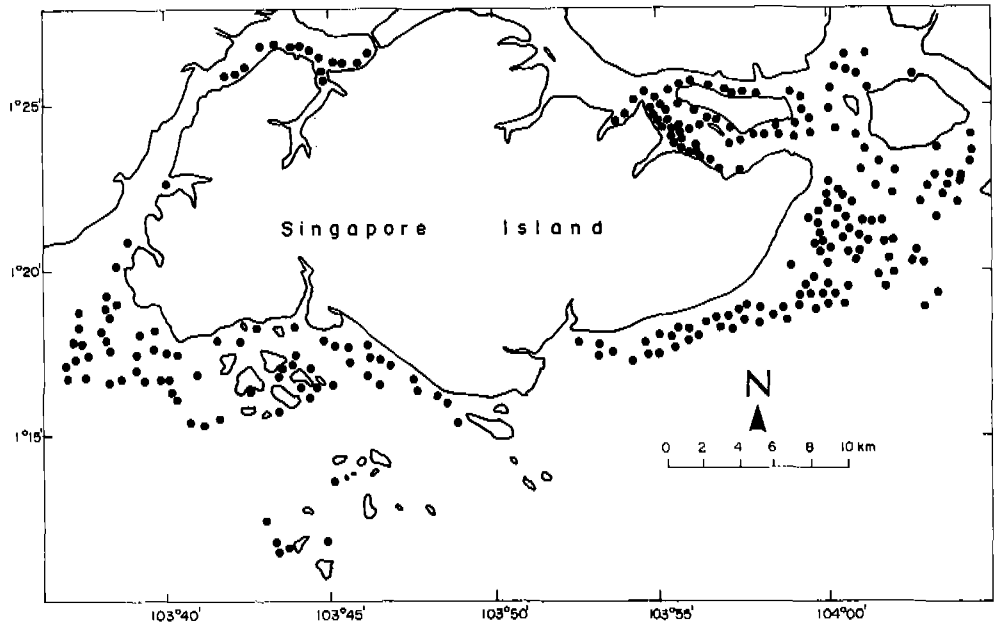

Fig. 5.2. Distribution of *kelong* in mid-1960s in Singapore.

The present level of fish production in Singapore coastal waters probably represents the economic production level the existing fishing effort can sustain. There are many interrelated factors that limit coastal fish production in Singapore. Some of these are:

1. Extensive coastal reclamation particularly since the 1960s, resulting in increased silting of coastal waters;
2. Removal of coastal (mangrove) vegetation;
3. Canalizing of river courses which reduces the amount of fine sediments and nutrients;
4. Increased shipping activities;
5. Increased land-based activities and the resulting deliberate or inadvertent discharge of oil and other pollutants in coastal waters;
6. Restrictions in giving licenses to operate fish traps; and
7. Availability of more lucrative alternative employment opportunities resulting in fewer fishermen.

Coastal aquaculture

Until the 1960s, Singapore had a thriving pond culture industry which included farming of shrimp, fish, crabs and reptiles on the coastal swampland. Today, except for a few remaining fishponds in the northern and northwestern coasts and P. Ubin, pond culture has virtually disappeared due to the filling of swamps and land reclamation (Chia 1982).

Shrimp ponds were first introduced in Singapore by the Chinese at the beginning of the twentieth century. Local tidal conditions, with their limited diurnal and seasonal range, are favorable for shrimp farming. The method employs the use of a bund to enclose 15-20 ha of swampland. A sluice gate allows the shrimp larvae to flow into the pond during high tide and, when the tide is going out, the pond is closed to maintain a desired level of water. Feeding to augment the natural supplies in the enclosed pond is done. Harvesting is made by opening the sluice gate and catching the adult shrimp as they are washed out into the open sea. It is necessary to have a fringe of mangrove swamp to reduce the force of the waves and avoid damage to the bund.

The shrimp breed out at sea. The larvae move towards coastal and estuarine waters where they spend the early part of their lives. According to Tham (1973a; 1973b), the breeding grounds of the main species of shrimp are found on the east of Singapore and off the Southern Johor east coast and perhaps in Strait of Malacca. The proximity of the breeding grounds ensures the success of the Singapore shrimp ponds.

In the 1950s and 1960s, the shrimp ponds were found mainly along Jurong, West Coast Road, Tampines, Serangoon, Ponggol and Chua Chu Kang Coasts; along the more sheltered portions of the coasts; the estuaries; and in P. Ubin and P. Tekong (Fig. 5.3). It was estimated that until the early 1960s, there were 810 ha of shrimp ponds (Teo E.S.L. 1965). By the early 1970s, according to the Agricultural Census of 1973, the area had been reduced to only 126 ha (Wong 1976) partly due to siltation and largely because of decreasing pond yield. Subsequent land reclamation and the recent construction of estuarine reservoirs further saw the lessening of shrimp ponds.

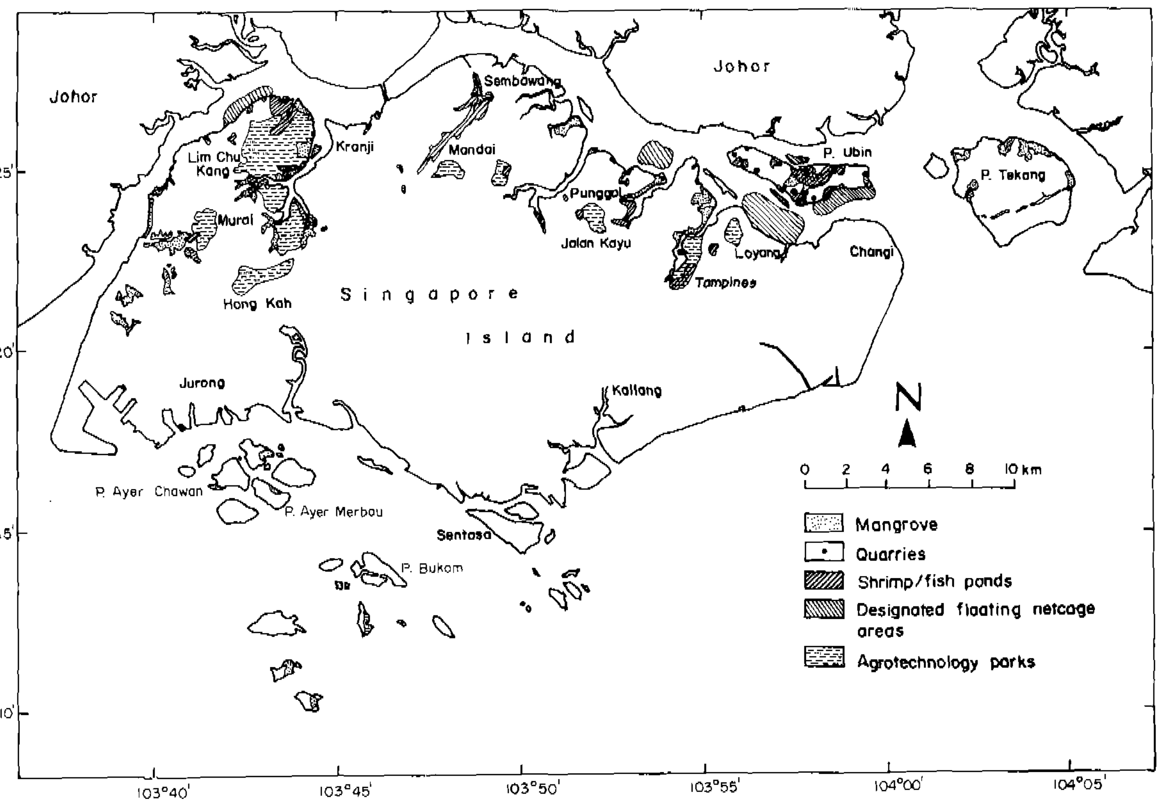

Fig. 5.3. Mangrove areas and shrimp/fish ponds in Singapore.

However, due to the recent booming of the shrimp industry, expansion of shrimp ponds occurred in specific areas, especially in P. Ubin. In 1987, there were 240 ha of shrimp ponds which produced about 76 t (Cheong 1988). Most shrimp ponds in Singapore have switched from extensive to intensive farming system by applying high stocking density and providing supplementary feeds. The main species caught in traditional shrimp ponds included Indian shrimp *(Penaeus indicus)*, sand shrimp *(Metapenaeus ensis and M. brevicornis)*. However, the species have been changed to the banana shrimp *(P. merguiensis)* and the tiger shrimp *(P. monodon)* in intensive pond cultivation both because of their food market demand and also the availability of culture technologies.

Cage culture and mussel farming began in 1970 and by the end of 1986, 35% of the 100 ha of seaspace in East and West Johor Strait set aside for floating farms had been leased

(MOND 1985). Finfish being farmed include seabass *(Lates calcarifer)*; groupers *(Epinephelus salmoides, Plectropomus maculatus, Cromileptis altivelis)*; snappers *(Lutjanus johni, L. argentimaculatus)*; siganids *(Siganus canaliculatus, S. guttatus)*; golden trevally *(Gnathodon speciosus)*; and yellowfin jack *(Caranx nobilis)*. Also farmed in netcages are shellfish such as mangrove crab *(Scylla serrata)*; banana shrimp *(P. merguiensis)*; and spiny lobster *(Panulirus polyphagus)*, while the green mussel *(Perna viridis)* is cultured on ropes suspended from floating rafts.

Total production from the coastal waters was 1,880 t in 1987 of which 410 t were finfish; 450 t, crustaceans; and 1,020 t, green mussels. Most marine food fish production comes from the floating cage farms located in East and West Johor Strait, with an aggregate net area of 35 ha and total facing area of 200 ha.

The industry

The total fresh fish supply in 1987 was 125,900 t with 110,000 t (88%) derived from imports (Cheong 1988). Local production made up the remaining 15,300 t of which 13,220 t (12%) were derived from coastal fisheries and 2,080 t from aquaculture (200 t from freshwater aquaculture). Current local production is inadequate to meet increasing demands. Fish constitute one-third of the total animal protein demand in the country where per capita consumption is about 30 kg. Traditionally, Singapore depends on its neighboring countries for fish supply.

Malaysia used to be the major supplier of fresh fish to Singapore. However, the latter has gradually diversified its sources of imports to reduce dependence on a single country, and is now involved in fish trade with many countries in the world. Table 5.23 shows the existing trade pattern.

In 1985, Taiwan was the principal source of fish imports, followed by Thailand, Peninsular Malaysia, the US, Hong Kong and Japan. Although local fish production is very

Table 5.23. Singapore's fish trade, 1985 (in $ thousand).

Destination	Total imports	Total exports	Domestic exports	Re-exports
Australia	16	2,475	2,343	132
Austria	–	445	440	5
Bangladesh	247	–	–	–
Belgium	58	1,310	1,286	24
Brunei	–	895	458	437
Burma	861	–	–	–
Canada	258	285	217	68
People's Republic of China	691	–	–	–
Denmark	353	1,167	1,154	13
Finland	34	448	448	–
France	204	4,931	4,897	34
Germany, Federal Republic of	129	5,504	5,477	28
Hongkong	8,820	1,355	652	703
India	5,596	6	3	3
Italy	59	3,740	3,468	272
Japan	7,323	98,214	3,220	94,993
Korea, Republic of	764	5,737	37	5,700
Kuwait	–	522	522	–
P. Malaysia	16,064	6,312	709	5,604
Netherlands	678	1,235	1,214	21
New Zealand	989	96	96	–

Continued

Table 5.23. (continued)

Norway	1,159	236	235	1
Panama	1,340	–	–	–
Philippines	2,294	128	128	–
Sabah	1,515	493	259	234
Sarawak	151	1,754	1,012	742
Saudi Arabia	–	1,589	1,589	–
Spain	227	1,104	809	295
Sweden	125	1,223	1,221	2
Switzerland	10	895	889	6
Taiwan	81,124	1,171	918	253
Thailand	22,581	5,411	1,715	3,696
UK	260	4,293	4,293	–
Uruguay	299	–	–	–
USA	13,943	23,153	12,612	10,541
USSR	2,024	2,297	2,297	–
Vietnam, S.R.	779	–	–	–
Other countries in Central and S. America	560	3	3	–
Other countries	660	1,459	1,354	104
Total	172,195	179,886	55,975	123,911

Source: DOS (1985).

small, the value of Singapore's fish exports has exceeded its import value. The bulk of the earnings, of course, came from re-exports, which refer to fish exported from Singapore in the same form as they have been imported without any transformation. Repacking, splitting into lots, sorting or grading, marking and the like are not considered as undergoing the process of transformation. Exports of processed fish products have also been quite substantial, and the main export markets are the US, Japan, Germany, UK, USSR, etc. Singapore is, therefore, playing the role of a major distributor rather than producer in the international fish market.

The contribution of fisheries to the country's GDP is negligible. For example, out of the total GDP (at current market prices) of $38,873.8 million in 1984, the entire agriculture and fishing sector contributed only $354.1 million, which is less than 1% of the GDP (see DOS 1985).

The fishing industry provides very little employment opportunities and prospects. There was a downward trend on the number of licensed fishermen and fishing vessels during 1974 to 1983 (Table 5.24). Fishing around Singapore waters using nonpowered boats is classified as

Table 5.24. Fishing vessels and fishermen, Singapore, 1974-1983.

Year	Fishing vessels			Licensed fishermen
	Total	Powered	Nonpowered	
1974	769	509	260	2,194
1975	737	499	238	2,054
1976	709	493	216	1,986
1977	736	539	197	2,078
1978	719	546	173	2,084
1979	685	546	139	1,959
1980	641	511	130	2,025
1981	655	526	129	2,047
1982	622	514	106	1,848
1983	575	519	56	1,641

Source: DOS (1965-1986); MOND (1985).

inshore fishing, and the bulk of such catches is from *kelong* and drift nets. Offshore fishing is mainly carried out in the South China Sea and part of Indian Ocean. The most commonly used offshore fishing gears are otter trawls and bottom long lines for demersal fish, and troll lines for pelagic fish. Auctioning of fish is carried out mainly at Jurong Fishing Port. The bulk of the fish auctioned actually comes from overseas, and a relatively small quantity of local landings is auctioned at Kangkar fish market.

The fishing industry in Singapore will continue to play a very minor role in the national economy because of the serious lack of fishing grounds. The adjacent waters of Singapore are fully exploited, and there is no possibility of increasing its coastal water limit. However, the demand for fish in Singapore is very high and will continue to rise with the increasing standards of living. The average consumption of fish per person is about 24,950 g, which is higher than many well-known maritime countries such as France, UK, Denmark and Japan (Chan and Say 1979). So, importation of fish from neighboring countries will further rise in the future.

Singapore's fish processing industry is also quite small in size. In 1983, there were altogether four establishments employing 29 workers involved in processing, curing and preserving seafoods. The total value added by the industry in that year was $449,000 which was about 2.2% of the total value added by the entire food industry (DOS 1985). The government has taken steps to promote this industry which has potential for development.

Aquarium fish production in Singapore has been quite promising. The value of aquarium fish exported in 1983 amounted to $32.3 million, and rose to $40.4 million in 1984. The government is helping develop this industry into a big foreign exchange earner. Advances have also been made in the techniques of aquarium fish rearing in recent years through research at Sembawang Research Station.

Retail Business Sector

Historically, shophouses and godowns were located along the waterfront. The development of the commercial center along the southern coastline of the island created the focus of government administrative buildings and the urban core area of the Republic. However, with the passing of time, many of the properties and buildings along the waterfront became dilapidated and had to be phased out while other solidly built public buildings had been preserved. Well-planned shopping centers, financial towers, high-rise hotels and other modern buildings had been developed in the last two decades creating a new skyline for the waterfront.

One of the main objectives of the redevelopment program was to satisfy the rising demand for Western-type office space in the city core, and for this purpose, the areas in the vicinity of the business district were steadily cleared of their excessive residential population. Shenton Way has been developed from a vacant plot and reclaimed land to become the financial nerve center of Singapore. An increasing number of international firms dealing in the world's money market have chosen to locate their regional offices in Shenton Way, which is also known as the "Wall Street of Singapore".

The most ambitious project implemented by URA is Marina City which will be linked directly with the Changi International Airport to the east and Jurong town to the west (Fig. 4.3). The bulk of the project is scheduled to be completed before the end of the decade. Another important undertaking by URA is the Singapore River project which plans to redevelop 81 ha of land in three zones (Boat Quay, Clarke Quay and Robertson Quay) to generate recreational and commercial activities.

Residential Uses

The natural aesthetic qualities of the coastal areas provide an ideal residential environment. Prior to 1970, residential development along the coastal zone was carried out mainly by private developers. Bungalows, located along the coast at Pasir Panjang and along Katong-Bedok areas, formed the main belt of residential facilities developed in the coastal zone in the 1960s. Foreshore reclamation has either removed them or pushed them inland.

Public housing

Low-cost public housing includes those built by the Singapore Improvement Trust (SIT) and the HDB. The latter was established on 1 February 1960 as a statutory board of MOND to build cheap flats for the poor and to replace the rather ineffective SIT which had been in existence since 1947. On 1 May 1982, HDB became the sole public housing authority in Singapore with the takeover of the residential units hitherto managed by JTC and the Housing and Urban Development Corporation (HUDC). Therefore, HDB is able to achieve the government's objective of creating integrated communities with a good mix of different income levels in the new towns and housing estates.

At the beginning of the 1960s, less than 9% of Singapore's 1.6 million people lived in some 23,000 units built by SIT under the British colonial administration. By 1986, more than 2 million people, or about 84% lived in 551,767 HDB flats. HDB has successfully completed its fifth five-year building program since its inception. The first program was aimed at constructing the maximum number of flats in the shortest time and at the lowest cost. The first few housing estates, for example, in Kallang Basin, Kallang Park, Redhill and Queenstown were often located on vacant land on the city's periphery within a 10-km radius from the city center. This distance was estimated to be close enough for commuting to the city without severe economic constraint.

By the 1970s, most of the available sites were quickly used up, and thus the second-generation new towns were located 10 to 13 km away from the city center (e.g., Bedok, Ang Mo Kio and Clementi). This dispersed housing pattern also reflects the increased private car ownership, which enables people to commute greater distances; the wider choice for employment, shopping and recreation; as well as the MRT system which would connect all new towns to the main centers of employment, thus minimizing the problem of distance. Later versions of new towns (of which Tampines is the first) incorporated the precinct concept through more imaginative uses of various building forms and improved accessibility to shopping and public facilities. Under the current sixth five-year building program (1986-1990), HDB proposes to build 160,000 units.

At present, there are 16 new towns in Singapore (Table 5.25 and Fig. 5.4). Seven of them have been virtually completed (Queenstown, Toa Payoh, Telok Blangah, Bedok, Ang Mo Kio, Clementi and Jurong East) while the rest are still under construction simultaneously (Woodlands, Yishun, Jurong West, Hougang, Bishan, Serangoon, Tampines, B. Batok and Zenghua). Collectively, all these towns, when completed, will have 517,000 flats housing well over 2 million people and will occupy a combined land area of 88 km^2 or one-seventh of the present size of Singapore.

Besides the new towns, there are also 19 housing estates (Table 5.26), which are much smaller in size with a maximum of 10,000 dwelling units per estate, under the management of HDB. Fig. 5.4 shows the new towns and housing estates which are relatively closer to the coastline. These include Telok Blangah, Clementi, Jurong West, Jurong East, Woodlands, Yishun, Punggol, Loyang, Tampines, Bedok, Marine Parade, and Changi.

Table 5.25. New towns in Singapore as of 1985.

New town	Year of construction	Total land area (ha)	Residential area allocated (ha)	Projected total no. of dwelling units	Dwelling units completed as of Mar 85	Dwelling units under construction as of Mar 85
Queenstown	1952	285	149	28,000	28,000	–
Toa Payoh	1965	339	167	36,600	36,600	450
Woodlands	1971	1,223	421	55,000	15,600	8,020
Telok Blangah	1972	96	68	13,700	13,190	–
Bedok	1973	751	277	48,800	47,540	–
Ang Mo Kio	1973	671	269	49,500	49,480	–
Clementi	1974	344	143	24,500	24,050	–
Yishun	1976	903	391	40,000	18,800	17,070
Hougang	1979	440	180	25,500	14,800	11,210
Jurong East	1979	236	82	12,800	12,800	–
Jurong West	1979	709	354	39,500	14,150	1,810
Serangoon	1979	212	110	18,000	7,990	4,460
Tampines	1980	957	331	45,700	24,450	6,320
Bukit Batok	1981	733	133	24,800	15,230	10,110
Bishan	1981	525	170	24,600	1,380	6,400
Zenghua	1981	380	211	30,000	–	3,740

Sources: HDB (1986); Straits Times, 14 February 1986 and HDB (various years).

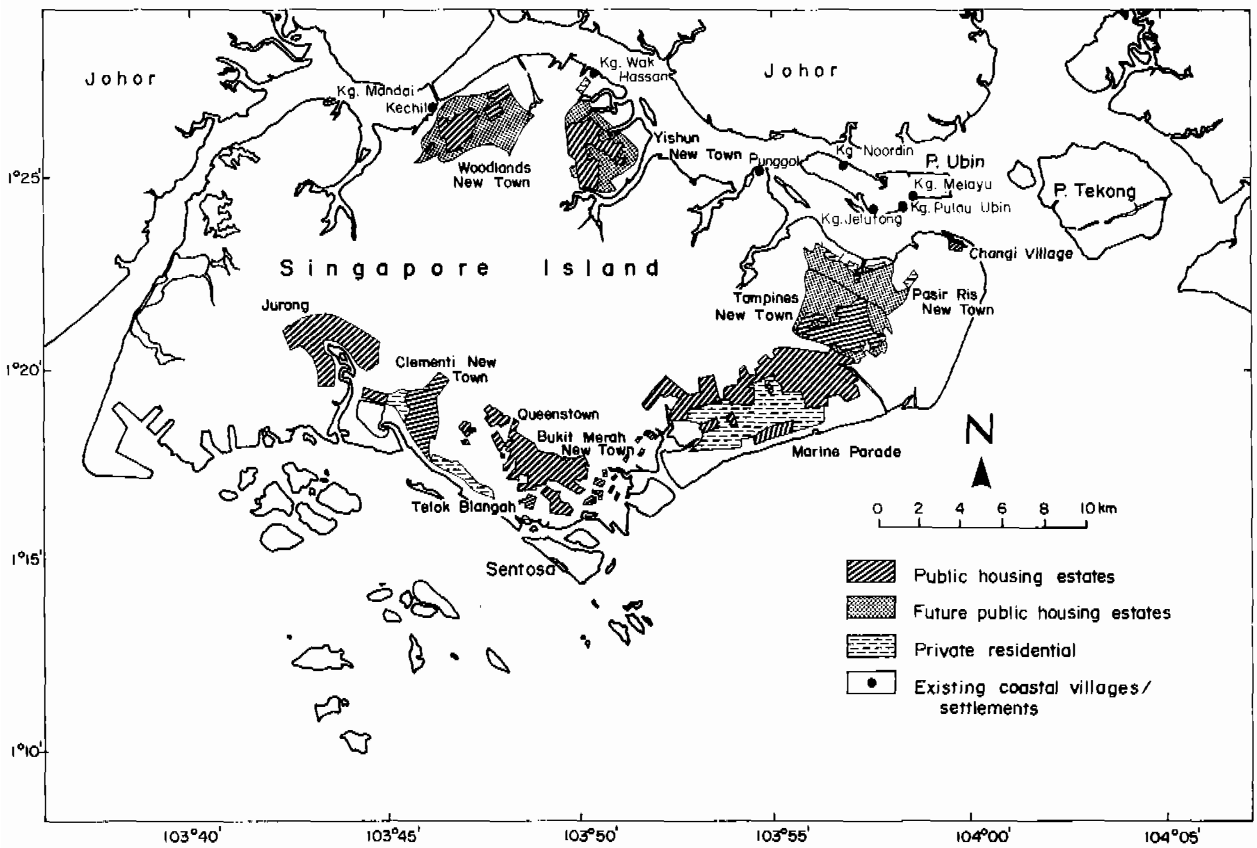

Fig. 5.4. Public housing estates and residential areas in Singapore.

Table 5.26. Housing estates under development in Singapore as of 1985.

Estate	Total land area (ha)	Residential area allocated (ha)	Projected total no. of dwelling units	Dwelling units completed in 1984/1985
Alexandra	10	9	1,590	–
Bukit Purmer	20	14	2,300	1,190
Delta Estate	10	9	1,420	–
Eunos	128	37	4,400	–
Geylang East	64	21	3,600	–
Joo Chiat/Changi Road	3	1	230	–
Kaki Bukit	196	21	2,910	290
Kampong Ubi	170	21	3,450	1,050
Kerbau Road	11	9	640	–
MacPherson Estate	·128	50	10,830	400
Potong Pasir	47	21	3,700	740
Redhill Balance	9	8	2,120	–
Rowell Court	5	5	1,020	590
Simei	105	51	9,400	–
St. George's Estate	14	11	2,440	500
St. Michael's Estate	23	19	3,450	–
Teban Gardens				
Towner Road/McNair Road	12	12	2,100	270
Upper East Coast	15	13	1,710	590

Source: HDB (1986).

The most interesting and perhaps the only true coastal new town will be Pasir Ris which is now under development landwards of Pasir Ris Park which is located on the waterfront. Deliberate plans have been made to provide easy access to the park. Details such as marine vistas from vantage points within the new town and the preservation of green areas have been taken into account in the planning. HDB has been promoting the new town on the basis of its coastal location and accessibility due to the extension of the MRT system to it by 1990.

Private housing

Private dwellings include high-rise flats/condominiums, bungalows and squatter areas. The flats and bungalows are associated with the middle- and upper-income groups; the squatters, with the lower-income groups. Private housing density is lower than that of public housing, with the exception of squatters in the Central Area. High-rise private flats can be found along Katong, Nicoll Highway and in Marine Parade and East Coast. The units along the reclaimed East Coast site, for example, include the blocks in Marine Parade Estate, Neptune Court, Lagoon View and Lagoon Park, Mandarin Gardens and Bayshore Park.

Bungalows and *kampong* predominate the coastal areas along Pasir Panjang, Katong, Bedok and Changi. Some of the bungalows along Bedok/Katong and Pasir Panjang are, however, no longer at the edge of the coast because of reclamation. Other such low-density settlements are associated with rural land (mixed cultivation areas), some of which are in the process of being cleared for other developments.

In the offshore islands (e.g., P. Ubin, P. Seking), housing density is very low, and except for Sentosa, St. John's Island, P. Bukom and other industrial islands where government or private quarters are found, the houses are of the traditional type.

Recreation on the mainland

Tourism plays an important role in Singapore economy. It accounted for 6% of the GDP in 1980 to 1983. With an average annual contribution of 16% to the total foreign exchange earnings, it is the third largest foreign exchange earner in the country, following transport and communications (19%) and manufacturing (15%) (MOTI 1984).

Endowed with varied and interesting scenic qualities and amenable to catering for water sports, the coastal zone has excellent recreational potentials. However, due to high demand for limited coastal resources from other competing activities, such as shipping and port and marine-related industries, only a small part of the coastal area can be devoted to the development of recreational facilities.

Golf clubs, swimming pools, botanical gardens, parks, water sports complexes and museums have been developed in various parts (Fig. 5.5 and Table 5.27). Most of the attractions are confined along the southern coast, although there are a few beach resorts in the northeastern coast.

Among the coastal parks with diverse facilities, the free-admission East Coast Park is the best known. The 140-ha park lies on a stretch of reclaimed land from Tg. Rhu to Bedok. Thousands come to the park to picnic, swim, play tennis or squash, sail, windsurf, bicycle, jog, fly kites or simply to enjoy the food at the restaurants. The lagoon is equivalent in size to 40 Olympic swimming pools; half of it is exclusive for swimming and the other half for windsurfing.

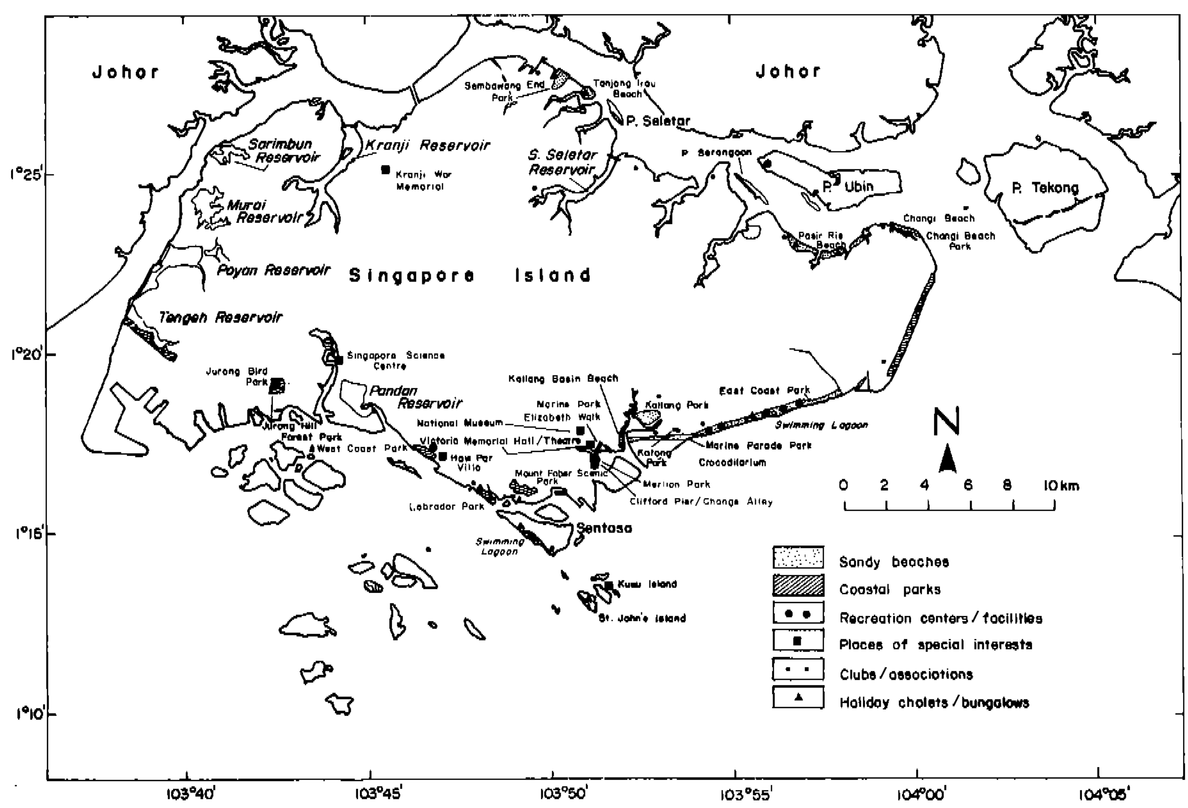

Fig. 5.5. Open spaces and recreational facilities in Singapore.

Table 5.27. Coastal recreational and tourist facilities in Singapore.

Jurong	1.	Jurong Bird Park
	2.	Jurong Town Swimming Pool
	3.	Jurong Family Club
	4.	Jurong Country Club
	5.	Jurong Town Hall
	6.	Japanese Garden
	7.	Chinese Garden
	8.	Science Centre
	9.	Mistsukoshi Garden—Jurong Water Sports Complex
	10.	Jurong Hill Forest Park
	11.	Warren Golf Club
	12.	*Kelong*—fishing stakes
	13.	Jurong Fish Market (2 am-7 am)
	14.	Singapore Yacht Club
Katong/ Marine Parade	1.	Big Splash
	2.	Chinese Swimming Club
	3.	Singapore Swimming Club
	4.	Singapore Tennis Centre
	5.	Golf driving range
	6.	East Coast Park
	7.	East Coast Swimming Lagoon
	8.	Crocodilarium—crocodile farm
Mountbatten	1.	Kallang Sports and Tennis Centre
	2.	National Stadium and Gymnasium
	3.	Leisuredrome
	4.	Wonderland Amusement Park
	5.	Kallang Bowl
	6.	Sultan Mosque
City area	1.	Forbidden Hill (present Fort Canning Park)
	2.	National Museum and Art Gallery
	3.	National Library
	4.	Singapore Recreation Club
	5.	Singapore Cricket Club
	6.	Parliament House/Supreme Court
	7.	Victoria Theatre and Memorial Hall
	8.	Satay Club/Elizabeth Walk/Padang
	9.	Raffles landing site
	10.	Merlion Park/Singapore River
	11.	Clifford Pier/Change Alley
	12.	Kuan Yin Temple (Waterloo Street)
	13.	Sri Mariammal Sultan/Sakya Muni Buddha Gaya
	14.	Cheetian (Hindu) Temple Tank Road
	15.	Temple of a Thousand Lights
River Valley	1.	National Theatre
	2.	Van Kleef Aquarium
	3.	River Valley Swimming Pool
	4.	China Town/People's Park
Changi/Punggol	1.	Changi Golf Club
	2.	Changi Swimming Pool
	3.	Changi Beach
	4.	Changi Tennis and Squash Courts
	5.	Changi International Airport
	6.	Changi Sailing Club
	7.	Changi Prison
	8.	Tanah Merah Club
	9.	Pasir Ris Beach
	10.	Punggol Point Boatil
	11.	Punggol Suradi's Water Ski School
	12.	Kelong
Keppel/ Pasir Panjang	1.	Pasir Panjang Bowl
	2.	Tiger Balm Gardens/Haw Par Villa
	3.	NUS/Poly canoe site
	4.	World Trade Centre/cable cars
	5.	Mt. Faber Scenic Park
	6.	Science Park
	7.	Kreta Ayer People's Theatre
	8.	Sentosa
	9.	West Coast Park
	10.	Keppel Club
	11.	Railway Station
Sembawang	1.	Sembawang Tennis Court
	2.	Sembawang Swimming Pool
	3.	Tanjong Irau Beach
	4.	Sembawang Golf Club
Seletar	1.	Seletar Tennis and Squash Courts
Kranji	1.	Kranji War Memorial
	2.	Woodlands Park

The East Coast Sailing Centre offers sailing on the lagoon or out at sea. Beaches along the park offer safe swimming in warm waters. These sites are also used for holding dragon boat competitions and international kite festivals which attract participants worldwide.

Recreation in the offshore Islands

Although Singapore has about 60 offshore islets, only a few of these have been developed for recreational and industrial activities. SDC, established in 1972, has the overall responsibility of developing the water-based tourist resorts in the country and the following offshore islands: Sentosa, St. John's, Kusu, Sisters, Buran Darat, Seletar, Jong, Renget, Lazarus, Hantu, Sudong, Terembu Retan Laut and Biola. Some of these have already been developed as tourist attractions, and they offer different types of recreational facilities.

Sentosa. Also called the "Island of Peace and Tranquility," Sentosa is the best developed of the islands. It lies half a kilometer to the south of the mainland (Fig. 5.6), measures 4.15 km long and 1 km wide, and covers 335 ha. The popularity of Sentosa is seen in its rising number of visitors. In 1977, it recorded 0.7 million visitors, 75% of which were local visitors and 25%, foreigners. The figure peaked to 1.9 million in 1983, with roughly the same proportion of local and foreign visitors (SDC Annual Report 1981-1986). Visitors can reach the island by cable car either from Mt. Faber or PSA Tower Jardine Steps mid-station. On arrival, the monorail is the main form of transportation and provides a scenic ride along the 6.1 km route, passing by sandy beaches, secondary forests, busy harbor, nearby islands and skyline.

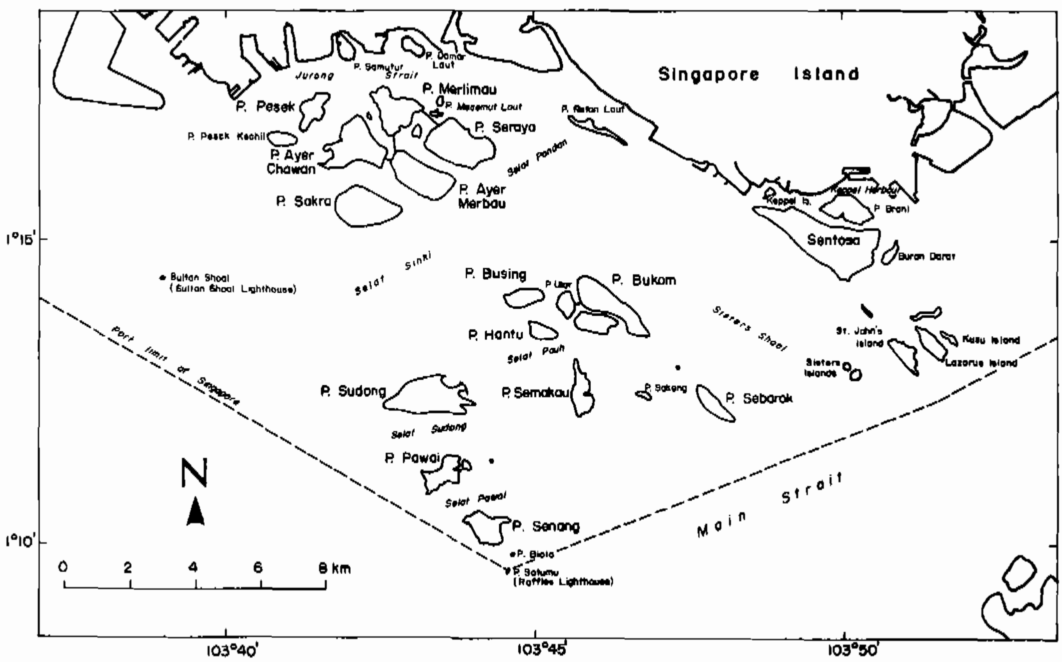

Fig. 5.6. Southern Islands, Singapore.

The two lagoons situated on the southern side are man-made and measure 1.2 km long and 0.14 km wide. Over 60% of the visitors to Sentosa come to the lagoons yearly. The lagoons for swimming, among the most popular attractions in Sentosa, offer various facilities such as pedal boats, rowing boats, rubber dinghies and bicycle services. The Canoe Centre situated at the eastern end of the lagoon offers fiber glass canoes for rent; conducts regular canoeing and windsurfing courses; holds fishing competitions and sea carnivals. Other beaches in the island include Tanjong Beach and Silosa Beach which are ideal spots for sunbathing, swimming and picnicking.

The World Insectarium, which officially opened on 15 December 1983, features a unique display of one of the largest collections of insects in the Asian Region. The history and development of the port of Singapore are recorded in the Maritime Museum. The Coralarium, a $2.5 million project, was opened on 3 August 1974. It covers an area of 1.2 ha and houses rare and colorful live corals, marine life associated with coral reefs and a collection of 2,000 seashells from all over the world.

Kusu Island. Also called "Tortoise Island," it is about 5.6 km from Singapore, covering 8.5 ha. The island has a religious and legendary background, attracting over 185,000 devotees each year after the ninth lunar month. Besides a Malay shrine and a Chinese temple, there are two swimming lagoons, beach shelters, turtle pool, three pavilions and a tortoise sanctuary.

St. John's and Other Islands. Occupying 37.6 ha and situated 6.5 km south of Singapore, St. John's is popular for swimming, picnicking, fishing and jogging. Facilities on the island include swimming lagoons, football field, tennis courts, holiday camps and bungalows.

Sisters Island comprises Subar Laut and Subar Darat, covering 6.2 ha and situated 9 km from Singapore. The waters are popular for scuba diving. P. Hantu which covers 13 ha consists of P. Hantu Besar and P. Hantu Kechil, and is situated 7 km southwest of Singapore. The islands with their beach shelters and swimming lagoons are popular among skin and scuba divers, waterskiers and powerboat enthusiasts.

Looking into the financial side, gross revenue from Sentosa in 1985 was $10.3 million, an 8% increase over the previous year. Total expenditure incurred was $10.5 million in 1985 compared to $9.1 million in 1984. The other offshore islands incurred an operational deficit of $2.5 million, which was financed by the government (SDC Annual Report 1981-1986). Although the offshore resorts are running at a deficit, the overall tourism industry of the country has always been making significant positive contributions to its economy.

Use of Offshore Islands

In this section, the utilization of offshore islands as resources in their own right will be considered separately. These islands are in a situation of development. However, it is unfortunate that abundance and quality of natural resources as well as the fact that islands can also be considered as ecosystems, have been largely put aside due to pressure from development.

Table 5.28 divides the islands according to types of activities being undertaken. The petroleum industry utilizes only 6 km^2 but its economic contribution has been the most spectacular. Port and shipping activities are located mainly in the coastal zone of the mainland, and some smaller offshore islands are used for supplementary purposes only (e.g., lighthouse, slop reception). Water-based resorts such as Sentosa, Kusu and St. John's Island offer various types of recreational activities. But most of the islands earmarked for tourism are yet to be developed. P. Tekong, the largest island, is used for military purposes while a few other islets fall within the live-firing zone and therefore cannot be used for other purposes. P. Ubin, the second largest island, is used for primary production but its contribution is minor.

There is little scope for expansion. Out of 50 km^2, 43 km^2 are already used up or planned for some specific uses. Reclamation is costly and may not be feasible in the future. Economic efficiency, therefore, lies in achieving higher productivity in existing uses and in the better utilization of available resources. Since petroleum and shipping industries have reached an "optimum" point, new niches cannot be created by expanding these activities. Resources should rather be released by trimming the capacity of these industries and reinvesting in some other sunrise industries.

Though the tourism industry performed badly in recent years, it is believed to have potential for future development. Greater attention by both public and private sectors is needed for developing recreational tourist attractions. Once facilities are developed, there will be a great scope for inter-island ferry services and cruising, which might be a potential worthwhile investment.

Table 5.28. Offshore islands used for various economic purposes.

Types of activities	Island	(km²)
Petroleum refineries and related activities	P. Ayer Chawan	1.70
	P. Ayer Merbau	1.25
	P. Bukom Besar	1.45
	P. Bukom Kechil	0.56
	P. Ular	0.32
	P. Merlimau	0.55
	P. Mesemut Darat	0.05
	P. Mesemut Laut	0.19
	P. Seraya	1.93
	Total	6.07
Port and shipping-related activities	P. Brani	0.86
	P. Satumn	0.01
	P. Sebarok	0.46
	P. Samulun	0.31
	Sultan Shoal	0.006
	P. Tekukor	0.05
	Coney Island	0.45
	Total	2.15
Tourist resorts and designated areas for future development of recreational activities	P. Biola	0.004
	P. Damar Laut	0.24
	Buran Darat	0.17
	P. Hantu	0.13
	P. Jong	0.006
	Kusu Island	0.07
	P. Renggit	0.13
	P. Sudong	2.08
	St. John's Island	0.41
	Lazarus Island	0.34
	Sentosa	3.08
	Sisters Islands	0.08
	Terumbu Retan Laut	0.25
	P. Seletar	0.39
	Total	7.38
Military uses and live firing zone	P. Tekong Besar	17.93
	P. Salu	0.006
	P. Pawaii	0.18
	P. Berkas	0.03
	Total	18.14
Agricultural activities	P. Ubin	10.20
	P. Sakung	0.08
	Total	10.28

Source: MOCI (1986).

P. Ubin offers excellent scope for high-technology farming and selected primary activities. Preservation of natural vegetation will have favorable impact on the environment and attract tourists. Other smaller islands which have not yet been utilized may be used for dumping rubbish or for building incineration plants. Such activities are now carried out in the mainland; by transferring them, it would be possible to release substantial portions of scarce land resource for better utilization.

Chapter 6
Coastal Pollution

Nature and Extent

The problem of pollution of coastal waters is highlighted in this chapter as it represents the main conflict between activities which may be described as "development" and "environmental conservation" in nature. The latter is a set of activities based on the exploitation of renewable resources supported by the natural ecosystem which need to be protected to maintain sustainable productivity of the resources.

The major sources of marine pollution in Singapore are: first, shipboard sources arising from inadvertent or deliberate oil spills from ships that come into Singapore's port waters or pass along Singapore Strait as well as accidental spillage of oil during ship-to-shore, shore-to-ship and ship-to-ship transfers; and second, from shore-based sources including oil refineries and petrochemical plants, oil-based power generation plants, industries, motor and engineering workshops; transportation such as oil tanker trucks; agricultural activities, particularly livestock farming; commercial activities, especially of restaurants, hospitals and food hawkers.

The pollution problem in the coastal waters of Singapore is by and large not considered serious, given the high population and high intensity of use of the coast. The still acceptable level of pollution is due largely to the excellent flushing effect of the tidal currents through the Southern Islands. However, Johor Strait may potentially pose a more difficult problem: first, because of the cutting off of water circulation by the causeway; and second, because of the agricultural, urban and industrial development and port activities on both sides of the straits.

Details on marine pollution were provided by Chia and Chionh (1987), Pakiam (1980) and Ch'ng (1971) while pollution of inland water bodies has been studied by Chen (1972), Chia and Chionh (1987), Lim (1980), Lye (1971), and Pakiam (1980). MOE's report (1980) on the National Seminar for the Protection of the Marine Environment and Related Ecosystems also provided useful information.

Control of Pollution of Inland Waters

The protection of inland water bodies--reservoirs, rivers and streams--deals with the control of discharge of effluents from industrial, commercial, domestic and agricultural sources. The control is done through the Water Pollution Control and Drainage Act 1975, which is administered by the Sewerage Department of MOE. Effluents are either discharged into the sewerage system or treated to an acceptable level before being discharged into the watercourses. The Act makes it an offence to discharge any oil, chemical, raw sewage or trade effluent into water bodies including coastal waters. Industrial and trade premises are inspected by officers of the Sewerage Department to ensure that all necessary measures are taken to minimize the discharge of waterborne pollutants. Inspections are also carried out on premises of sewered areas to prevent the discharge of wastewater into watercourses.

The discharge of trade effluents into any watercourse within a natural catchment area of reservoirs is also prohibited. This prohibition is under the responsibility of the Water Department of PUB as provided for under the PUB (Catchment Area Parks) Regulations and the PUB (Water Supply) Regulations 1977. Under these regulations, bathing or washing of any animal, person or thing in the reservoirs or streams in any part of the catchment area parks is prohibited, the violation of which carries a penalty of a fine not exceeding $500. The Animals and Birds (Licensing of Farm) Rules 1972 controls the discharge of pigpens outside the catchment areas.

Farm activities, especially pig rearing, have been the target for control following the construction of reservoirs and dams across the mouth of the major rivers in Singapore. The regulations require the owner or occupier of farm premises to provide facilities for the removal, treatment and disposal of waste matter. Since 1979, pig farmers in the water catchment areas and urban river systems have been moved in stages to Punggol area where land has been developed with government assistance for large-scale pig rearing farms. Smaller farms have also been consolidated into larger ones for easier control and more economical operation.

Attention has also been directed at other sources of pollution including hawking and duck farming, which has been prohibited recently. The problem of unsewered premises has also been brought under control.

In 1977, an intensive program to clean up the Singapore and Kallang Basin catchments and the unprotected water catchments was launched by MOE. The program, undertaken for tourism and public health purposes, includes:

1. Eliminating pig farming from the catchments;
2. Phasing out polluting riverine activities;
3. Resiting of street hawkers into prepared premises;
4. Extending the sewerage system; and
5. Redeveloping rundown areas (MOE 1980).

Most of the work was completed by 1987.

The discharge of solid wastes into water bodies is governed by the Environmental Public Health Act which prohibits the deposition of any refuse or rubbish into any stream, river, drain, channel, watercourse or reservoir.

The Registry of Vehicles (ROV) has been alert to the problem of oil spills from buses running without fuel tank caps. During the early 1970s, many cases were brought to court, and offenders were fined. In recent years, these oil spills have ceased to be a problem.

Table 6.1 shows the water quality of some of the major rivers and canals in Singapore as measured in 1978 and 1981. There has been substantial reduction in the levels of biological oxygen demand (BOD), suspended solids and ammoniacal nitrogen (Amm-N, a measure of the nutrient content of water) especially of the highly polluted S. Kallang. Other rivers which used to be listed as highly polluted have satisfactory levels of pollution now, given the urban situation within which they are found.

The quality of treated water supply is well within standards set by the World Health Organization (WHO). Table 6.2 shows the quality of town tapwater which is safe to drink. Some 99.5% of the population of Singapore is now supplied with potable water in their homes. The quality of industrial water determined in 1979 is shown in Table 6.3.

Table 6.1. Quality of water (mg/l) in some Singapore rivers and canals.

River/Canal	1978 Biological oxygen demand[b]	1978 Suspended solids	1978 Ammoniacal nitrogen	1981[a] Biological oxygen demand	1981[a] Suspended solids	1981[a] Ammoniacal nitrogen
Singapore River	21	108	3.8	5	45	1.8
Bukit Timah/Rochore Canal	35	89	14.6	9	39	2.9
Sg. Kallang	335	1,025	67.2	79	314	27.3
Sg. Whampoa	105	156	56.4	11	57	3.6
Pelton Canal	23	65	20.2	7	78[c]	3.5
Sg. Geylang	32	49	16.5	8	133[c]	3.3

[a]Measurements made during January-March 1981.
[b]Biological oxygen demand (BOD) each 20°C and five days.
[c]High suspended solids due to presence of silt.

Source: MOE press release (31 March 1983).

Table 6.2. Quality of town water (value as of 1979), Singapore.

Characteristics	Water (in mg/l where applicable)
Physical and chemical	
Color (Hazen units)	Less than 5
Turbidity (Silica units)	Less than 5
pH	7.5
Temperature (°C)	29
Conductivity (micro mhos/cm)	70
Taste	Unobjectionable
Odor	Unobjectionable
Ammoniacal nitrogen (as N)	Less than 0.15
Nitrite nitrogen (as N)	Nil
Nitrate nitrogen (as N)	0.10
Residual aluminum (as Al)	Less than 0.05
Residual chlorine (as Cl)	0.10
Chloride	14
Total alkalinity (as $CaCO_3$)	12
Total hardness (as $CaCO_3$)	30
Calcium hardness (as $CaCO_3$)	12
Magnesium hardness (Mg CO_3)	18
Total solid residue	50
Iron (as Fe)	Less than 0.5
Sulfate (as SO_4)	8
Fluorine (as F)	0.70
Phosphate (as PO_4)	–
Silica (as SiO_2)	6
Manganese (as Mn)	–
Copper (as Cu)	–
Bacteriological	
Bacteriological standard plate count per ml in 24 hr at 37°C	Less than 10
Coliform organisms per 100 ml in 24 hr at 37°C	0

Source: Pakiam (1980).

Table 6.3. Quality of industrial water (value as of 1979), Singapore.

Physical and chemical characteristics	Value
Color (Hazen units)	20 – 30
Turbidity (JTU)	3.3 – 12.4
pH	7.3 – 7.5
Biological oxygen demand (mg/l)	4.6 – 13.4
Chemical oxygen demand (mg/l)	55 – 89
Dissolved oxygen (mg/l)	3.6 – 4.8
$NH_3 - N$	29 – 35
Suspended solids	3.5 – 10.9
Total solids	150 – 1,010
Chloride (as Cl^-)	150 – 600
Total phosphate (as PO_4)	2.3 – 2.7
Total hardness (as $CaCO_3$)	67 – 250
Detergent (LAS)	0.9 – 2.6
Alkalinity (as $CaCO_3$)	157 – 240

Source: Pakiam (1980).

Control of Pollution of Coastal Waters

The waters surrounding the islands of Singapore are subjected to potentially very high risks of pollution from the many oil tankers which traverse them. Singapore is a signatory to the Prevention of Oil Pollution Convention and the Convention on Civil Liability for Oil Pollution Damage 1969. Pollution within its territorial waters is under the charge of the Anti-Sea Pollution Unit of PSA. Pollution control is governed by the Prevention of Pollution of the Sea Act 1971, the Civil Liability (Oil Pollution) Act 1973 and regulations passed under the Port of Singapore Authority Act. Under the Prevention of the Sea Act, it is an offence to discharge oil or a mixture of oil and water containing more than 100 parts per million (ppm) of oil into Singapore waters from any vessel, place on land or apparatus used for tranferring oil from or to any vessel. The offence carries with it a maximum penalty of a fine of $500,000 or an imprisonment not exceeding two years or both. However, the Act provides that liability does not include discharging the oil to secure the safety of the vessel or to prevent damage to any vessel or cargo or to save lives.

The Prevention of Pollution of the Sea Act 1971 also makes it an offence for any vessel or person to discharge or throw into Singapore waters any refuse or other waste matter; substances of a dangerous or obnoxious nature; or trade effluent. Such an offence carries a fine of up to $10,000 or an imprisonment for a term not exceeding two years or both.

Under the Civil Liability (Oil Pollution) Act 1973, the owner of a ship or onshore or offshore facility is liable for: (1) any damage caused in any area of Singapore by contamination, resulting from the discharge or release of oil (which includes oil of any description, oil refuse and oil mixed with water); (2) the cost of any measure reasonably taken after the discharge or escape to prevent or reduce any such damage in the area; or (3) any damage caused in the area by any measure so taken. The limit of liability shall be in accordance with Section 295 of the Merchant Shipping Act which is approximately $203.70 for each ton of the ship's tonnage (Pakiam 1980).

The Singapore Port Regulations 1977 prohibits any person from throwing, discharging, depositing or causing to be thrown into port waters any ashes, solid ballasts, sludges or other matter without the permission of PSA, which operates garbage collection barges providing garbage removal services to vessels anchored within the port waters. A Slop and Sludge Reception and Treatment Center on P. Sebarok provides facilities for the reception, treatment and disposal of slops, sludges, dirty ballasts and tank washings.

The Prevention of the Pollution of the Sea Regulation 1976 requires each oil refinery to maintain certain anti-pollution operation equipment and to keep a stock of at least 10,000 l of approved dispersants at all times. The dispersant should be biodegradable; high in dispersant capacity; low in toxicity; and have a flash point of above 65^{o}C; less than 3% aromatic hydrocarbons; and less than 0.05 mg/l of chlorinated hydrocarbons (Phang 1978).

Several measures have been drawn up by PSA to combat oil spills. The Marine Emergency Action Procedures (MEAP) requires that equipment maintained by PSA include an oil skimmer which can absorb at 15 m^3/hr and has a holding capacity of 50 t of oil. Apart from the oil refining companies, the military and other government agencies have been assigned tasks to assist PSA in case of a severe oil spill. The oil companies keep their own oil-fighting equipment at strategic places for easy deployment (Singapore's *Straits Times,* 3 October 1982).

Toxic materials in the waters and bottom sediments in the waters around Singapore must come about either naturally or through introduction by marine- and land-based activities. Rahman et al. (1980) showed that the landfills are a potential source of pollution. Determination of the levels of heavy metals in the surface water and in the bottom sediments at seven locations are given in Table 6.4 and are shown to be low and below the limits established for the

Table 6.4. Concentration of various heavy metals in Singapore's coastal water and bottom sediments.

Location	Lead Water (ug/l)	Lead Bottom sediment (mg/l)	Nickel Water (ug/l)	Nickel Bottom sediment (mg/l)	Cobalt Water (ug/l)	Cobalt Bottom sediment (mg/l)	Mercury Water (ug/l)	Mercury Bottom sediment (mg/l)
World Trade Centre, Jardine Steps	10	28	95	94	0	13	-	0.092
Shell Refinery, P. Bukom	40	20	90	90	0	18	-	0.094
Slope Reception Centre, P. Sebarok	30	26	80	75	15	21	-	0.099
Esso Refinery, P. Ayer Chawan	0	20	70	75	10	14	-	0.100
Mobil Refinery, Jurong	0	-	55	-	0	-	-	-
BP Refinery, Labrador	30	23	80	79	15	12	-	-.089
Singapore Petroleum Refinery, P. Merlimau	40	20	100	98	0	13	-	0.085

Source: Rahman et al. (1980).

quality of trade effluents discharged into Singapore waters (Table 6.5) under the Water Pollution Control and Drainage Act 1975 (Rahman et al. 1980).

As for pollution of nonterritorial waters, Singapore Strait and Strait of Malacca are vital channels for international shipping, and where annually, large numbers of fully laden oil tankers traverse. Since April 1983, the Inter-Governmental Maritime Committee (IGMC) sanctioned the Traffic Separation Scheme. The scheme limits the underkeel clearance of vessels to not less than 3.5 m and separates east- from west-bound tankers at several critical stretches of the straits including Philips Channel, Main Strait and the eastern entrance to Singapore Strait (Chia 1981). In line with the greater emphasis on the prevention of oil pollution, the Marine Department of MOCI has, since 1979, imposed stricter control, including safety measures on ships registered under the Singapore flag.

PSA also requires all tug boats, since 1 January 1984, to be suitably equipped with anti-pollution equipment. These equipment comprise a pump able to deliver 250 l/min of water at 70 m head, an inductor, a nozzle and a minimum of 400 l of the approved dispersant. Also, all masters, engineers and engine drivers of harbor tugs are expected to have received the necessary training in oil spill fighting (Singapore's *Straits Times,* 5 January 1983).

Sources of land-based marine pollution are the solid matter from boat yards and sawmills as well as the oily discharge from motor workshops and small industries. Rahman and Chia (1977) found that a significant proportion of oil spills reported within the port areas is due to operations at the wharves involving bunkering and transferring of oil spills from ship to shore or vice-versa. They concluded that the few occasions of major spills contribute more than all the medium and minor spills put together and that human error is the main cause of oil spill incidences. Information on oil pollution in Singapore's coastal waters is updated in Rahman et al. (1980).

The lighters (or "bum boats") serving the ships anchored in the "roads" and plying the lower reaches of the main rivers of Singapore have been a major source of pollution of coastal riverine waters. These lighters have been prohibited, since September 1982, from operating in Rochore and Kallang Basins; and from August 1983, from operating in the Singapore River, Marina Bay and Telok Ayer Basin. The lighters are now operating out of the Pasir Panjang Wharves.

Table 6.5. Permissible limits for trade effluent discharge.

Parameter	Sewer	Water course (in mg/l or as stated)	Controlled water course
Temperature of discharge	45°C	45°C	45°C
Color	–	7 Lovibond units	7 Lovibond units
pH value	6 – 9	6 – 9	6 – 9
BOD (5 days at 20°C)	400	50	20
COD	600	100	60
Total suspended solids	400	50	30
Total dissolved solids	3,000	2,000	1,000
Chloride (as chloride ion)	1,000	600	400
Sulfate (as SO_4)	1,000	500	200
Sulfide (as sulfur)	1	0.2	0.2
Cyanide (as CN)	2	0.1	0.1
Detergents (linear alkylate sulfonate as methylene blue active substances)	30	15	5
Grease and oil	60	10	5
Arsenic	5	1	0.05
Barium	10	5	5
Tin	10	10	5
Iron (as Fe)	50	20	1
Beryllium	5	0.5	0.5
Boron	5	5	0.5
Manganese	10	5	0.5
Phenolic compounds (as phenol)	0.5	0.2	Nil
Cadmium[a]	1	0.1	0.01
Chromium[a] (trivalent and hexavalent)	5	1	0.05
Copper[a]	5	0.1	0.1
Lead[a]	5	0.1	0.1
Mercury[a]	0.5	0.05	0.001
Nickel[a]	10	1	0.1
Selenium[a]	10	0.5	0.01
Silver[a]	5	0.1	0.1
Zinc[a]	10	1	0.1
Metals in total[a]	10	1	0.1
Chlorine (free)	–	1	1
Phosphate (PO_4)	–	5	2
Calcium	–	200	150
Magnesium	–	200	150
Nitrate (NO_3)	–	–	20

[a]The concentration of toxic metals shall not exceed the limits as shown, individually or in total.
Source: Chia (1985).

In the case of a major oil spill, PSA may activate the MEAP to mobilize all PSA resources and those of the terminals, the Ministry of Defense (MOD) and MOE. Oil-based industries are obligated by law to provide anti-pollution equipment and to maintain stocks of approved dispersants to assist in cleaning up oil spills. However, for oil spills occurring in the vicinity of the oil refineries, the oil refining companies concerned are responsible for cleaning them up. In cases of major oil spills, it is necessary to obtain the cooperation of all available capabilities from not only the oil refining companies but also from other relevant government bodies, armed forces, civilian groups and private organizations.

The cleanup operations on land are coordinated by MOE while that on the sea, by PSA. Such operation has already been put to the test in combating the Showa Maru oil spill in the waters outside Singapore's territorial waters in 1975. More recently, on 18 May 1985, an oil spill resulting from fire on a barge which subsequently sank off the East Coast Park led to severe oil pollution on the shore.

Chapter 7
Management of Singapore's Coastal Area

The purpose of this profile is essentially to provide background information on Singapore's coastal area with the objective of developing a management plan that can be implemented on a multisectoral, multiple-use and integrated manner. For Singapore, the task is especially urgent for a number of reasons. First, the pressure to ensure the country's viability and social and economic well-being has resulted in very intensive use of the coastal area, particularly on the main island and some nearby offshore islands. The development thus far has tended to be basically unisectoral and has little regard to the possibilities of fully exploiting the opportunities available. There has also been insufficient considerations given to safeguarding and enhancing ecological and marine qualities in planning how coastal land and offshore islands might be best utilized.

For coastal waters, first priority has been given to their use for navigation and as a harbor. However, as a result, the jurisdiction and management of these waters have fallen on the shoulders of PSA whose primary concern is to run the port efficiently. Clearly, there are now many uses of seaspace, including recreation and tourism; defence and security; and marine fisheries and aquaculture. The question is whether the PSA, in its present form, is the appropriate institution for the overall management of seaspace in Singapore.

As discussed in the previous chapter, there is the potentially serious problem of pollution of coastal waters. The solution lies in the control of the sources of pollution not just by a single agency but rather with the cooperative and coordinated efforts of all users of the coastal area. As the use of the coastal environment becomes further intensified, the need for its better management will correspondingly rise. The oil-spill contingency plan should be reviewed and other pollution control measures carefully examined to ensure that the heavy investments made by the various marine sectors be safeguarded.

In keeping with the rise in expectations of Singapore as a result of the coming of age of its economy and society, a national policy on the preservation, conservation and rehabilitation of its coastal environment is needed. Definite measures are needed to prevent the coastal environment's further damage; to minimize the adverse impacts of both existing and intended future development projects; and to find ways to revitalize the coastal environment as has been done so admirably for the Singapore and Kallang Rivers.

The Role of the Government

In the management of Singapore's coastal area, the government plays a crucial role as it owns more than 70% of land in the country and nearly all the coastal land on the main and offshore islands; it has total jurisdiction over the seaspace. Land use has been carefully planned and the resources are already intensively utilized. Detailed physical planning has been undertaken since the mid-1950s to ensure optimal use of limited land to accommodate the needs of a growing population (Chua 1973; 1976). The problem of land shortage as a constraint to rapid economic growth and public housing has been solved in part by land reclamation. The reversion of military land by the British to the Singapore Government provided large tracts of coastal land and useful infrastructure and facilities such as those in the naval base at Sembawang and the air base in Changi. These opened up development opportunities for the country.

During the 1960s, the government established a number of highly effective quasi-government agencies such as the JTC, HDB, PSA and URA, which have important developmental functions. The Planning Department (PD) under MOND coordinates and oversees the overall development of land. Effective legislation in the form of the Land Acquisitions Act and the legislation which brought into being the agencies mentioned, made it possible for private land to be acquired at prices based on the 1973 level. Although this was changed in 1988 so that land acquired would henceforth be compensated at 1986 prices. Also, no compensation was needed for foreshore areas affected by land reclamation. Thus, very considerable amounts of land came under the control of the Land Office under MOND and then passed on to these agencies for development purposes. Near full utilization of land has induced the government to turn their attention to coastal land and thus marine resources have become the focus of current development.

Analysis by Chia (1985) showed that the coastal zone has undergone fundamental changes in utilization and ownership (Table 7.1). Private residential uses have been the main losers in terms of their giving way to government-initiated uses. Other losers are agriculture, aquaculture, private housing and population settlement. Gains are spread among the seaport and airport development, manufacturing industries, public housing, recreation/tourism and others.

Table 7.1. Changes in land use/activity in the coastal area of Singapore.

From \ To	1	2	3	4	5	6	7	8	9	10	11	12	[illegible]	[illegible]	[illegible]	16	17
1. Seaport																	
2. Manufacturing industry																	
3. Recreation/tourism					X												
4. Road transport	X																
5. Commerce																	
6. Airport																	
7. Public housing																	
8. Private housing	X		X		X	X	X					X					
9. Communications																	
10. Sea sports	X					X											
11. Nature reserve																	
12. Water reservoir																	
13. Agriculture	X	X	X	X		X	X	X		X		X					
14. Sea fishing	X									X							
15. Aquaculture	X	X	X				X					X					
16. Population settlement	X	X	X			X	X										
17. Historic sites/monuments																	

The Planning Framework

In Singapore, physical planning is coordinated under PD through a process of consultation under the Planning Committee wherein all relevant agencies will have an opportunity to provide inputs into the final plan for implementation (Chia 1979b; Olszewski and Chia, in press). The formal nationwide planning process began in the 1950s when the then British administration initiated the Statutory Master Plan to control the physical development of land. The plan was completed in 1955, officially adopted in 1958 and remains today the main instrument for land use control. The plan is revised once every five years; it has been an effective tool for planning to meet the requirements for various development needs. Planning has progressed to include more details. The more recent (1980 and 1985) Revised Master Plans include, for example, details for the development of entire new towns, industrial estates and the central area.

The Master Plan divided the country into three broad zones, i.e., the central area, town area, and rural and island areas. Control is effected through zoning which determines the predominant land use for each type of zone as well as the use of the plot ratio and net residential density. Zoning also ensures separation of land for commercial and residential use from industrial areas where the more polluting activities take place.

However, in spite of its effectiveness, the Master Plan proved to be inadequate to serve the needs of a rapidly expanding and open economy. On its own, the plan can only respond to demands for changes and cannot anticipate future developments or changes in national policies affecting the pattern of land use. To overcome this inadequacy, the development of a more flexible Long-range Comprehensive Concept Plan was began in 1967 and completed in 1971. The plan projected the physical development of the country to target years of 1982, 1992 and 2000, adopting the so-called "ring plan". The broad features of the plan are given in Skeates and Olszewski (1971) and Chia (1979b). Unfortunately, only the broad outline of the plan has been made public. Albeit, the success of the plan can be seen in the high degree of conformance in the way physical development of the Republic has proceeded after its adoption (Olszewski and Chia, in press).

The features envisaged in the Concept Plan have already been incorporated into the revised Master Plan of 1975 and its subsequent revisions. Relevant features to the use of coastal areas are the following:

1. The allocation of land, including coastal land and islands, to the various planning agencies has been affected.

2. The entire south coast extending from Jurong on the western end of the island to Changi to the east has been designated a corridor of intensive development.

3. The "central area" with its coastal location remains the focal point of development, although the waterfront is to be pushed seaward through land reclamation. The land reclaimed will then be developed as primary extensions of the Central Area type development in the form of the new Marina City which will be stitched to the existing CBD through the provision of access roads, expressways and an extension of the MRT currently being constructed.

4. Apart from the Jurong industrial estates (Jurong Town), various coastal areas were reserved for more industrial estates, including Kranji, Sembawang and Changi to take advantage of the coastal position whereby the imports of essential inputs and the exports of the finished products can be effected. This will also minimize adverse effects of air pollution.

5. Environmental considerations are incorporated through the reservation of coastal land, including the East Coast Park and West Coast Park, for open space and for the needed recreational facilities.

Clearly, the planning of land use based on the tandem of the Concept Plan and the Master Plan has been instrumental in determining the overall development of the coastal zone.

It should be noted, however, that the planning has been totally land-bound and does not extend beyond the shorelines of either the main or offshore islands.

The Institutional Framework

Due to the fact that the country has a one-tier governmental structure--at least until the newly initiated Town Council system for the administration of new towns is fully extended--the basic institutional framework bearing on the management of the coastal area is simpler than in other ASEAN countries.

The agencies administering coastal resource uses are basically unisectoral. The advantage of this arrangement is that it is highly effective in implementing schemes rapidly and efficiently, as has been shown for the PSA. Note also the preference for quasi-government statutory boards rather than for departments in various government ministries. This is to ensure flexibility, allowing them to operate on a commercial basis without excessive control. The role and function of various public agencies involved in the use and management of coastal resources are briefly described in the following section.

Agencies under the Ministry of Communications and Information (MOCI)

MOCI, earlier known as the Ministry of Communications, administers a number of transport and related bodies, including the powerful PSA, which are directly concerned with coastal area uses and development.

Port of Singapore Authority (PSA). Apart from being responsible for the management of port waters and controlling navigation and providing port-related services, PSA undertakes reclamation works for the expansion of wharf and berthing facilities. Dredging is undertaken to deepen the water to improve conditions for navigation and port-side activities. The authority also is responsible for the overall task of combating oil pollution, and works closely with MOE. The Civil Liability (Oil Pollution) Act gives PSA the authority to impose penalties on ship operators for damage caused by oil pollution of Singapore waters. The PSA has, over the years, extended its activities to include the provision of ferry services; warehousing and fumigation services; and engineering and engineering consultancy services as well as engaging in other non-port-related activities.

In marine pollution control, PSA is responsible for preventing and cleaning up marine pollution derived from land-based and shipboard sources. It is responsible for enforcing the provisions of the Prevention of Pollution of the Sea Act 1971; the Merchant Shipping (Oil Pollution) Act 1981; and the Prevention of the Sea Regulations 1976. Surveillance and bringing offenders to book are carried out by the Port Master's Department (PMD) of PSA and the Marine Police. The government's Scientific Services Department tests the samples collected, and prosecution is carried out by the police.

Marine Department (MD). MD is charged with the administration of Singapore shipping registry; certification of shipboard officers; conducting inquiries into shipping casualties and contraventions of the laws by merchant shipping; application of international conventions on shipping; promotion of Singapore's marine interests; and other matters relating to navigational safety, including pollution control by ships. MD works closely with PMD. The *National Maritime Board (NMB)* regulates the employment and looks after the welfare and training of seamen to ensure that they meet international maritime standards and regulations.

Civil Aviation Authority of Singapore (CAAS). Among other functions relating to the operation of civil aviation, the authority is responsible for the development of Changi Airport which is located at the eastern end of the south coast of the main island. CAAS is currently expanding the capacity of the airport by reclaiming land for a second terminal and runway.

Singapore Meteorological Services (SMS). SMS provides weather forecasts for air and marine transport and the public, while the *Telecommunications Authority of Singapore (TAS)* is concerned with the laying of cables on and under the seabed between the mainland and the offshore islands. Long distance undersea telecommunications cables have been laid to provide links with other countries. An example is the development of the ASEAN Submarine Cable Network.

Jurong Town Corporation (JTC)

The government created the Economic Development Board (EDB) in 1961 to develop the industrial sector. The first major project of the board was to develop the Jurong Industrial Estate out of the swampy and hilly areas in Bulim. By the end of the 1960s, together with the JTC-owned Jurong Port and access roads and rail serving the industries there, the estates have proved to be highly successful. In 1968, EDB created JTC, as a separate statutory board which was charged with the management and further development of Jurong (renamed Jurong Town), which already included residential low-cost housing. JTC also took charge of the development of other industrial estates in the Republic. By early 1981, JTC had under its management 19 industrial estates with more than 24,000 establishments employing about 200,000 workers or 61% of the total labor force engaged in manufacturing.

JTC also undertook special development projects such as the aviation industrial centers at Loyang and Selatar, Jurong East warehousing complex, marine bases in Loyang and Jurong, all of which are on the coast, and the development of some of the Southern Islands. The most recent major project was the Tuas Reclamation Scheme completed in 1988.

Housing and Development Board (HDB)

Under the first national development plan (1961-1964), HDB, a statutory board, was formed in 1961 together with EDB to form two arms to achieve rapid economic and social development and to solve the problem of unemployment. The HDB was given wide powers and substantial financial backing and was bolstered with necessary legislation to acquire land; build and manage low-cost housing; clear squatters; and undertake resettlement of farmers and others on acquired land. Initially, low-cost public housing estates were built within and at the fringe of the Central Area. But since the early 1970s, large new towns across the entire main island were developed. By and large, the public housing estates have avoided the coastal areas, although some apartment blocks were built along the East Coast on reclaimed land. Albeit, as noted, there are many housing estates located near the coast. There is, however, the prospect of the first truly coastal town, Pasir Ris New Town, which is being developed.

Primary Production Department (PPD)

PPD is under MOND and is a major agency directly concerned with the utilization and management of coastal resources. It is responsible for managing the agriculture sector including aquaculture. Freshwater aquaculture on coastal land and marine aquaculture have been transformed over the last three decades in response to the changing land use and socioeconomic conditions in Singapore (Chia 1979b; 1982); and accordingly new challenges have been posed to the department. The PPD has found a new mission in putting in efforts in research and development focused on high-technology intensive agricultural production and marine aquaculture as indicated by the projects on netcage culture of valuable marine fish as well as the rehabilitation of the Singapore River. There is close consultation between PPD and PSA on matters relating to the use of seaspace.

Ministry of the Environment (MOE)

The MOE is concerned with all matters on environmental and public health aspects. Its main functions include control and monitoring of air and water pollution; planning, developing and operating of sewerage, drainage and solid waste disposal facilities; and providing public health services. The Sewerage Department under the ministry is in charge of extending sewers to all premises; treatment of wastewater; prevention and control of water pollution; and conservation and augmentation of potable water supply through wastewater reclamation.

The Drainage Department under the ministry constructs and maintains the main drainage system to provide proper land drainage and alleviate flooding. It also undertakes cleansing and structural maintenance of all earth streams, and lining canals and major outlet drains to prevent seepage of polluted water into openwater courses leading to coastal lands and the sea.

The Environmental Health Department of the ministry is responsible for solid waste disposal and management, including the operation of the sanitary landfills and the Ulu Pandan Incinerator.

Multiple and Integrated Use of Coastal Resources

Many activities require exclusive use of land or seaspace. On land, for example, the port area is, for security reasons, restricted and exclusively caters to those with businesses in the port. Similarly, shipyards, refineries and power generation plants require exclusive use of land. Industries along the waterfront within a planned industrial estate enjoy the benefit of access to ships that transport goods to and from their premises. Other potential uses on the same land cannot be pursued unless there is a change in the zoning affecting the entire estate or larger surrounding areas--a decision requiring planning at a higher level.

The utilization of seaspace is quite different in that water is mobile and fish, pollutants, and other material can be carried into and out of a particular sea area. Also, there are no visible boundaries and no private ownership rights to seaspace. The state owns all the seaspace within the territorial waters and the foreshore areas seawards of landed property. However, the lease of seaspace for marine aquaculture, started in the late 1970s, may have introduced a new regime in the use of seaspace in Singapore. Within the port waters, there are designated zones for anchorages (Fig. 4.2) and for various shipping/port-related purposes. Portions of the sea near hazardous industries are also kept free from other users while certain areas near military installations are similarly exclusively used for defense purposes.

Within the port waters, cargo vessels, lighters, tugboats and supply ships, passenger vessels and vessels bound for the shiprepair yards intermingle with pleasure crafts and fishing boats. Conflicts of interest among the diverse users arise. Some users, notably fishermen and palisade trap *(kelong)* operators have had to give way to navigational and port-related users.

Developing a Coastal Area Management Plan

A comprehensive scheme to cater to the needs of the entire range of diverse users of coastal resources should be developed to maximize benefits, to avoid conflicts and to ensure safety and public health. The scheme should attempt to encourage uses which are compatible and/or complementary. Attention should be given to potential uses such as desalinization of seawater, and greater attention to conserving and rehabilitating the marine environment and preventing marine pollution in all its manifestations.

Management plans for coastal areas in many developed countries and in some developing countries such as Sri Lanka have already been implemented. The basic principles for coastal area management are already well-understood. However, due to great variations in the characteristics of particular coastal stretches, their existing settlement and development patterns, available financial, technical and other resources, and sociocultural, political and economic background, each situation has to be treated individually. Management strategies and tools have to be selected and specially tailored to suit local conditions. A special blend of management developed over time with contributions from government, private enterprise and groups, and private citizens will emerge from the exercise. The more usual top-down strategy employed in Singapore will probably need to be modified to take into account much more the perceptions of private interests.

Filling the Information Gap

For a management plan to be effective, the characteristics of the coastal zone need to be documented and examined through monitoring and surveys. Also it is necessary to identify and monitor all coastal activities and development projects. These are already being pursued, although the exercise is a continuing one requiring the full cooperation of all relevant public agencies and private coastal resource users. Information gathered should be stored using computer-based methods to facilitate additions and changes, retrieval and manipulation of data as well as for computer mapping for spatial analysis. It should be noted that there is an ongoing Australian government-funded marine environment research project which will fill some of the information gaps on the physical, chemical and biological conditions of the local coastal waters.

Identifying Marine Issues

Many marine-related issues have already been implicitly discussed above. The following highlights a few management issues for stimulating further discussion:

1. Present government policy on the use of marine resource use emphasizes high value added marine industries, port services and tourist developments. This entails substantial government investments, perhaps even some overinvestment. If so, are there objective methods, e.g., cost-benefit analysis, that can be used for evaluating the development projects in the light of alternative projects? Should not the long-term view in assessing the projects and in selecting appropriate development projects be adopted?

2. Given the existing politico-economic framework, what would be the appropriate institutional arrangement for managing Singapore's coastal resources? Should PD extend its function in managing physical planning of land areas to include the country's seaspace as well? Would it not be better for PSA to act as the key agency for coordinating all coastal users? Or should there be a new umbrella agency which would be responsible for the overall management of coastal resources?

3. How should coastal resources be managed? Should there be greater participation on the part of private organizations and groups in the decisionmaking process? While there are a range of management tools (e.g., permits, water quality standards, reserved areas and zoning), which of these would be appropriate and should be adopted? Finally, what should be the mechanisms for resolving conflict between and among users?

4. For coastal land, the main issue appears to be accessibility both by way of availability of coastal land and the provision of right of way to enable the public to get to the waterfront. There is a need for opportunities for waterfront recreation to be identified and for ways to promote greater access to valuable, often unused opportunities. Then, given the constraints mentioned earlier, in what ways could JTC and PSA assist to promote access to industrial and port waterfront areas?

The Way Ahead

A number of fairly discrete steps are envisaged which will lead towards adopting a coastal area management plan for Singapore.

Step 1. A proposed management plan incorporating a series of coastal resource and utilization maps has been completed. The plan would identify specific management problems that need to be addressed and make suggestions on appropriate measures to solve them.

Step 2. A national workshop should then be convened to provide an opportunity for all concerned to discuss the proposed plan with the view to modifying it to take into account the deliberations, including specific recommendations, made at the workshop.

Step 3. Beyond step 2, decisions are required from the government to adopt the plan in principle for implemention. The process of implementation would involve setting an appropriate institutional arrangement for management. This would be followed by deciding on specific goals to be adopted and selecting appropriate measures to achieve them.

Step 4. This step does not need to follow sequentially from the above. A program for promoting marine/coastal research and environmental education should be adopted. The process of raising public awareness on the value of coastal resources as part of the environment of Singapore requires time and therefore should be initiated at the earliest possible opportunity. Efforts by the Malayan Nature Society in this direction have already begun and should be supported by the government.

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