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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

UNITED NATIONS ENVIRONMENT PROGRAMME

SCS/80/WP/94d (Rev.)

The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution

SINGAPORE

SOUTH CHINA SEA FISHERIES DEVELOPMENT AND COORDINATING PROGRAMME
Manila, March 1980

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The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution
- Singapore -

by

Zoology Department
University of Singapore
Bukit Timah Road
Singapore 1025

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PREPARATION OF THE REPORT

The FAO/UNEP project on "Impact of Pollution on the Mangrove Ecosystem and its Productivity in Southeast Asia - Preparatory Phase, Project No. 0503-79-04, called for the preparation of country status reports on the impact of pollution on mangrove ecosystem and its productivity in Southeast Asia. Selected specialists from the ASEAN countries were then commissioned to prepare these country reports which were subsequently discussed in an Expert's Consultation Meeting, sponsored by the project and held in Manila on 4-8 February 1980. It was necessary to consolidate the data accumulated from the reports into a regional synopsis for the area.

The synoptical report (SCS/80/WP/94) is supplemented by the five country reports for Indonesia, Malaysia, Philippines, Singapore and Thailand (SCS/80/WP/94a to SCS/80/WP/94e) which were presented at the above meeting. The presented paper is based on the work of the cooperative work of six authors of the Zoology Department of the University of Singapore with editorial reviewing by Dr. W. W. Kühnhold of the SCSP.

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THE PRESENT STATE OF MANGROVE ECOSYSTEMS IN SOUTHEAST ASIA AND THE IMPACT OF POLLUTION
- SINGAPORE -

by

Zoology Department
University of Singapore
Bukit Timah Road
Singapore 1025

Contributors in alphabetical order:
L.M. Chou, S.H. Ho, H.W. Khoo,
T.J. Lam, D.H. Murphy
and
W.H. Tan

ABSTRACT

This report is an account of the special situations of the mangrove forests in Singapore, which declined from 10-12% of the total land area 150 years ago to 3% in 1978, and to an estimated 1% in 1980. A description of the knowledge on Singapore's swamp forest is given, including a - historical summary, not present state - record of mangrove species and its associated terrestrial and aquatic fauna and flora. In view of the land constraints in Singapore industrial for development, the report analyses the state and impact of human activities from land development to land use and pollution. Chemical analysis of some pollutants in the environment have been made, but there are few and only laboratory studies of the effects of pollutants on animals, but one of land development and related activities on the ecosystem. The discussion points out the gaps in ecological understanding of these problems, and lists priority research needs and desirable international support and cooperation.

1. EXTENT AND LOCATION OF MANGROVE IN THE COUNTRY (H.W. Khoo)

1.1 Geography of Singapore

Singapore is an island republic situated in Southeast Asia. It is linked to west Malaysia by a causeway 1.2 km long. In 1979, it was 616 km^2 in total area, consisting of a main island and 60 small offshore islands. The main island has a 128 km coastline (Planning Department Singapore 1975). It is about 41.5 km from east to west and about 22.5 km from north to south.

Its relief is gentle, mostly less than 30 m above sea level. The drainage pattern radiates outwards from the central peaks, the highest which is around 175 m (Bukit Timah). Rivers are short, the longest is Sungei Seletar which is 5.6 km.

1.2 Total area of mangrove swamps

There used to be many wide estuaries lined by mangrove swamps. To-date, there are onlu about 11.9 km^2 and 5.8 km^2 of relatively undisturbed swamps on the main island and the offshore islands, respectively. Only 2.96% of the total land area of Singapore is under mangrove swamps.

1.2.1 Previous extent and reclamation

Before the estuary of Singapore river was developed for human settlement in 1822, about 10-12% of the land was under mangrove. By the end of the nineteenth century, swamps occur only around estuaries of Kallang, Serangoon, Kranji, and Murai, along a stretch from S. Changi to S. Tampines, and on the southwestern part (Jurong) from S. Berih to S. Pandan. All the offshore islands were covered with swamps. In 1931, the Kallang basin was reclaimed to build a civil airport which was completed in 1937 and at the same time a harbour for shallow craft was developed. In 1928, the swamp at Changi was cleared to build the Changi-base for the Royal Artillery Batteries. By 1938, the Sembawang naval base was completed together with Tengal, Seletar and Sembawang aerodromes which were built along the banks of the respective rivers. By 1945, swamps in areas such as Kallang, Changi, Seletar, Sembawang and central parts of Jurong were cleared for development. The swamps on off-shore islands remained untouched (Sidhu, 1974).

By 1953, patches of swamps had been reclaimed on the southwest coast from Tuas to Tanjong Gul reducing the areas of swamps at the southwestern coast of the island. Swamps around S. Tampines and S. Selerang were also affected and used for mixed cultivation. Between 1961 and 1966, the Jurong Industrial Estate was established on reclaimed swampy land at Jurong. A shipyard was developed on P. Samulun and P. Damar Laut was also reclaimed. Further reclamation between S. Pandan to Tanjong Tuas continued in 1967. To date, most of the swamps on the islands of the Chawan-Merlimau group just off Jurong were reclaimed for industrial use. Further reclamation of the Kallang Basin for a housing and industrial estate took place after 1967. Recently a section of the Kranji estuary was reclaimed for saw milling industry. Thus, over the past 150 years, the areas under mangrove swamps were substantially reduced (Table 1). Swamplands were filled and used for housing, industry, parks, refuse disposal, agriculture and water impoundments. The rate of consumption of the swamps was about 5.2 km^2 per annum (Chua, 1975). The 1975 land use map of Singapore is shown in Figure 1.

During the early seventies, the Kranji-Pandan reservoirs were created by barraging the Kranji and Pandan estuaries. Subsequently, other estuaries such as Berih-Poyan, Tengeh, Murai and Sarimbun were also dammed. Thus demands for freshwater impoundments for domestic and industrial use made further inroads into the remaining mangrove resources in recent years. There are also suggestions to barrage, in the future, the Seletar, Punggol and Serangoon estuaries (Wong, 1969; ECAFE, 1965).

Table 1. Decline in swamp areas in Singapore since 1958

Year	Square kilometers (km^2)
1958*	51.8
1963*	44.8
1966*	36.0
1978**	32.1
1980***	11.9

* Wong (1969)
** Map of Singapore, 1978
*** 1978 estimate of swamp areas minus those along estuaries recently reclaimed for water impoundment.

1.2.2 Present geographic distribution (Fig. 2)

Only small areas of mangrove swamps are left in Singapore. In places a few stands of mangrove trees may be left. Most of them are degraded and disturbed mangrove forests. The relatively undisturbed areas are located at Pulau Ubin and Pulau Tekong (Fig. 2). In 1969, there was about 0.13 km^2 of undisturbed mangroves (excluding P. Tekong and about 30.58 km^2 of disturbed mangrove forest. About 6.17% of the land area was under mangal (Hill, 1977; Murphy, 1979, unpublished). Based on the 1978 Map of Singapore published by the Ministry of Defence which reflects the land use conditions 2 to 3 years back, the total area of mangrove swamps was 32.10 km^2 (including P. Tekong); 23.86 km^2 on the mainland and 8.24 km^2 on the islands; this amounts to 5.37% of the total land area (598 km^2 in 1975).

Taking into account the closure of the Kranji, Tengeh, Pasir Laba, Bajau, Berih and Poyan, Murai and Serimbun estuaries to form freshwater reservoirs for industrial and agricultural use as well as the reclaimed swamps on Chawan-Merlimau group of islands except P. Seburus Dalam for industrial use, the remaining mangrove area on the main island at the end of 1979 is about 12.45 km^2 and in the offshore islands about 5.77 km^2. Thus the total mangrove swamp area remaining is about 18.22 km^2 which is about 2.96% of the total land area (most recent figure for the total land area of Singapore is 616 km^2), and of this about a quarter is on the two northeastern islands of Tekong and Ubin.

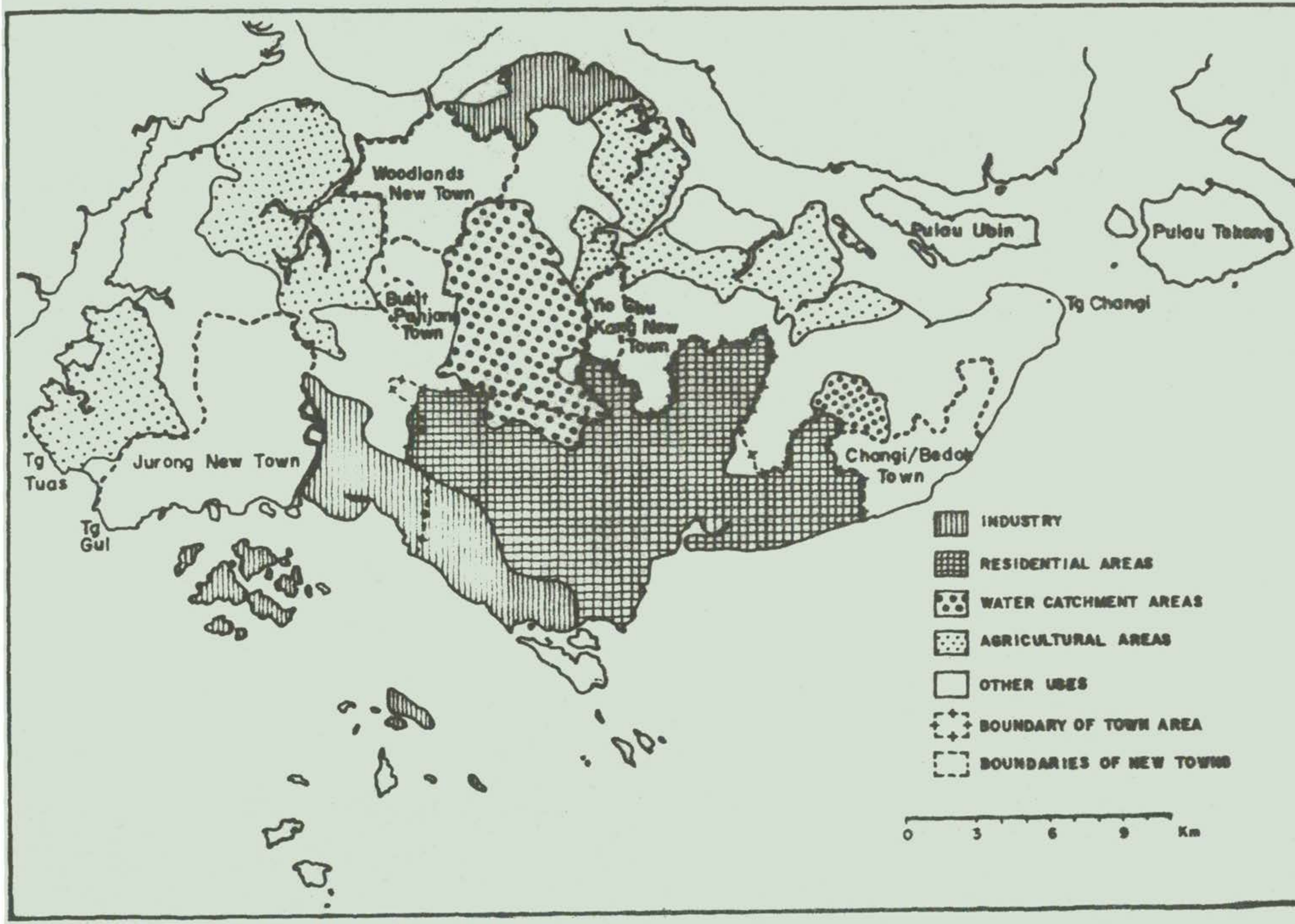

Fig. 1. Land use map of Singapore

1.2.3 Future use of mangrove areas

The future trend appears to be complete obliteration of the mangrove swamps on the main island. However, P. Tekong is also scheduled for development. Thus there will only be 3.5 km^2 of mangroves left and most of it will be on P. Ubin.

Besides the demand for land for housing and industrial development, there are also great pressures for suburban housing estates situated near mangroves to modify the mangrove ecosystem for health reasons. The mangrove is a source of a vast fauna of insects and other land arthropods, which are pests to households and also a source of the anopheline mosquito, *Anopheles sundaicus*, which is an efficient vector of malaria. Hence for health reasons, small areas of mangroves would be sprayed with oil to control mosquito breeding. In the process most of the mangroves would be affected. Studies on the impact of this oil spraying on the mangrove should be made.

2. MANGROVE ECOSYSTEM

2.1 Extent of knowledge on mangrove ecosystems in country (H.W. Khoo)

There are only a few studies on the mangrove swamp as an ecosystem in Singapore. One of these studies was conducted by Berry (1963) who investigated the vertical and horizontal zonation of the mangrove swamp fauna located at the Pandan Mangrove Reserve which is today converted into a freshwater reservoir for industrial use. According to Berry (1963), this mangrove swamp is similar to those described by Watson (1928). The latter, on the other hand, mentioned in the report on the "mangrove forests of the Malay Peninsula" that Singapore mangroves are unrepresentative of those in Malaya. Singapore apparently has the abnormal conditions where the swamps have the characters of both east and west coast mangrove forms. It is also different in that the mangroves in Singapore have been over-exploited for many years and have been constantly interfered with by human activities such as drainage diversion, land reclamation for urban and industrial use, conversion of tidal estuaries lined by mangrove swamps into freshwater reservoirs and construction of brackishwater impoundments for fish and prawns culture.

A brief description of the mangrove flora in Singapore was given by Johnson, A. (1973), and the fauna of the mangrove swamp was described by Johnson, D.S. (1973). Chuang (1961) also gave succinct descriptions of the flora and fauna found in local mangroves. Recently a paper was presented by Murphy (1979, unpublished) at the Unesco regional seminar held at Dacca on "the mangrove ecosystem: human uses and management implications." Other than the above, there were more specific studies conducted on individual species or groups found in the mangroves (see References).

The mangroves are found on sheltered estuarine shores in valleys reaching far inland. It is found along tidal river mouths, estuaries and bays with finger-like extensions. According to Wong (1966), the mangrove swamp in Singapore is developed in three main types of area: (i) the sheltered parts of the estuaries (most of the swamps in Singapore are of this type); (ii) the enclosed parts behind barriers such as spits; and (iii) small isolated areas where conditions are favourable.

Legend to Fig. 2. Map of Singapore showing location of existing mangrove **swamps along rivers (Sungei), and islands (Pulau), and their size in hectares** (1978)

MAIN ISLAND

1.	Sungei Blukang	56.45
2.	S. Tengeh*	164.52
3.	S. Pasir Laba	9.68
4.	S. Bajau	45.16
5.	S. Pasir, Berih, Poyan*	370.97
6.	S. Pergam	22.58
7.	S. Murai*	43.55
8.	S. Gedong	4.84
9.	S. Karang, Hantu	46.77
10.	S. Serimbun*	20.97
11.	S. Perempan Besar	25.81
12.	S. China	14.52
13.	S. Buloh Kechil	43.55
14.	S. Buloh Besar	32.26
15.	S. Kranji*	540.32
16.	S. Mandai	38.71
17.	S. Mandai Kechil	12.90
18.	S. China	30.65
19.	S. Sembawang	53.23
20.	S. Dekar	6.45
21.	S. Simpang	151.61
22.	S. Khatib Bongsu	120.97
23.	S. Seletar	216.13
24.	S. Punggol	53.23
25.	S. Serangoon Kechil	16.13
26.	S. Serangoon	109.68
27.	S. Bukar, R. Taib	50.00
28.	S. Tampines	29.03
29.	S. Selarang	54.84
	T o t a l	2 385.51

SMALLER ISLANDS

30.	Pulau Seletar	19.35
31.	P. Serangoon	8.06
32.	P. Ketam	13.71
	Pulau Ubin (224.19)	
33.	S. Teris	12.90
34.	S. Asam	16.13
35.	S. Puaka, Batu Kekok Maman, Besar, Jelutong	195.16
36.	S. Pulau Ubin	
	Pulau Tekong (225.81)	
37.	S. Tanjong & Permatang	17.74
38.	S. Unum	20.97
39.	S. Belang & Chek MatNoh	74.19
40.	S. Sayongkong	80.15
41.	S. Seminei	32.26
42.	P. Semakau	32.26
43.	P. Sakeng	3.23
44.	P. Pawai	43.55
45.	P. Pesek, Ayer Chawan, Sakra, Bakau, Merlimau, Seraya, Meskol, Seburus Luar, Ayer Merbau*	238.71
46.	P. Mesemat Laut*	3.23
47.	P. Seburus Dalam	7.26
48.	P. Sudong*	4.84
	T o t a l	824.2

* Recently reclaimed for water impoundments.

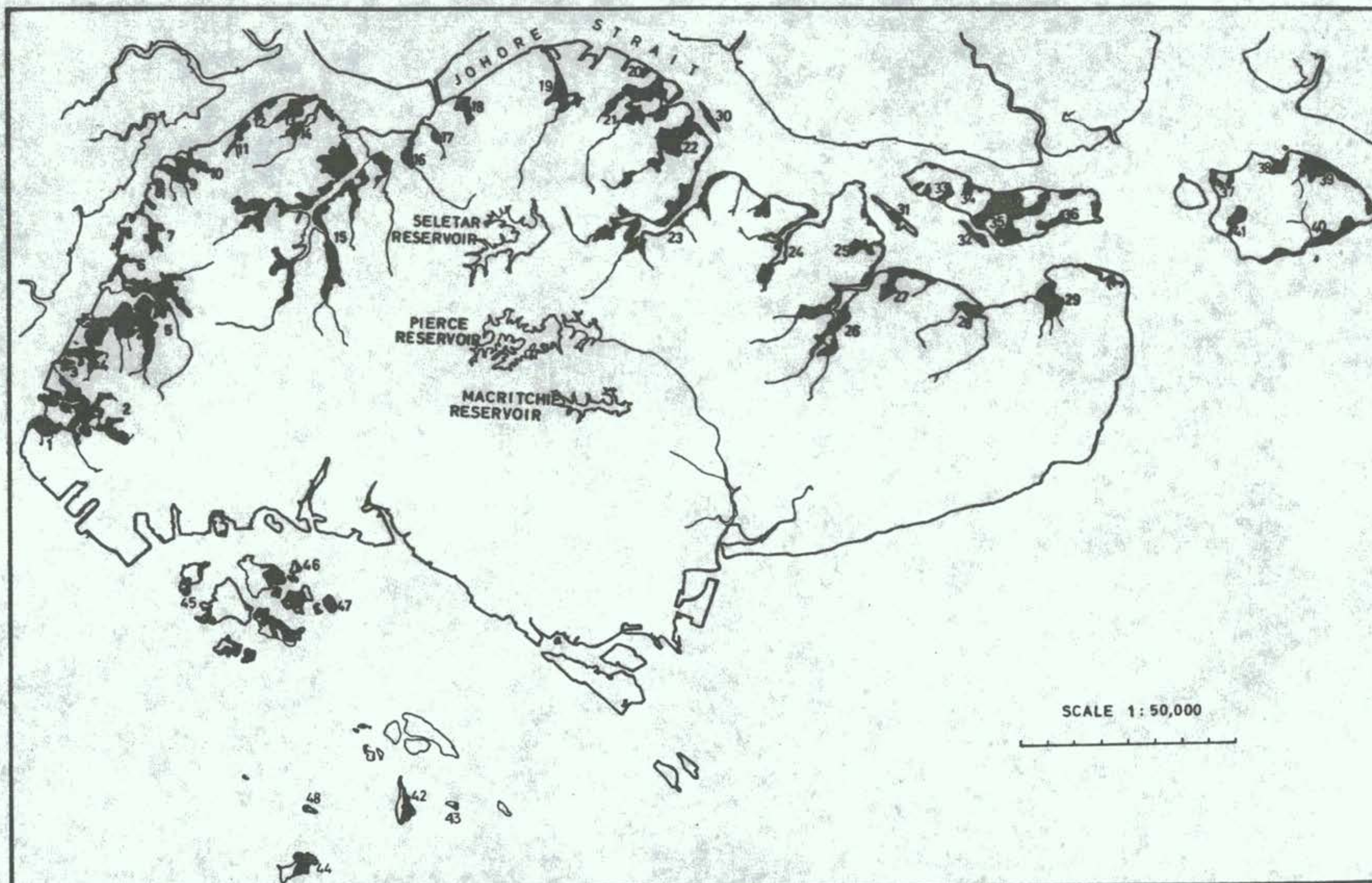

Fig. 2. Distribution of mangrove swamps in Singapore (for location names and areal breakdown see legend on previous page)

Areas with abundant freshwater develop a nipah palm dominance but this is not common in Singapore (Wong, 1969). Pandan swamps dominated by screwpines (Pandanus) are also uncommon. The mangrove coast in Singapore is colonized mainly by woody mangrove vegetation characterized by Avicennia and Rhizophora.

The tree flora is few in species and is confined to four families Rhizophoraceae, Lythraceae, Verbenaceae, and Meliaceae (Johnson, A., 1973). Most of the species are adapted to the "physiological dryness" of the environment which consists of unstable substratum, saline water and oxygen deficient fine mangrove mud. They have thick and fleshy leaves with glossy surface and sunken stomata, and other features for an arid existence.

As for the mangrove fauna, Berry (1963) recognized five habitat types defined by the tidal range, tidal height, substratum and distance from the sea. These are: (i) leaves, stems and aerial roots of the mangrove vegetation; (ii) the mud surface; (iii) the coastal mud bank; (iv) the dead wood; and (v) the streams and rivulets. He further zoned the fauna according to the dominant animals into (i) Littorina Zone (high tree zone); (ii) Nerita Zone (lower tree zone; (iii) Bivalve Zone (marginal zone); (iv) Uca Zone (mud surface); and (v) Burrower Zone. In a subsequent paper on Malaysian swamps he modified these zones, taking into account distance, substratum and tidal factors into: (i) seaward foreshore; (ii) marine pioneer; (iii) eroded mangrove banks; (iv) true mangrove forest; (v) rivers, streams and gullies; and (vi) terrestrial margin; and he placed the dead wood as a special case (Berry, 1972). In the mangrove of Singapore, these zones frequently merge and are not clearly demarcated due to extensive clearing and other human activities and, to the narrowness of the mangrove belt.

Johnson, D.S. (1973) grouped the animal life in mangrove swamps into three groups according to whether they are: (i) terrestrial; (ii) amphibious; or (iii) fully aquatic.

2.2 Species of mangroves flora and associated fauna (D.H. Murphy and W.H. Tan)

2.2.1 Taxonomic problems

The list submitted (Appendix) takes origin from an ongoing survey of a single site on the north coast of the island (Mandai river estuary) but has been extended by adding known records from elsewhere in Singapore, abstracted from publications, unpublished reports and documented specimens in local collections. The plankton lists have been almost entirely compiled by Dr. W.H. Tan. Many literature records are old and perhaps no longer reflect the current state of the biota, and since the listing was done at very short notice, it is certainly incomplete and has not been fully checked for nomenclature. This may explain inconsistencies in some author citation.

There is great variation in taxonomic standard. Some groups such as nematodes, rotifers, catenulid platyhelminths and mites, and also some insect groups have not been studied at all and substantial collection remain to be analyzed. Some such bacteria and protozoa have been only roughly identified by picture-matching or very crude tests such as stab-cultures on postgate medium for Desulphovibrio, contact-preparations and visual examination of agar plates, but without formal systematic treatment. At the other extreme, some groups like onchidiid molluscs, sarcophagid flies and orthoptera report advanced taxonomic studies and even anticipate the state of formal taxonomy in the group. In well documented groups such as higher plants and fish, the list is possibly close to being comprehensive, but in most areas it is certain that only a small part of biota present has been classified. Even so, the working list of some 1 200 recognized taxa presents formidable problems in organization.

The list is arranged in accordance with a 9-letter mnemonic code (not reproduced here) which is used in the Mandai mangrove survey and some inland ecosystem surveys which preceded it. This allows one to coordinate data, reference collections and the complex cross-referencing between different organisms such as are involved in food relationships. The need for this is perhaps more obvious when considering the larger context, since an ecosystem is often as strikingly defined by species it excludes as by those it contains. This code very roughly corresponds with the first three letters of phylum, a convenient intermediate taxon, and family so that all organisms can be cross-referred alphabetically. This is modified by some arbitrary devices which preserve something near accepted taxonomic sequence, and retains alphabetic order among groups with the same initial letters. The arbitrary codes are most noticeable among the higher groupings where, for example, the prefix AA - separates prokaryotes and primary saprobes and the prefix X - separates the euchlorophytic plants. Thus the listing is for saprobes, animals and plants in that order. Interested workers should consult the author for details.

2.2.2 Ecological species groups

In practice, although a comprehensive list is an essential background tool, most ecosystem survey work does not need to take account of all taxa known. It is convenient to abstract from it a short list of subjective categories appropriate to the ecosystem model defined by the project and site. The following categories are used.

2.2.3 Key-species

"Key-species" - presumed single species that are unusually abundant or significant in the system model. This is, of course, a loaded concept similar to the botanical idea of a dominant organism. Particular projects may attribute key-species status to different organisms but some at least would be generally agreed. Zonal trees are an obvious example. <u>Desulphovibrio</u> virtually defines the entire "sulphide system" (Fenchel and Riedl, 1970) of which mangroves are one expression. <u>Thiobacillus</u>, as a chemautotroph has an environmental impact out of all proportion to its relatively small biomass. The mudlobster <u>Thalassina</u> is a major land-forming organism that virtually constructs an entire zonal sequence within the mangroves. However, there are many less conspicuous organisms that almost monopolize significant energy pathways or play a dominant role when a special-purpose model is being examined. For this reason the concept is deliberately left flexible.

2.2.4 Species-swarms

"Species-swarms" (a term which has been used in other senses and if the concept proves itself, a new name will be needed.) Certain higher <u>systematic</u> taxa are unusually diverse in particular ecosystems, even though they occur and perhaps provide "key-species" elsewhere. These seem to indicate a unique correlation between ecosystem structure and the adaptive characteristics of the taxon. They may draw our attention to significant, but not necessarily obvious structural features of the system. In effect, certain features of the mangrove system are obvious to the human eye, but other and perhaps equally significant regularities will be appreciated by the senses of a fish or an insect. Well-known species-swarms of the mangroves are the onchidiid molluscs, the gobiid fish and the sesarmine (grapsid) crabs. It is not always obvious, from a species list such as is appended, where such a swarm exists for it presupposes a knowledge of diversity in other ecosystems and often considerable taxonomic knowledge. I believe examples are to be detected in the Capitellid worms, sarcophagid and dolichopodid flies (at family level), in the genera Psychoda (moth-flies), Limnophora (related to house-flies), Stenothyrea (molluscs) and in very many other taxa. There is a rich field of research and insight in the study of these swarms, but for many purposes it is enough to recognize their existence without detailing their composition.

2.2.5 Species-guilds

Accepted ecological (but non-taxonomic) groupings such as the "guild", e.g. the web-spinning spiders, water-strider bugs, and aerial hunting dragonflies; general categories such as climbers or epiphytes, and sample types oriented towards particular subsystems such as plankton, berlese-samples, endopsammon or plate isolates, can often be treated as unit "taxa". For general survey and teaching, I find that about 50 such categories will provide a working knowledge at a particular site. The essential point is critical selection for this short list in context with the model under study.

In the master-sheets of the Mandai survey, there is much information on zonation, microhabitat, gut-contents and general biology. Nevertheless, it is far from complete and inevitably concentrates on supposed key-species or those that were involved in special projects, and much is inadequately replicated, unsystematic or even speculative. Even so, we are probably at a stage where relatively good guesses can be made, for example in choosing candidates for screening as pollutant indicators, given adequate information on the likely behaviour of the pollutant in the physical system.

Partial systematic treatments are being accumulated for many mangrove taxa and it is hoped to produce an introductory identification manual in the future. However, the requested "description of local species" cannot be provided here. Local names used in Singapore exist only for trees and vertebrates and are those taken from literature applying to Peninsular Malaysia (Malay) which should be consulted.

3. ECOLOGICAL FACTORS (L.M. Chou, W.H. Tan, and S.H. Ho)

3.1 Salinity relations

Work done on the Ponggol estuary (northeast of Singapore) by Chua (1966) showed that salinity varied seasonally with two maxima and two minima recorded within a year.

Table 2. Salinity values (in parts per thousand) of Ponggol Estuary (from Chua, 1966)

	High tide	Low tide
River mouth	26.28-28.77	22.05-27.92
Middle reach	23.01-28.14	12.58-25.45
Upper reach	18.00-26.86	-

Low salinities were observed during the months of January (coinciding with the northeast monsoon) and July (coinciding with the southwest monsoon), while high values were observed during the months of April and October.

This seasonal variation of salinity was found to be similar to that of the Johore Straits (Khoo, 1966) and the Singapore Straits (Tham, 1953). The salinity patterns of these two straits were also found to have two maxima and two minima at similar months during the year. It may be assumed that the waters of these straits exert a pronounced and immediate effect on the salinity pattern of the Ponggol estuary.

Table 2 shows that salinity varied between low and high tides. Higher salinities were recorded during high tides when the estuary is inundated with sea water and lower salinities at low tides when fresh water flows out to sea. As the estuary is short (3000 meters), no wide horizontal salinity gradient was observed. Only slight variations between surface and bottom salinity at the river mouth and the middle reach were observed as the estuary is quite shallow.

The longitudinal succession of riverside vegetation was studied by Corner (1978) who showed the following succession of belts of vegetation from the river mouth inland: mangrove, nipah, putat (Barringtonia conoidea) and rassau (Pandanus helicopus). These are related to the degree of salinity tolerated by the plants. As the Singapore estuaries are relatively short, these belts are not very distinct. Moreover, the inland freshwater sections of most of the rivers in Singapore have already been cleared and used for farming and other human activities. There are practically no nipah forests on the main island.

Most of the mangrove fauna can withstand salinity variations, and a few salinity tolerance experiments on local mangrove swamp species have been conducted (Table 3). Johnson, D.S. (1973) also discussed the distribution of some local species due to salinity.

3.2 Soil types

The characteristics of Singapore soil was studied by Chia (1976) but very few data on soil conditions in the various tidal swamps of Singapore are available. Information on the geology of the island is, however, available (Public Works Department, Singapore, 1976). In 1965, the advisory group (ECAFE, 1965) inspected the soil conditions of the various mangrove swamps, and the soil in the swamp of Sungei Berih-Poyan was studied in more detail.

The soils of the tidal swamps in Singapore have very high content of organic matter and the upper 0.5 to 1.5 m is slightly clayey woody peat. The deeper subsoil contains more clay and consists mainly of non-calcareous clayey peat.

Table 3. Salinity tolerance studies (LT_{50} = time for 50% mortality)

Animal	Classification	Sampling site	Salinity of water	LT_{50} (days)	Reference
Glauconome straminea	Mollusca:Bivalvia	Sungei Mandai	10 $^{o}/oo$ (low tide)-26 $^{o}/oo$ (high tide)	8.4 (0 $^{o}/oo$); no mortality at 2 $^{o}/oo$ above for 2 weeks	Chan, Y.T. (1975)
Coecella horsfieldi horsfieldi	Mollusca:Bivalvia	Sungei Mandai	do	7.6 (0 $^{o}/oo$, 8.6 (2 $^{o}/oo$); 10.1 (5 $^{o}/oo$); 10.5 (50 $^{o}/oo$)	Chan, Y.T. (1975)
Mesopodopsis orientalis	Crustacea:Mysidae	Prawn pond off West Coast Road	15 - 19 $^{o}/oo$	About 2.5 (5 $^{o}/oo$); about 10 (20 $^{o}/oo$); about 3 (25 $^{o}/oo$); about 3 (31$^{o}/oo$); 100% mortality at 0 $^{o}/oo$ in 1/2 day; low mortality between 10-20$^{o}/oo$	Lee, H.B. (1972)
Uca vocans	Crustacea:Decapoda Brachyura:Ocypodidae	Ponggol, Track 22	18 $^{o}/oo$ - 29 $^{o}/oo$ (Chua, T.E., 1966)	1.4 (1.5 $^{o}/oo$); 100% mortality at 0 $^{o}/oo$; low mortality above 6 $^{o}/oo$	Poon, K.H. (1976)
Gambusia affinis	Pisces:Poecilidae	Serangoon River	15 $^{o}/oo$ - 22 $^{o}/oo$	3.5 ($^{o}/oo$), no mortality in 30 $^{o}/oo$ for 6 days	Lun, K.C. (1971)
Oryzias javanicas	Pisces: Cyprinidontiformes	Sungei Mandai	3 - 13 $^{o}/oo$ (low tide)	10.7 ($^{o}/oo$); no mortality above 0.3 $^{o}/oo$ for 1 week	Teo, L.L. (1980)

Information on the effect of soil type on the distribution of the fauna and flora in the mangrove swamps of Singapore is, however, not available.

3.3 Tidal characteristics

Mangrove swamps of Singapore are subjected to semi-diurnal tides. Spring tides range from 3.34 m (high) to 0.15 m (low) while neap tides range from 1.82 m (high) to 1.22 m (low). The differences in tidal heights around the island are within 0.3 m. Thus the maximum tidal range is 3.2 m and the minimum about 0.61 m. There are generally three to four spring tides a year which cause minor flooding in the low lying areas.

The mangrove forests extend out to sea only as far as the level of about mid-tide or low water neaps, i.e. upper part of the inter-tidal zone. The main portion of the forest is between mean high water and extreme high tides. The mangrove mudflats, however, extend down to the lowest spring tide.

Because of the high tidal level of the mangrove forest, the animals are subjected to long periods out of water. Most marine animals cannot withstand this. Crabs and snails, however, have adapted to this environmental stress. Hence the dominant animals in the mangroves are the crabs and snails. The effect of tidal cycles on the distribution of these and other animals in the mangrove swamps of Singapore has not been investigated.

3.4 Climatic conditions

Singapore's climate is rather stable except for the two monsoon periods each year. The northeast monsoon (November-February) brings higher precipitation than the southwest monsoon (June-August).

Water temperatures recorded at the mouth of the Ponggol estuary by Chua (1966) showed a maximum of 31.1°C (in April) and a minimum of 28.5°C (in January). Water temperatures fell in January and June, which coincided with the monsoon months. Very little variation was observed in the water temperature of the river mouth and the upper reaches. Vertical gradient of water temperature was found to be negligible. The flora and fauna of the mangrove swamps of Singapore are thus not normally subjected to wide temperature fluctuations, except when a power station discharging warm-water effluent is located nearby, as discussed under Section 4.10. The thermal tolerance of a few mangrove animal species has been studied (see Table 9). It was found that within the temperature range of 25°C to 45°C, an increase in temperature was accompanied by a decrease in oxygen consumption (Chin, 1975).

Rainfall has the effect of lowering salinity as discussed earlier. Turbidity is also increased through direct agitation and the washing of more suspended particles down the estuary. Chua (1966) showed the phytoplankton counts usually peaked after heavy rainfalls. His study also showed that phytoplankton blooms were independent of salinity and temperature influences and that zooplankton peaks (especially copepods) followed phytoplankton blooms. Rainfall then, seems to be the major factor influencing plankton blooms in estuaries.

The rise in zooplankton also led to increased numbers of nekton as determined from catch analysis. This included the squid Loligo, the common edible swimming crab Portunus pelagicus, and fishes such as Sillago, Leiognathus, Acentrogobius, Clupeoides, Stolephorus, Atherina, Mugil, Ambassis, Butis, and Apogon.

4. IMPACT OF HUMAN ACTIVITIES (S.H. Ho and H.W. Khoo)

4.1 General aspect of pollution

Pollution is defined here as any "change in the physical, chemical and biological properties of any habitat or ecosystem, due to any discharge of liquid, gaseous or solid substances, which is liable to create harmful effects on living organisms or that may affect the domestic agricultural, industrial and recreational activities of human beings".

Numerous studies were conducted on the effects and consequences of air pollution in Singapore but few studies were made on water pollution particularly marine pollution. There are no specific and detailed studies made on the effects and impact of pollution on the mangrove ecosystem as a whole in Singapore. However, some studies on certain aspects of pollution in selected local mangrove species have been made. These are restricted mainly to tolerance studies conducted in the laboratory. As for field situations, most of the information on pollution were indirect and qualitative.

Human activity is one of the main sources of disturbance and pollution to the mangrove community. Drainage and reclamation activities are removing many areas of brackish swampland for industry, housing, agriculture, and even for fish and prawn ponds. Owing to the scarcity of land and the rising population which is approaching 2.7 million in Singapore, there is very strong pressure to reclaim all mangrove swamps for land use.

Initially about two-thirds of Singapore was under primary rain-forest; about 10 to 12% under mangrove swamps, and the rest was bushland. Today about 3% of Singapore are under mangrove swamps.

4.2 Land development

Development of mangrove swamps into catchment areas is another source of encroachment into the limited mangrove resources in Singapore. In order to improve the infrastructure facilities in Singapore, the Economic Commission for Asia and the Far East (ECAFE, 1965) recommended the damming of some estuaries, reclamation of the surrounding tidal swamps and conversion of the existing channels into freshwater reservoirs.

With the reduction in the flow of the freshwater element into the sea due to the damming of these estuaries, environmental conditions would change and hence affect the mangrove communities in adjacent areas. The impact of such measures on the mangrove swamps has not been properly evaluated. Before this can be done, the effects of such modifications on the ecological factors such as shade, salinity, oxygen, and soil composition and hardness which in turn determine the habitat types would have to be studied in detail.

There is also a competing demand for land from refuse disposal. Land is required for solid waste disposal, since disposal into the sea would cause obvious marine pollution. Selected pieces of swamp are therefore used for solid waste disposal. There is bound to be some degree of pollution particularly from the leachage. However, using the sanitary landfill method, care has been taken to ensure minimal leachage into nearby water courses. With this method of refuse disposal, the areas filled may eventually be developed into parks, and housing and industrial sites (Lye, 1972). With the recent introduction of incineration, pulverisation and compaction methods of refuse disposal, demands for mangrove swamps as refuse dumping grounds are reduced. The amount of refuse produced in Singapore is about 2 000 kg/day. Incineration reduces the solid waste refuse weight to 25% or even 10% of the original volume.

4.3 Reclamation

The traditional uses of mangrove vegetation were for poles for fishing stakes (Oncosperma), for charcoal (Rhizophora timber) and for tanning (Rhizophora bark). Food items such as Acetes, Glauconome, Telescopium, Melanoides and Scylla serrata used to come from local mangroves but today most of these mangrove products are imported. Mangrove swamps were in the past also cleared for brackishwater fish and prawn rearing. General accounts of fish and prawn ponds were given by Hall (1962) and Tham (1968, 1973). In 1965, about 650 ha were brackishwater fish and prawn ponds which were built on swamps simply by clearing off the mangroves and erecting mud bunds (ECAFE, 1965). In 1976, due to reclamation only about 375 ha of brackishwater remained (Primary Production Department, 1978). In 1976, abut 16 500 kg of fresh fish were produced by local fishermen. Of these only 4% were contributed by aquaculture and only 10% of these came from brackishwater ponds.

In the past, about half of the local fish production was from offshore landings using troll and longlines, and the other half from near-shore catches which were mainly from palisade traps (kelong) and beach seines. The inshore landings declined in recent years because most of the traditional fishing areas located near mangrove swamps were reclaimed. Several coastal fishing villages in the past were located near mangrove swamps such as those at Ponggol and Kranji. The beach seiners from these villages used to fish off the mudflats located at the mangrove swamp's seaward fringe. There are now no more beach seiners in Singapore. The deleterious effect of reclamation on the inshore fishery is very obvious. This is further compounded by the removal of most of the palisade traps located along the southern coast of Singapore because the southern coast is zoned for anchorage of ships.

Murphy (1979) mentioned that even moderate reclamation activity near a working prawn-pond seems to have a significant effect on catches possibly because of the turbidity due to the inorganic silt in the water. Hence large scale reclamation would be expected to decimate the prawn and the fauna in adjacent ponds.

The most obvious effects of reclamation by land-fill is the complete obliteration of the mangroves and the extinction of rare species such as the phallostethid fishes, whose distribution, abundance and ecological requirements are not known. Ceratostethus bicornis and Neostethus lankesteri had been recorded from Sungei Kranji, S. Seletar, and S. Kangkar mangrove swamps. Destruction of scientifically interesting animals, plants and environment is one deleterious by-product of reclamation of the swamps.

Land reclamation will also create silting and increases turbidity in the water making the area at the river mouth unfit for swimming and other recreation such as fishing.

The use of swamps for solid waste disposal also poses a threat to the mangrove communities of adjacent areas due to the increase in organic load and the acidity of the leachage. However, these had been solved by incinerating and compacting the refuse before using them to land-fill the swamps. The land-fill methods used are such that the resulting land can eventually be used for housing and recreational or industrial development. The dumping grounds were located at 11 km Tampines Road, Lorong Halus, Chua Chu Kang and Serangoon estuary (Ministry of the Environment, 1973).

One beneficial effect of swamp reclamation is the reduction of mosquitoes and animals which are vectors or carriers of malaria and other arbovirus diseases.

4.4 Effects of watershed development

The larger estuaries located on the western coast of the island were already barraged to form freshwater impoundments, and the mangroves on the shores were cut and land-filled for agricultural purposes. The effect of barraging would be to change the drainage of the area concerned and the presence of a large impoundment of freshwater would definitely change the soil conditions of adjacent swamps through seepage. Moreover the withholding of the freshwater flow into the sea would change the salinity regime of the mangrove swamps located near to the water impoundment. The water would become more saline and less brackish. Moreover, the organic component that is normally drained from land into the rivers would not now contribute to the allochthonous source of energy for the mangrove ecosystem. As such, the mangrove community would be expected to change. The detritus component probably would be gradually replaced by a more autotrophic component.

4.5 Utilization of mangroves - forestry

Mangrove plants that are economically useful were exploited a long way back. *Oncosperma* poles were used for fishing stakes. The bark of *Rhizophora* was used for tanning and the timber for charcoal. *Avicennia* branches were used for firewood, but with modernization this practice stopped and did not pose any serious threat to the mangrove vegetation.

4.6 Utilization of mangrove swamps - fisheries, aquaculture

4.6.1 Subsistence fisheries

Harvesting natural populations of animal species in Singapore mangrove swamps has long been practised but usually at the 'subsistence' level. As low tide, a variety of species is gathered mainly for family consumption or sale in the local markets. The noteworthy species include *Telescopium telescopium*, *Cerithidea obtusa* (gastropods); *Glauconome rugosa*, *G. straminea*, *Coecella horsfieldi horsfieldi*, *Mytilus viridis*, *Paphia luzonica* (bivalves); *Scylla serrata* (portunid crab); *Penaeus* spp.; *Metapenaeus* spp. (penaeid prawns); *Acetes vulgaris* (sergestid shrimp); *Leoignathus equulus*; *Stolephorus indicus*; *Clupea fimbriata* and *Liza dussumieri* (fishes).

4.6.2 Prawn and crab culture

Only the penaeid prawns have been exploited on an extensive and somewhat controlled basis, although 'fattening' of young crabs in brackish-water ponds has increasingly become a common practice in recent years. Juveniles and young adults of the hard crab, Scylla serrata, are collected in the swamps and coastal areas and transferred to the ponds. They are fed trash fish and allowed to grow to a marketable size. They are then harvested and sold.

Prawn ponds were a common sight in Singapore in the fifties and sixties. These were constructed in the mangrove swamps at Pasir Panjang, Jurong, Chua Chu Kang, Ponggol, Tampines and Pulau Ubin (see Fig. 2). Large tracts of mangrove were cleared by felling the trees and areas of suitable sizes were bunded off with mud embankments. These earth bunds formed ponds which received the incoming tidal currents through specially constructed sluice gates twice a day and let off excess water with the receding tide, keeping the water in the pond at a depth of about 0.6 m. The size of each pond thus constructed varied from 1 to 25 ha, the optimal (economic) size being 12 ha. This is the maximum size which can be managed by the minimum number of workers (4) required to operate a prawn pond. Details of the construction and operation of a prawn pond are given by Tham (1955a, 1968, 1973) and Hall (1962).

This method of prawn culture in Singapore depends on the presence of commercially important species in the vicinity of the area where the pond is to be constructed. Young prawns are not stocked in the pond by operators but are brought in by tidal flow. Tham (1973) noted that once inside the pond, the prawns do not appear to make much effort to leave until they are at least 5 cm in total length (i.e. when they begin to mature). They then have an 'urge' to move out to sea and that is when they are caught by the filter net placed at the controlled openings (sluice gates) of the ponds.

The important penaeid species caught in quantity are Penaeus indicus, P. merguiensis, Metapenaeus ensis, M. bukenroadi and M. brevicornis while P. monodon and P. semisulcatus are caught in lesser numbers. Production averaged 0.25 to 0.79 tons/ha/year (Hickling, 1961), while the better managed ponds could yield up to 1.0 ton/ha/year (Tham, 1973). However in 1978, the average yield was only 0.2 to 0.3 tons/ha/year (Primary Production Department, 1978).

The main reason for this decline in yield was land reclamation. In 1960, the area of mangrove swamps that had been converted into prawn ponds was 564.4 ha (Hickling, 1961). This figure would have increased but for the industrialisation programme embarked upon by the Government since the early sixties. Extensive areas of prawn ponds and virgin mangroves were cleared and filled in to make room for industrial estates. In 1978, the total area for brackishwater pond was only 375.0 ha (Primary Production Department, 1978).

4.6.3 Ornamental fish culture

Of the original pond areas, only Chua Chu Kang, Pulau Ubin and Ponggol remain albeit reduced in area owing to rapid urbanization. At Tampines, the mangrove swamps have given way to marine and freshwater aquarium farms. Exports of ornamented fish amounted to US$11.5 million in 1977 (Ministry of Culture, 1978).

4.7 Organic pollution

4.7.1 Domestic sewage

Organic pollution is a serious problem in many estuaries in Singapore since the latter are usually centres of human activities. The best examples are Singapore and Kallang rivers. There were swamps around these estuaries prior to 1822. Today Singapore river has become a drainage canal with concrete walls and has become the "sewer" of the town centre. The unpleasant sight and smell emanating from these two rivers during low tides have recently prompted a government effort to rehabilitate Singapore river so that "fish may swin again in the river".

Today a very efficient system of domestic sewage treatment plants is available to collect all raw sewage sediments and digest them before the effluents are disposed into the water courses (Tan, H.B., 1972). Hence pollution from this source is minimal in Singapore. Most of these treatment works are located near mangrove swamps. One of these is located at Serangoon river (see Fig. 2). The effects of the effluent on the mangrove ecosystem are not known.

4.7.2 Organic industrial waste

The types and manner of disposal of trade effluents from the food industries are discussed by Tan, H.B. (1972). Pollution from this source is indirect since most of them are located inland and most of their effluents are discharged into sewers which will eventually be treated by the sewerage treatment plants mentioned above.

4.7.3 Organic agricultural waste

At Sungei Punggol situated in the northeast part of the main island, there was at one time a high degree of organic pollution due to the effluents and wastes from the pig farms which were concentrated in that area. However, new management systems have been devised to control and reduce the pollution from the pig waste (Primary Production Department, 1979). Nevertheless, the effects of these pollutants on adjacent mangroves have not been studied and the true extent of the impact is not known. Johnson, D.S. (1973) suggested that the resulting deoxygenation from organic pollution would prevent upstream migration of fish and other organisms. A new pig farming estate will be set up at Lim Chu Kang in the future. These will be large modern farms with waste treatment facilities for the pig wastes (Primary Production Department, 1979a, 1979b).

4.8 Heavy metal pollution

4.8.1 Environmental analysis

Apart from mercury (which will be discussed later in relation to mercury tolerance), there is no information on the levels of heavy metals in the mangrove ecosystem in Singapore. However, the concentrations of mercury and certain other heavy metals in the waters around Singapore have been measured, and the data are shown in Table 4-6.

Table 4. Concentration of certain heavy metals in sediment and water samples collected around Singapore (after Rahman et al., 1979)

Location	Lead (µg/1)		Nickel (µg/1)		Cobalt (µg/1)		Mercury (µg/1)	
	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment
WORLD TRADE CENTRE, Jardine Steps	10	28	95	94	0	13	-	0.0°4
SHELL REFINERY, Pulau Bukom	40	20	90	90	0	18	-	0.0°4
SLOP CENTRE, Pulau Sebarok	30	26	80	75	15	21	-	0.099
ESSO REFINERY Pulau Ayer Chawan	0	20	70	75	10	14	-	0.100
MOBILE REFINERY, Jurong	0	-	55	-	0	-	-	-
BP REFINERY, Labrador	30	23	80	79	15	12	-	0.089
SPC REFINERY Pulau Merlimau	40	20	100	98	0	13	-	0.085

Data on the level of cadmium in Singapore waters and sediments are not available. The concentration of heavy metals in marine organisms has also been determined and found to be generally low (Chai and Wong, 1976), indicating low levels of these metals in the marine environment (Tables 5a-5e).

Table 5a. Mean concentrations of selected heavy metals in the bivalve, Paphia luzonica (Veneridae) from coastal areas of Singapore, 1974 (µg/g dry weight basis) (after Chai and Wong, 1976)

Elements	Area 2 Punggol Point	Area 2 Punggol Point	Area 6 Mata Ikan	Area 10 Pasir Parjang	Area 13 Lim Chu Kang	Area 13 Lim Chu Kang
Cd	0.11	0.84	0.10	0.13	0.12	0.78
Co	0.45	7.38	0.44	0.52	0.63	7.10
Cr	0.25	5.80	0.30	0.29	0.34	5.80
Cu	2.72	2.56	2.10	2.57	2.12	2.47
Fe	17.5	12.5	19.0	18.7	17.7	13.2
Hg	0.026	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	1.69	1.63	2.15	3.68	4.46	1.58
Ni	0.56	6.90	0.64	0.68	0.63	6.54
Pb	1.61	13.3	1.31	1.35	1.32	12.1
Zn	10.6	3.83	11.2	12.0	11.7	3.68
Tissue	Flesh	Whole animal	Flesh	Flesh	Flesh	Whole animal
Av. wet/ dry weight ratio	4.38	1.12	5.07	4.90	4.96	1.20

Table 5b. Mean concentrations of selected heavy metals in fishes, squids, prawns and crabs collected from the Straits of Singapore (Kelongs Nos. SE 41 and SE 52), 1974 (µg/g dry weight basis) (after Chai and Wong, 1976)

Elements	Selar sp. oxeye or bigeye scad*	Selaroides Leptol. yellow stripe trevally	Stolephorus indicus* (Anchoviella i.) Indian anchovy	Eulamis melanoptera Black shark	Scomberomorus sp. Spanish mackerel	Rastrelliger sp. Mackerel	Siganus canaliculatus* (siganus oramin) White spotted spinefoot	Sepiotheutis indica Squid	Penaeus indicus Prawn		Neptunuspelagicus Swimming crab	
Cd	0.036	0.029	0.045	0.059	0.039	0.034	0.028	0.038	0.059	0.13	0.042	0.081
Co	0.26	0.26	0.24	0.19	0.24	0.28	0.14	0.19	0.32	0.45	0.24	0.60
Cr	0.24	0.18	0.31	0.33	0.25	0.20	0.27	0.17	0.46	0.77	0.17	0.84
Cu	1.56	1.32	1.12	2.45	1.34	1.33	1.18	2.49	4.70	14.8	2.52	7.20
Fe	10.2	3.51	3.81	1.96	4.23	7.10	4.03	0.88	8.08	10.9	2.42	10.0
Hg	0.045	0.034	0.044	0.062	0.039	0.037	0.024	0.045	0.046	-	0.062	-
Mn	0.14	0.12	0.40	0.13	0.10	0.16	0.12	0.15	0.17	0.59	0.25	1.71
Ni	0.23	0.23	0.26	0.23	0.23	0.20	0.19	0.27	0.28	0.42	0.27	0.44
Pb	0.26	0.25	0.28	0.38	0.28	0.30	0.22	0.27	0.44	0.83	0.28	1.00
Zn	2.47	1.60	4.20	0.39	2.22	1.20	2.82	6.57	9.12	15.6	11.7	8.50
Tissue	flesh	flesh	flesh	flesh	flesh	flesh	flesh	flesh	flesh	whole animal	flesh	whole animal
Av. wet/ dry weight ratio	4.00	3.94	4.64	4.00	3.47	3.28	5.21	4.34	3.47	3.85	4.26	3.49

*) Names of teleosteens corrected according to Fischer, W. and P.J.P. Whitehead, 1974. FAO species identification sheets for fishery purposes. Eastern Indian Ocean (fishing area 57) and Western Central Pacific (fishing area 71, Rome, FAO pag. var.).

Table 5c. Mean concentrations of selected heavy metals in fishes, squids, prawns and crabs collected from the Straits of Malacca (Kelong No. W 22), 1974 (μg/g dry weight basis) (after Chai and Wong, 1976)

Elements	Selar sp. oxeye or bigeye scad*	Selaroides Leptol. yellow stripe trevally	Stolephorus indicus* (Anchoviella i.) Indian anchovy	Eulamis melanoptera Black shark	Scomberomorus sp. Spanish mackerel	Rastrelliger sp. Mackerel	Siganus canaliculatus* (siganus oramin) White spotted spinefoot	Sepiotheutis indica Squid	Penaeus indicus Prawn		Neptunuspelagicus Swimming crab	
Cd	0.040	0.045	0.07	0.039	0.049	0.042	0.045	0.030	0.073	-	0.015	-
Co	0.063	0.14	0.29	0.14	0.17	0.16	0.17	0.16	0.16	-	0.17	-
Cr	0.10	0.090	0.20	0.067	0.070	0.082	0.072	0.080	0.090	-	0.15	-
Cu	1.80	1.00	1.68	1.48	1.96	2.60	1.26	2.20	3.20	-	4.36	-
Fe	9.15	2.75	4.22	1.30	4.12	7.20	3.60	1.75	7.95	-	5.82	-
Hg	0.048	0.057	0.051	0.057	0.038	0.031	0.010	0.048	0.052	-	0.12	-
Mn	0.17	0.17	0.76	0.070	0.070	0.080	0.065	0.13	0.25	-	0.69	-
Ni	0.28	0.21	0.48	0.24	0.24	0.23	0.27	0.28	0.30	-	0.28	-
Pb	0.55	0.38	0.92	0.30	0.45	0.62	0.34	0.27	0.56	-	0.61	-
Zn	2.70	1.68	4.10	2.52	2.05	1.30	3.32	6.50	7.40	-	12.3	-
Tissue	flesh	flesh	flesh	flesh	flesh	flesh	flesh	flesh	flesh	whole animal	flesh	whole animal
Av. wet/dry weight ratio	3.93	4.46	4.55	4.50	4.23	3.84	4.41	4.90	4.53	-	5.79	-

*) Names of teleosteens corrected according to Fischer, W. and P.J.P. Whitehead, 1974. FAO species identification sheets for fishery purposes. Eastern Indian Ocean (fishing area 57) and Western Central Pacific (fishing area 71, Rome, FAO pag. var.).

Table 5d. Mean concentrations of selected heavy metals in a marine green algae (Ulva reticulata) from coastal areas of Singapore, 1974. (µg/g dry weight basis) (after Chai and Wong, 1976)

Elements	Area 1 Sembawang	Area 2 Punggol Point	Area 3 Changi Point	Area 4 Telok Paku	Area 5 Kg. Ayer Gem	Area 8 Sentosa	Area 9 Labrador	Area 10 Pasir Panjang	Area 12 Sarimbun
Cd	0.44	0.41	0.40	0.45	0.56	0.43	0.43	0.41	0.45
Co	2.70	2.90	3.30	3.00	2.25	2.44	3.14	3.03	2.64
Cr	1.87	3.95	2.03	2.93	2.02	1.79	2.85	2.54	2.47
Cu	8.10	12.4	5.26	6.37	5.74	7.78	8.73	9.11	5.45
Fe	191	192	174	269	160	179	183	190	193
Hg	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mn	36.1	79.1	11.3	61.6	40.8	32.2	33.9	38.1	61.9
Ni	4.80	7.77	5.05	6.00	5.24	4.35	5.84	6.46	5.39
Pb	8.36	12.6	8.94	9.16	4.20	6.96	8.27	7.88	6.86
Zn	43.9	29.2	41.3	34.4	34.6	19.9	28.8	25.5	33.5
Av. wet/dry weight ratio	9.26	7.81	7.86	7.95	8.69	7.42	7.24	6.25	7.88

Table 5e. Mean concentrations of selected heavy metals in marine brown algae (Sargassum sp. and Padina commersonii) from coastal areas of Singapore, 1974. (µg/g dry weight basis) (after Chai and Wong, 1976)

Elements	Area 1 Sembawang	Area 4 Telok Paku	Area 5 Kg. Ayer Gem	Area 8 Sentosa		Area 9 Labrador		Area 12 Sarimbun
	Padina commersonii	Padina commersonii	Padina commersonii	Padina commersonii	Sargassum sp.	Padina commersonii	Sargassum sp.	Padina commersonii
Cd	0.46	0.48	0.47	0.45	0.70	0.41	0.63	0.49
Co	2.45	2.58	2.50	3.55	3.69	3.17	3.34	2.71
Cr	5.37	5.72	5.90	3.42	1.99	3.21	1.55	5.00
Cu	5.24	4.04	4.75	4.59	5.41	4.07	6.30	6.35
Fe	169	173	185	142	147	159	172	182
Hg	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mn	59.2	67.0	70.6	59.0	72.6	60.7	64.0	70.1
Ni	4.72	5.18	4.93	4.84	5.11	4.37	4.45	5.87
Pb	5.37	5.66	5.45	5.67	5.45	5.98	4.51	5.68
Zn	30.5	23.8	29.8	42.6	43.9	42.8	43.8	40.7
Av. wet/dry weight ratio	8.10	7.93	8.22	8.33	8.80	8.41	9.00	9.20

Table 6. Cadmium and mercury tolerance studies

Animal	Classification	Sampling site	Heavy metal	Median tolerance limit (TLm)	Reference
Glauconome straminea	Mollusca:Bivalvia	Sungei Mandai	Cadmium	9.63 ppm (168 hr)	Fernando, A. (1977)
Coecella horsfieldi horsfieldi	Mollusca:Bivalvia	Sungei Mandai	Cadmium	0.65 ppm (168 hr)	Fernando, A. (1977)
Mytilus viridis	Mollusca:Bivalvia	Serangoon Harbour	Cadmium	1.01 ppm (168 hr)	Fernando, A. (1977)
Uca vocans	Crustacea:Decapoda Brachyura:Ocypodidae	Ponggol, Track 22	Cadmium	Adults: 2.4 ppm (96 hr) Larvae: 0.1 ppm (24 hr)	Poon, K.H. (1976
Oryzias javanicus	Pisces: Cyprinidontiformes	Sungei Mandai	Cadmium	Adults: 11.6 ppm (96 hr) Larvae: 1.75 ppm (96 hr)	Teo, L.L. (1980)
Mytilus viridis	Mollusca:Bivalvia	Ponggol Point	Mercury	3.5 ppm (24 hr) 1.2 ppm (48 hr) 0.5 ppm (72 hr)	Goh, T.S. (1973)

4.8.2 Effects on some mangrove animals

The impact of pollution by heavy metals on mangrove animals as such has not been studied, but a few species of animals collected from mangrove areas have been treated with various concentrations of cadmium and mercury in the laboratory. The tolerance of the animals to these metals in terms of the median tolerance limit (TLm) has been assessed by several workers and their results are presented in Table 7. Goh (1973) has analysed water samples for mercury from both polluted and unpolluted rivers of Singapore (Table 8).

Table 7. Mercury level in water sampled from both polluted (sites 1-8) and unpolluted (sites 9-12) rivers of Singapore (from Goh, 1973)

Site of collection	Location	Concentration of mercury (in ug/1)
1	Sungei Jurong	0.050
2		0.049
3		0.046
4		0.038
5		0.037
6		0.187
7	Sungei Pandan	0.023
8		0.024
9	Sungei Kranji	0.026
10	Sungei Seletar	0.020
11	Sungei Ponggol	0.025
12	Sungei Serangoon	0.036

4.9 Oil pollution

Oil is another source of pollution which is of concern when one considers the mangrove ecosystem. Because of its low level oil tends to be trapped within the mangrove in the tide-pools which form at the roots of the plants, or adhering to the plants themselves. In the southern part of Singapore, the source of oil is mainly from ships that use the busy sea lane of the Straits of Singapore (Fig. 3), and those that anchor at the various designated anchorage areas which practically occupy the whole of the southern territorial waters of Singapore. Because it is a busy shipping lane, a number of oil spills due to collisions involving oil tankers had occurred. A survey of oil pollution in waters around Singapore is given by Rahman and Chia (1977). Table 8 gives a listing of ship casualties and oil spill for the period 1975 and 1976. However, the effects of the oil spill and the subsequent cleaning up operations using dispersants on the small mangrove communities situated on the southern islands are not known. Oil also comes from the shipyards and marine oriented industries situated in Jurong. In the north, oil pollution also comes from shipyards located at the Sembawang Industrial Estate and

Table 8. Shipping casualties in the Strait of Singapore (after Finn et.al, 1979)

Date	Registration	Name of Ship	Type	Tonnage	Cause	Location	Comments
6 Jan. 1975	Japan	Showa Maru	Tanker	237 698	Grounding	Buffalo Rock, off Singapore	1 000 tons oil spilled
16 Jan. 1975	Japan Liberia	Isuzugawa Maru Silver Palace	Tanker Tanker	122 233 21 226	Collision	Outside of Singapore Port limits	Isuzugawa Maru had cargo of crude oil; no spillage
5 Apr. 1975	Britain	Mysella	Tanker	212 759	Grounding	1°12'04" N 103°50'54" E	2 000 tons oil spilled
18 Apr. 1975	Japan Liberia	Tosa Maru Cactus Queen	Tanker Tanker	42 790 152 035	Collision	1 mile south of St. John's Island	Tosa Maru broke in two and sank
14 June 1975	Panama	Kowei Baru Monte Cristo	Freighter	- -	Collision	Eastern Roads, Singapore	
30 June 1975	Panama	Liengku	Freighter	-	Collision	Malacca Straits	Ship sank with 300 tons of charcoal
17 July 1975	Japan Pakistan	Neissei Maru Ravi	Tanker Freighter	231 986	Collision	1°15'03" N 104°09'03" E	Neissei Maru had cargo of crude oil
24 Oct. 1975	Liberia	Seatiger	Tanker	123 693	Collision, grounding	4.8 km. south of St. John's Island	
29 Oct. 1975	Greece	Kriti Sun	Tanker	123 484	Struck by lightning	Singapore Port	
11 Dec. 1975	Britain Poland	Sachem General Madalineki	Tanker Bulk Carrier	29 908 23 298	Collision	Eastern anchorage, Singapore	
17 May 1976	Liberia East Germany	Margo Georg Hanake	Freighter Freighter	-	Collision	Eastern anchorage, Singapore	
26 July 1976	Britain Greece	Forresbank Mareva A.S.	Freighter Freighter	-	Collision	Eastern anchorage, Singapore	
6 Sept. 1976	Panama Greece	Soyakaze Marrita E.	Freighter Freighter	- -	Collision	Off St. John's Island	
26 Oct. 1976	Italy Philippines Panama	Citta di Savona Philippine Star Esso Spain	Tanker Tanker Tanker	64 805 - 81 827	Collision	Eastern anchorage, Singapore	Savona and Star had cargos of crude oil; 1 000 tons oil spilled

ships that ply the Johore Straits to these shipyards as well as the new port on the Malaysian side of the Straits. The number of ships involved is small compared to the southern coast of Singapore. However, the fact that the Straits of Johore is straddled by a solid causeway which divides it into two semi-enclosed estuaries, has to be taken into account, since any pollution in these areas would not be easily dispersed or carried away by the currents and tides; moreover, most of Singapore's remaining mangroves are located in these areas.

The effect of oil on mangrove plants according to Mathias and Charles (1978) is through clogging of root pneumatophores and prop roots, with secondary effects from raised water temperatures and depressed oxygen concentrations.

4.10 Thermal pollution

Temperature *per se* increases degradation by bacteria and the rate of organic decomposition resulting in increased oxygen decomposition resulting in increased oxygen consumption and decreased oxygen tension in the water and the mud, thus influencing the survival of the infauna and the tide-pool fauna. Thermal pollution may be an important consideration in the Straits of Johore. The Senoko Power Station is situated on the northern coast of the main island to the east of Sungei Sembawang (see Fig. 2). It uses the sea water for cooling. The temperatures recorded at the condenser outfall of another power station located at Pasir Panjang are 32°C for a small capacity generator and 35°C for a large capacity generator. Sometimes the temperature may reach 40°C (Chin, 1975). With the power plant at Senoko and the semi-enclosed nature of the Johore Straits, deleterious effects of thermal pollution on the adjacent mangroves can be expected.

Tropical marine organisms live at environmental temperatures close to their thermal limits. The usual lethal temperature for most organisms is 35°C. However, no information regarding the impact of thermal pollution in the field is available, although a laboratory study on five mangrove species of molluscs, viz. *Coecella horsfieldi horsfieldi* (Gray), *Diplodonta cumingii* Hanley, *Terebralia sulcata* (Born), *Melongena pugilina* (Born), and *Mytilus viridis* L., showed that heat stress is experienced by these organisms at 32°C (normal temperature is about 29°C) (Table 9). Thus the power stations are discharging water at temperatures above the heat coma temperature involved in thermal stress deleterious effects on mangrove communities would be expected. The rate of heat exchange between the water and the atmosphere probably determines the temperature level of the water.

Table 9. Thermal tolerance of some mangrove animal species (based on data obtained by Chin, 1975)

Animal	Collection sites	6-hour TLm* (°C)
Coecella horsfieldi horsfieldi	near estuary of Sungei Mandai	45.8
Diplodonta cumingii	near estuary of Sungei Mandai	41.5
Terebralia sulcata	near estuary of River Senoko	44.9
Melongena pugilina	mangrove at Kranji	41.2
Mytilus viridis	kelong poles in Johore Straits	39.1

* 6-hour median tolerance limit

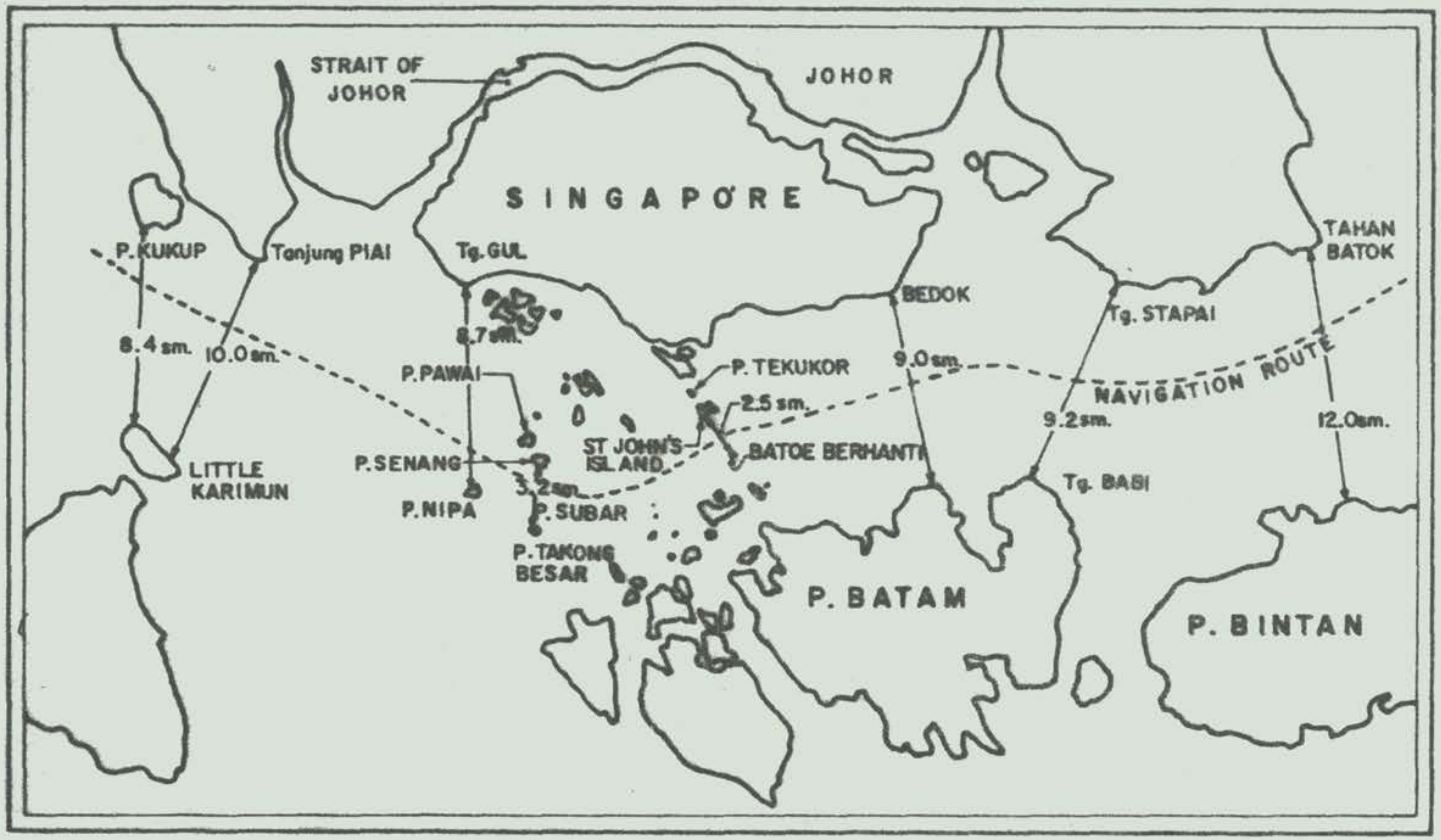

Fig. 3. Navigation route with Straits of Singapore. The heavily travelled narrow strait poses a risk for trip casualties and oil spills (see Table 8)

5. DISCUSSION

5.1 Gaps in knowledge

Although the mangrove flora and fauna and their zonation have been described, the dynamics of the mangrove ecosystem have hardly been studied. It is important that these be fully understood in order that the impact of pollution can be realistically evaluated.

Many questions concerning the mangrove ecosystem remain largely unanswered. These include the following:

(1) What in quantitative terms are the respective energy inputs into the ecosystem from the vegetation, the river and the sea?

(2) What specific roles do the soil microorganisms play?

(3) What roles do burrowers like crabs and mud-lobsters play in the soil dynamics?

(4) What roles do 'visiting' fauna play vis-a-vis the 'resident' fauna?

(5) How important is the mangrove swamp as a nursery ground for estuarine and/or marine fishes?

(6) What roles do the terrestrial fauna (e.g. insects) play?

These are broad-based questions within which no doubt many specific questions could be asked. In general terms, we would want to know the major processes maintaining and modifying the mangrove environment and how the organisms interact with one another and with environmental factors.

With so much unknown variables about the basic biological processes, it is of little wonder that the impact of pollution on the mangrove ecosystem is still poorly understood, at least in the Singapore context. Most of the available information in this regard is based on laboratory tolerance studies of single mangrove animal species to pollutants. How this is related to the ecosystem at large is often a matter of conjecture.

The effects and impact of those human activities which contribute to changing the mangrove ecosystem indirectly, such as modification of the drainage pattern, land reclamation of adjacent areas, and watershed development, are also still not understood. All we know is that the affected mangrove ecosystem will change; however, we do not know the immediate or proximate factor or factors that eventually cause this change. For example, barraging of a river upstream would result in the destruction of the mangrove; the question is how does it come about? Is it due to the lack of fresh water input or is it due to the absence of organic matter input? It could have been a physical process such as the lack of sedimentation contributing to land accretion in the mangroves, or a chemical process such as the lack of coagulation of the suspended silt as the fresh water from the river meets the salt from the sea, resulting in most of the silt material being washed out into the sea. At the same time, the utilization of the organic pool by bacteria and other mud feeders in the mangrove and the erosion of fine sediments by currents and tides in the absence of input from upriver would probably be the more immediate factors that would change the faunal and floral structure of the mangroves.

On the other hand the allochthonous factors may not be as important as the autothonous factors. The effects of barraging the river could be due to the direct absence of fresh water to maintain the brackish environment and hence "freshwater" component of the biota. Which are the species that require this input is at present not completely known. Thus knowledge of these direct and indirect factors for each polluting situation is one of the gaps.

On the regional basis a few sources of "pollution" should be considered with priority. These are:

(1) The effects of inland forest clearance on the mangroves. This increases river flow and increases the freshwater input into the mangroves and at the same time increases the rate of erosion of the mangrove sediments.

(2) The effect of oil pollution. Oil pollution seems inevitable; thus we must know the resilience of the system, the tolerance of individual species especially the "key" species (which are yet to be identified), the rate at which the system could "purify" itself or break down the oil and the effects on commercially important species including those that use the mangroves as a nursery.

(3) Other pollutants that will constitute a health hazard to human beings, for example heavy metals such as mercury and lead, PCBs, and organophosphates. The capacity of mangrove species to accumulate these pollutants to levels detrimental to human beings is of immediate importance.

(4) Can the mangrove system be rehabilitated? Studies should be conducted to establish mangrove trees in previously cleared mangrove areas or areas that were heavily polluted, and where the source of pollution has now been removed and methods to reforest the mangroves should be identified.

5.2 Problem areas and priority research needs

The problem areas concern: pollution effects, and ecosystem dynamics.

(1) Pollution effects

As little is known, this area of research is wide open, at least in Singapore.

Singapore offers particularly good opportunities for the study of effects of reclamation (siltation) and watershed development on mangrove swamps adjacent to the affected sites. Oil and petrochemical pollution is also of interest.

Other aspects that may be studied in Singapore include: effects of organic pollution (from pig dung and domestic sewage); effects of heavy metals from industries; effects of thermal pollution from power plants; and effects of refuse disposal. At present, these forms of pollution are kept under control.

(2) Ecosystem dynamics

From the standpoint of pollution, priority should perhaps be accorded to efforts directed at identifying those weak or sensitive components of the ecosystem (links in the energy flow) which are most suitable for assessment of pollution effects. In this regard, the roles of the soil microorganisms and the burrowers should perhaps be studied in greater detail.

In terms of fisheries, it is important to study the larval fishes which 'visit' the mangroves. What species do they belong to? Do they come to the mangroves to feed? What do they feed on? How long do they stay in the mangroves? Do they follow the tides? What are their predators? These and other questions need to be answered if we want to know how mangrove pollution would affect fisheries.

Special techniques and methods should be developed to study the mangrove system. For example special vehicles or gears which are portable have to be devised to transport and aid the investigators within the forest proper and on the soft mud flats. For the latter a sort of mud "mukluk" or "scooter" will be helpful to investigators.

One of the reasons why the mangrove ecosystem is not properly investigated is the lack of enthusiastic and interested personnel (scientists, students and helpers). This lack is due to the relatively impenetrable and inaccessible mangrove swamps. Access from the sea is impracticable because at low tide the soft mud will discourage anyone, except the most dedicated, to approach the forest.

At high tides, the forest is inundated, however, the streams and rivulets within the forest are too small for ordinary boats to maneuver. The raised roots and low branches will also hinder progress within the forest. Moreover, the "hot, dirty and snake and mosquito infested swamps" tend to discourage many students of biology.

At the same time field and laboratory methods and techniques would have to be devised and standardized with special attention on quantitative methods. Instructional manuals on how to investigate the mangrove ecosystem are very desirable*.

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*) Note: This task is being tackled by the SCOR/UNESCO Working Group 60 on Mangrove Ecology (ed.).

5.3 Needs for international support of national research programmes

At present, as far as we know, there is no national research programme directly related to mangroves.

However, according to a report by the Primary Production Department of Singapore (1978), there are plans to include prawn pond research in the second phase of aquaculture development. As pointed out in 4.7, the traditional trapping-holding-culturing prawn ponds are land-intensive and low-yielding. As land is relatively scarce in Singapore, there is need to increase productivity in these ponds and develop more intensive culture methods. International support would be needed to augment this research. The technology developed could then be transferred to the countries in the region.

5.4 International co-operation among the countries in the sub-region

Since so much is still not known about the mangrove ecosystem and the impact of pollution thereon, there is a great need for international co-operation if full understanding is to be achieved in the shortest possible time.

Singapore's participation in such a co-operative effort may involve the following:

(1) Identification of mangrove fauna and key species. Singapore disposes of competent taxonomists/systematists as well as a good zoological reference collection (former Raffles Museum Collection) for this purpose.

(2) Development of rapid mangrove-swamp survey techniques, including topography, mapping, collection, sampling and recording. Mr. D.H. Murphy is prepared to run a course on this.

(3) A detailed study of the effect of tidal range on zonation. This would involve a continuous recording of tidal fluctuations at the site of study and correlating them with animal zonation.

(4) Field studies of effects of reclamation, watershed development, oil and other forms of pollution on the mangrove swamp.

(5) Laboratory studies of specific effects of pollutants and the interplay among pollutants on individual mangrove animal species.

Since the mangrove swamps in Singapore will eventually be utilized and modified they are not of priority in national research programmes. International funding is therefore necessary to facilitate full participation by the University of Singapore. There is considerable urgency in mangrove research, since mangroves are fast disappearing from the Singapore scene.

6. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In summary it can be briefly stated that our knowledge and studies of the mangrove swamps in Singapore are fragmentary and few. Much less is known of the effects and impact of pollution on the mangrove environment and the response of the biota to human influences.

The present area of Singapore that is under mangrove is only 3% of the total area of 616 sq km. and they are located mainly in Pulau Ubin and Tekong and the north eastern coast of the main island. Eventually all the mangrove swamps on the main island will in one way or another be affected by national development.

Many species of plants and animals have been recorded in Singapore and there are many more which have to be described and identified. How many of these recorded species are still present in the mangrove swamps in Singapore today is not known.

The greatest threats to the mangrove ecosystem in Singapore are land reclamation and watershed development.

There are numerous gaps regarding the knowledge on the ecological processes of the mangrove ecosystem, and unless these gaps are filled our assessment of the impact of the various types of pollution on the mangrove swamps would not be practicable.

Regionally a high proportion of the land is under mangrove swamps and many of the inhabitants in this region are dependent on the mangrove ecosystem for a livelihood. Hence there should be more efforts made to co-ordinate studies on this system in the region and this can be facilitated by international funding.

Singapore is undergoing rapid urbanization and the existing mangrove swamps should therefore be studied in order to monitor the effects of these activities. The data obtained could therefore contribute to the understanding of a "disturbed" mangrove ecosystem.

The Zoology Department of the University of Singapore could participate in any regional efforts by providing experties on biota identification, in studying the local mangrove swamps, and providing training courses.

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APPENDIX

LIST OF SPECIES RECORDED IN SINGAPORE MANGROVE SWAMPS

FOREWORD TO APPENDIX

The list is arranged in accordance with a 9-letter mnemonic code which is used in the Mandai mangrove survey and some inland earlier ecosystem surveys. This code very roughly corresponds with the first three letters of phylum and family so that all organisms can be cross-referred alphabetically. This is modified by some arbitrary devices which preserve something near accepted taxonomic sequence, and retains alphabetic order among groups with the same initial letters. The arbitrary codes are most noticeable among the higher groupings where, for example, the prefix AA - separates prokaryotes and primary saprobes and the prefix X - separates the euchlorophytic plants. Thus the listing is for saprobes, animals and plants in that order. Interested workers should consult the author for details.

LIST OF SPECIES RECORDED IN SINGAPORE MANGROVE SWAMPS

TAXON

BACTERIALES

(Eubacteria)
- Bacillus spp.
- Cocci indet. (agarlytic)
- Cocci indet. (non-agarlytic)
- Corynebacterium spp.
- Desulphovibrio spp.
- Macromonas sp.
- Thiobacillus sp.
- Thiovolum sp.

(Spirochaeta)
- Spirillum sp. (chitinolytic)
- Spirillum spp.

CYANOPHYTA

(Beggiatoaceae)
- Beggiatoa sp.
- Vibioscilla sp.
- indet. gliding sigmoid

(Entophysalaceae)
- Entophysalis deusta (Menegh.)
- Johannesbabtista pollucida (Dick.)

(Chroococcaceae)
- Agmenellum sp. (as "Merismopoedia")
- Anacystis dimidiata (Kutz)
- Coccochloris elabens (Breb.)

(Nostocaceae)
- Anabaena? lichiniformis Bory
- Anabaena oscillarioides Bory
- Calothrix crustacea Sch. & Th.
- Nostoc commune Vauch.
- Nostoc spumigena (Mert.) Dr.
- Scytonema hoffmannii Agardh

(Oscillariaceae)
- Lyngbya sp.
- Oscillatoria limosa
- Oscillatoria princeps
- Oscillatoria sp.
- Spirulina sp.

FUNGI

Ascomycetes

(Amphisphaeriaceae)
- Physalospora hibisci Rac.

(Asterinaceae)
- Lembosia javanica (Pat.) Rac.

(Dematiaceae)
- Helminthosporium subsimile Sacc.

(Diatrypaceae)
- Diatrype parvula Penz. & Sacc.

(Hypocreaceae)
  Micronectriella pterocarpi (P. & S.)

(Pleosporaceae)
  Pleospora sp.
  Lulworthia sp.
  Pyricauda pelagica

BASIDIOMYCETES

(Agaricaceae)
  Phellinus sp.
  Trametes sp.
  Tricholoma sp.

(Hydnaceae)
  Grandinia sp.
  Odontia sp.

(Polyporaceae)
  Fomes fastuosus Lev.
  Fomes sp. 2
  Hexagonia tenuis
  Hexagonia umbrosa Lloyd
  Polyporus gilvus Fries
  Polyporus ostreiformis Berk.
  Polyporus theobromae Lloyd
  Polystictus cervinogilvus Jungh.
  Polystictus sanguineus Fries

(Schizophyllaceae)
  Schizophyllum commune

(Thelephoraceae)
  Asterostroma investiens Schw.

Deuteromycetes

(Stilbaceae)
  Podosorium consors Sacc.

  Form-taxon Lichenes (not sorted)
  Myomycota not recorded
  Virales present but not documented

ANIMALIA
ANNELIDA

(Enchaetraeidae) spp. indet.
(Lumbricidae)
  Diplogaster sp.

(Eunicidae)
  Diopatra neapolitana
  Lumbriconereis sp.

(Glyceridae)
  Glycera spp.

(Neriidae)
  Ceratonereis sp.
  Lycastris indicus
  Nereis spp.

(Capitellidae)
- Heteromastus sp.
- Leiochrides australis
- Paraheteromastus tenuis
- Capitellidae sp. indet. 1
- Capitellidae sp. indet. 2

(Serpulidae) sp. indet.

XIPHOSURA
(Limulidae)
- Carcinoscorpius rotundicauda (Latr.)
- Tachypleus gigas (Muller)

ARACHNIDA
Acarina
(Anoetidae) sp. indet.
(Bdellidae) spp. indet.
(Eriophyiidae)
- Eriophyes ?cheriana Massee
- Eriophyes hibiscitileus Nalepa
- Eriophyes sp. 3

(Halacaridae)
- ?Soldanellonyx sp.

(Hydryphantidae) sp. indet.
(Oribatei lat.) many spp. indet.
(Tetranychidae) spp. indet.
(Trombidiidae) spp. indet.

ARANEIDA
(Argiopidae)
- Argiope n. sp.
- Cyrtarachne sp.
- Gasteracantha brevispina
- Argiopidae spp. indet.

(Clubionidae) sp. indet.
- ?Corinna sp.

(Hersiliidae)
- Hersilia sp.

(Oxyopidae)
- Oxyopes sp. 1
- Oxyopes sp. 2
- Peucetia sp.

(Salticidae) spp. indet.
(Sparassidae)
- sp. indet. 1
- sp. indet. 2

(Tetragnathidae)
- Leucauge grata
- Leucauge sp. 2
- Tetragnatha sp. 1
- Tetragnatha sp. 2

(Theridiidae)
- Achaeranea sp.
- Argyrodes sp.
- Ariamnes sp.
- ?Enoplognatha sp.
- Episinus sp.
- Theridula sp.

genus indet. (doubtful Theridiid)
(Thomisidae)
Thomisus sp.
genus indet.

CRUSTACEA
Anemura
(Paguridae)
Clibanarius longispinosus

(Porcellanidae)
Petrolisthes sp.
Varuna litterata
(Thalassinidae)
Thalassina anomala (Herbst.)
Upogebia n. sp.

AMPHIPODA
LIL Liljeborgiidae ? n. gen.
(Talitridae)
Parhyale sp.
Parorchestia sp.

BRACHYURA
(Grapsidae)
Chiromanthes eumolpe de Man
Chiromanthese fasciatum Lanch
Chiromanthes indiarum de Man
Chiromanthes lanchesteri Tweedie
Chiromanthes onychophorum de Man
Chiromanthes semperi Burger
Chiromanthes n. sp.
Clistocoeloma merguiense de Man
Metaplax elegans de Man
Metaplax sheni Gordon
Metapographsus sp.
Neoepisesarma edamensis (de Man)
Neoepisesarma batavicum (Moreira)
Neoepisesarma bocourti (Milne-Edw.)
Neoepisesarma bracki (de Man)
Neoepisesarma chentongensis Serene
Neoepisesarma crassimanum (de Man)
Neoppisesarma edwardsi (de Man)
Neoepisesarma gemmiferum (de Man)
Neoepisesarma indicum (de Man)
Neoepisesarma johorensis (Tweedie)
Neoepisesarma kraussi (de Man)
Neoepisesarma kr. borneensis (Tw.)
Neoepisesarma minutum (de Man)
Neoepisesarma palawanensis (Miln.)
Neoepisesarma pontianacensis (de M.)
Neoepisesarma sedilensis (Tweedie)
Neoepisesarma singaporensis (Tw.)
Neoepisesarma versicolor (Tweedie)
Sarmatium crassum Dana
Sarmatium smithi Milne-Edw.
Sesarma batavianum de Man
Sesarma melissum de Man
Sesarma rutilimanum Tweedie
Utica borneensis de Man

(Ocypodidae)
Ilyoplax sp.

Uca acuta rhizophorae Tweedie
Uca dussumieri spinata Crane
Uca forcipata (Adams & White) = "manii"
Uca lactea (de Haan)
Uca rosea Tweedie
(Uca triangularis (Milne-Edw.)

(Portunidae)
Scylla serrata (L.)

(Xanthidae)
Ozius granulosus (de Man)
Ozius guttatus Milne-Edw.
spp. indet.
CIRRIPEDIA
(Thoracica)
Balanus hawaiiensis Broch
Chthamalus withersii

CLADOCERA
(Polyphemidae)
Evadne sp.

COPEPODA
(Calanoidea)
Acrocalanus gibber Gries
Arcatia erythraea Gries
Arcatia spinicauda Gries
Calanus spp.
Centropages sp.
Paracalanus crassirostris Dahl
T Temora sp.
Tortanus forcipatus (Gries)

(Cyclopoidea)
Corycaeus sp.
Cyclops (lat.) sp.
Oithona sp.

(Harpacticoidea)
Cleta sp.
Nitocra sp.
Onychocamptus bengalensis
Stenhelia sp.

ISOPODA
(Anthuridae)
Cyathura sp.
(Armadillidae)
Cubaris sp. 1
Cubaris sp. 2
(Cheluridae)
Chelura terebrans
(Cirolanidae)
Cirolana sp.
Excirolana sp.

(Ligiidae)(not exot. & hawaiensis)
- Ligia sp. 1
- Ligia sp. 2

(Limnoriidae)
- Limnoria lignorum

(Oniscidae s. lat.)
- Olibrinus sp. near antennatus (B.L.)
- Olibrinus sp. nr. nicobaricus (Barn.)
- Olibrinus sp. nr. mangroviarum Ferr.
- Olibrinus sp. 4

(Sphaeromiidae)
- Sphaeromia sp.

MYSIDACEA
- Mesopodopsis orientalis Tatt.
- Rhopalophthalmus egregius Hansen
- Nanomysis insularis Nouvel

NATANTIA

(Alpheidae)
- Alpheus microrhynchus de Man
- Alpheus paludosus

(Atyidae)
- Caridina excavatoides Johnson
- Caridina gracilirostris de Man
- Caridina propinqua de Man
- Caridina tonkinensis Bouvier

Luciferidae)
- Lucifer sp.

(Palaemonidae)
- Leandrites celebensis de Man
- Leandrites deschampsi (Nobili)
- Leptocarpus potamiscus Kemp
- Macrobrachium equidens (Dana)
- Macrobrachium idae
- Macrobrachium rosenbergi
- Palaemon semmelincki
- Pontoniinae sp. indet.

(Penaeidae)
- Metapenaeus brevicornis (Milne-Edw.)
- Metapenaeus burkenroadi Kubo
- Metapenaeus elegans (de Man)
- Metapenaeus ensis (de Haan)
- Metapenaeus intermedius (Kish.)
- Metapenaeus lysianassa (de Man)
- Metapenaeus mastersii (Haswell)
- Metapenaeus mutatus (Lanch.)
- Metapenaeus spinulatus Kubo
- Penaeus indicus Milne-Edw.
- Penaeus merguiensis de Man
- Penaeus monodon Fabr.
- Penaeus semisulcatus de Haan
- Trachypenaeus fulvus Dall.

(Sergestidae)
- Acetes sibogae Hansen
- Acetes vulgaris Hansen
- Syncarida sp. indet.
- Tanaeidacea spp. indet.

INSECTA
- Apterygota
- Collembola

(Entomobryidae)
- Homidia sp.
- Pseudosinella sp.
- Willowsia sp.

(Hypogastruridae)
- Xenylla sp.

(Isotomidae)
- Archisotoma sp.
- Axelsonia littoralis
- Axelsonia nitida
- n. gen. nr. Axelsonia

(Neanuridae)
- Anuritelsa n. sp.
- Pseudanurida billitonensis (Schott)
- Pseudanurida sawayana

(Onychiuridae)
- Onychiurus nr. rectopapillatus Stach

(Paronellidae)
- Salina spp.

(Sminthuridae)
- Debouttevillea marina Murphy
- Sphaeridia n. sp. 1
- Sphaeridia n. sp. 2

COLEOPTERA

(Carabidae)
- Odacantha sp.
- Tachys sp. 1
- Tachys sp. 2

(Cerambycidae)
- Demonax sp. 1
- Demonax sp. 2
- Doesus sp.
- Gnatholea sp.

(Chrysomelidae)
- sp. indet. 1
- sp. indet. 2
- Phyllochoris undulata
- Tricliona sp.

(Coccinellidae)
- Harmonia sedecimnotata

(Elateridae)
- sp. indet. 1
- sp. indet. 2
- sp. indet. 3

(Lampyridae)
Pteroptyx tener
Pteroptyx sp. 2
(Melyridae)
sp. indet. 1
sp. indet. 2
(Nitidulidae)
sp. indet. 1
sp. indet. 2
(Platypodidae)
Crossotarsus squamulatus
Platypus biuncis
Platypus forficula
Platypus pseudocupulatus
Platypus sp. indet.
Trachyosteus saundersii
(Scarabaeidae lat.)
Dynastini indet.
Macronotus elongatus
Valgini indet.
(Scolytidae)
Poecilips fallax
Poicilips rhizophorae
Stephanorhopalus inermis
Xyleborus cognatus
Xyleborus riehli
Xyleborus similis
Xyleborus perforans

(Staphilinidae not sorted)

DIPTERA
CAL (Calliphoridae)
Chlororhinia exempta
Chrysomya megacephala
Hemipyrellia ligguriens
Phumosia n. sp.
Synamphoneura sp.
(Cecidomyiidae)
Stephaniella falcaria Felt
sp. 2 (Heritiera leaf-gall)
sp. 3 (Hibiscus leaf-gall)
sp. 4 (Clerodendron stem-gall)
spp. indet.
(Ceratopogonidae)
Atrichopogon sp.
Bezzia sp.
Culicoides damnosus
Culicoides niveus gp.
Culicoides (Trithecoides) sp. 1
Culicoides (Trithecoides) sp. 2
Dasyhelea sp.
Forcipomyia sp. 1
Forcipomyia sp. 2
Monohelea sp.
Stilobezzia pseudofestiva
Stilobezzia subviridis
Stilobezzia sp. 3

(Chirinomidae)

Endochironomus sp.
Orthosmittia sp.
Polypedilum sp. 1
Polypedilum sp. 2
Pontomyia sp.
Pseudosmittia sp.
Stictochironomus stupidus
Tanytarsus sp.

(Chloropidae)

Cadrema sp. 1
Cadrema sp. 2
Cadrema sp. 3
Rhodesiella sp.
Thressa sp.

(Culicidae)

Aedes albopictus
Aedes fumidus
Aedes longirostris
Aedes masculinus
Anopheles sundaicus
Culex cinctellus
Culex nigropunctatus
Culex reidi
Culex sitiens
Culex spathifurca
Culex tritaeniorynchus
Culex variatus
Mansonia (Leicesteria) sp.
Uranotaenia lateralis

(Dolichopodidae)

Chrysosoma sp. 1
Chrysosoma sp. 2
n. gen. nr. Paralleloneurum
n. gen. nr. Rhaphium
Thinophilus sp. 1
Thinophilus sp. 2
Thinophilus sp. 3
Thinophilus sp. 4
gen./spp. indet.

(Drosophilidae)

Baeodrosophila sp.
Drosophila sp.
Scaptodrosophila sp.
Scaptomyza sp.

(Ephydridae)

Allotrichoma sp.
Atissa sp.
Chlorichaeta sp.
Discocerina sp.
Brachydeutera longipes
Notiphila sp.
Ochthera sp.
Paralimna major
Paralimna fasciata
Paralimna sp. 3
Placopsidella cynocephala
Trimerogaster sp.

(Empidae)
sp. indet.
(Lauxaniidae)
Homoneura sp. nov.
(Lonchaeidae)
Lonchaea sp. nov. n. bicoloricornis
Lonchaea sp. nov. 2
Silba sp. indet.
(Micropezidae)
Grammicomyia sp. nov.
Mimegralla albimana
Mimegralla sp. nov.
(Muscidae)
Atherigona s. nov. nr. dybasi
Buccophaonia subcostalis
Coenosia sp.
Dichaetomyia pallens
Dichaetomyia n. sp.
Limnophora plumiseta
Limnophora n. sp. 1
Limnophora n. sp. 2
Limnophora n. sp. 3
Lispe albifacies
Lispe cana
Lispe inaequalis
Lispe n. sp.
Helina sp.
Musca domestica
Musca sorbens
Musca n. sp.
Ophyra chalcogaster
Orthellia cuprea
Orthellia timorensis
Orthellia n. sp.
Phaonina corbetti
(Phoridae - not sorted)
(Platystomatidae)
Euprosopia sp. 1
Euprosopia sp. 2
Euprosopia sp. 3
Physiphora aenea
Plagiostenopterina aenea
Plagiostenopterina enderleini
Plagiostenopterina trivittata
Pseudepicausta chalybea
Pseudepicausta sp. 2
Scholastes cinctus
Scholastes sexvittatus
(Psychodidae)
Psychoda sp. 1
Psychoda sp. 2
Psychoda sp.3
Psychoda sp. 4
Psychoda sp. 5
(Sarcophagidae)
Boettcherisca javanica
Boettcherisca peregrina

Curranea n. sp.
Curranea scopariiformis
n. genus nr. *Goniophyto*
Liosarcophaga dux
Parasarcophaga aliena
Parasarcophaga orchidea
Pseudothyrsocnema serrata
Pseudothyrsocnema n. sp.
Sarcolopezia littoralis
Seniorwhitea reciproca
Souzaisca singaporensis

(Sciomyzidae)
Sepedon sp.

(Sepsidae)
Sepsis n. sp.
n. genus, n. sp.

(Sphaeroceridae)
Leptocera spp.

(Stratiomyiidae)
Negritomyia sp.
Pachygasterini sp. 1
Pachygasterini sp. 2
Pachygasterini sp. 3
Ptecticus vittatus

(Syrphidae)
Allobaccha amphithoe
Eristalinus arvorum

(Tabanidae)
Atylotus sp.
Tabanus sp. 1
Tabanus sp. 2

(Tephritidae)
Adrama apiculata
Dacus spp.
Myoleja sp.
Sphaeniscus sp.
n. genus, n. sp.

(Tachinidae - not sorted)
(Tipulidae) - not sorted)

HETEROPTERA
ARA (Aradidae)
sp. indet. 1
sp. indet. 2

(Coreidae)
Anoplocnemis phasiana
Mictis n. sp. (B.M. no.3)

(Corixidae)
sp. indet.

(Cydnidae)
sp. indet.

(Gerridae)
Halobates sp.
Limnogonus fossorum (F.)
Limnogonus sp. 2

(Hebridae)
sp. indet.

(Lygaeidae)
Dieuchus sp.
Leptocoris n. sp. nr. auger
Leptocoris rufomarginatus
Rhyparochromini sp. indet. 1
Rhyparochromini sp. indet. 2
(Miridae - not sorted)
(Pentatomidae)
Antestiopsis sp.
Calliphara nobilis
Coptosoma modiglianii
Coptosoma pulchra
Glaucias sp.
(Pyrrhocoridae)
Antilochus sp.
Dysdercus decussatus
(Veliidae)
Halovelia sp. 1
Halovelia sp. 2

HOMOPTERA
(Aphididae)
Anophyllaphis podocarpi
Aphis gossypii
Toxoptera aurantii
(Cicadellidae)
Coelidia sp.
Drabescus sp.
Litura unda Knight
Tartessus sp.
Zizyphoides sp. 1
Zizyphoides sp. 2
Zizyphoides sp. 3
(Cicadidae)
Purana tigrina
(Cixiidae)
Andes sp. 1
Andes sp. 2
(Coccoidea lat.)
Ceraplastes sp.
Ceraplastodes sp.
Coccus viridis
Coccus sp. 2
Coccus sp. 3
Crypticerya sp.
Icerya sp.
Lecanodiaspis sp. 1
Lecanodiaspis sp. 2
Lecanodiaspis sp. 3
Lepidosaphes sp.
Pseudaulacaspis sp.
Pseudococcus sp.
Pulvinaria sp.
(Delphacidae not sorted)
(Dictyopharidae)
Doryphorina sp.
Thanatodictya fuscovittata

(Flatidae)
- Lawana guttifascia
- Salurnis marginellus

(Meenopliidae)
- Nisia atrovenosa

(Membracidae)
- Tricentrus spp.

(Psyllidae)
- Boreioglycaspis forcipata (Cr.)
- Boreioglycaspis sp. 2
- Haplaphalara dahli (Rubs.)
- Mesohomotoma hibisci
- Miyatakea flava (Cr.)
- Nesiope sp.

(Ricaniidae)
- Pochazia antica (Wlk.)

(Tettigometridae)
- Egropa sp.

(Tropiduchidae)
- Kallitaxila sp. (not granulata)

HYMENOPTERA

(Anthophoridae)
- Ceratina n. sp.
- Xylocopa confusa

(Apidae)
- Apis florea
- Apis javanica
- Lasioglossum sp.

(Chalcidoidea not sorted)

(Megachilidae)
- Chalicodoma sp.

(Eucharitidae)
- Eucharitidae sp. indet.

(Eumenidae)
- Allorhynchium sp.
- Euodynerus sp.
- Parancistrocerus sp.
- Subancistrocerus sp.

(Formicidae)
- Anochetus sp. nov.
- Aenictus sp.
- Diacamma sp.
- Bothroponera sp. 1
- Bothroponera sp. 2
- Camponotus maculatus
- Camponotus sp. 2
- Camponotus sp. 3
- Cardiocondyla sp. 1
- Cardiocondyla sp. 2
- Crematogaster sp. 1
- Crematogaster sp. 2
- Echinopla sp. 1
- Echinopla sp. 2
- Hypoponera sp.
- Iridomyrmex spp.
- Monomorium floricola

Monomorium sp. 2
Oecophylla smaragdina
Odontomachus n. sp.
Paratrechina sp. 1
Paratrechina sp. 2
Ponera sp.
uadristruma sp.
Pheidole sp. 1
Pheidole spp. (unsorted)
Polyrhachis sp. 1
Polyrhachis sp. 2
Polyrhachis sp. 3
Strumigenys sp.
Tapinoma sp.
Tetraponera sp. 1
Tetraponera sp. 2

(Ichneumonoidea not sorted)

(Pompiloidea absent-needs expl.)

(Scelionidae) mostly unsorted

Gryon sp.

(Sphecidae)

Crabro sp.
Trypoxylon sp. 1
Trypoxylon sp. 2
Trypoxylon sp. 3

(Vespidae)

Parischnogaster n. sp. nr. jacobsoni
Polistes stigma
Polistes sp. 2
Rhopalidia artifex
Rhopalidia sumatrana
Rhopalidia sp. 3
Rhopalidia sp. 4
Vespa tropica

LEPIDOPTERA

(Geometridae)

Geometridae sp. indet. 1
Geometridae sp. indet. 2

(Gracillariidae)

sp. indet. (Bruguera leaf-mine)
sp. indet. (Derris leaf-mine)
sp. indet. (Heritiera leaf-mine)
sp. indet. (Brownlowia leaf-mine)

(Hasperiidae)

Suastus gremius
Hesperiidae sp. indet.

(Lyonetiidae)

Bucculatrix sp.

(Noctuidae)

Caradrina sp.

(Oecophoridae)

Oceophoridae sp. indet.

(Olethreutidae)

Olethreutes leveri

(Papilionoidea)

Elymnias hypermnestra
Euploea phanaereta

Idea leuconoe
Nacaduba pavana
Neptis hordonia
Neptis hylas
Polyura hebe
Rapala cowani
(Psychidae)
Psychidae sp. 1 (on Avicennia)
Psychidae sp. 2 (on Rhizophora)
Psychidae sp. 3 (on Aegiceras)
(Pyralidae)
Ambia paritialis (?)
Hyaloptychis sordida
Oligostigma ?bilinealis
Oligostigma ?villidalis
Pyraustinae nr. Mecyna sp.
Pyraustinae ? n. gen.
Perisyntroches ?ossianalis
Zinckenia fascialis
Nymphulinae gen. sp. indet.
(Tortricidae)
Tortricidae sp. indet. 1
Tortricidae sp. indet. 2
(Fam. indet.) sp. indet.

NEUROPTERA
(Chrysopidae)
Chrysocercoidea n. sp.
Chrysoma ?ruficeps
Glenochrysa splendida
(Mantispidae)
Mantispilla sp.
(Coniopterygidae)
Coniocompsa sp.

ODONATA
(Libellulidae)
Agrionoptera insignis
Diplacodes trivialis
Neurothemis fluctuans
Pantala flavescens
Potamarcha obscura
Tetrathemis hyalina

ORTHOPTEROID ORDERS
(Acridoidea)
Xenocatantops humilis
(Blattodea)
Anaplecta n. sp.
Euhebardula stellata
Margattea n. sp.
Neostylopyga n. sp.
Periplaneta n. sp.
(Gryllacridoidea)
Rhaphidophora n. sp.
(Gryllodea)
Aphonoides sp. 1
Aphonoides sp. 2
Apteronemobius sp.

Gryllotalpa n. sp.
Mnesibulus bicolor
Ornebius karnyi
Ornebius n. sp.
Paratrigonidium n. sp.
(Isoptera)
Nasutitermes sp. 1
Nasutitermes sp. 2
Neotermes sp. 1
Neotermes sp. 2
(Mantodea)
Hierodula sp.
Statilia sp.
(Phasmida)
Prisomera sp.
(Tettigonioidea)
Phisis n. sp.
? Scytocera sp.
Psocoptera (mainly unsorted)
Archipsocus sp.
Thysanoptera (mainly unsorted)
Dinothrips sp.
Trichoptera
Trichoptera sp. indet.

MYRIAPODA
Diplopoda
Trigoniulus sp.
Chilopoda
(Mecistocephalidae)
Mecistocephalus pahangiensis
Mecistocephalus sp. 2
Mecistocephalidae gen. indet.
(Scolopendridae)
Scolopendra sp.
(Scutigeridae)
Thereuopoda sp.

ASCHELMINTHES
Chaetognatha
Sagitta dioica
Nematoda (not sorted)
Rotifera (not sorted)
Brachiopoda
Lingula unguis (larvae)
Chidaria (mot sorted)
Ctenophora
Mnemiopsis sp.
Pleurobrachia sp.
Ectoprocta
Carnosa
(Arachnidiidae)
Sundanella sibogae (Harm.)
(Nolellidae)
Victorella bengalensis
(Vesiculariidae)
Bowerbankia sp.

MOLLUSCA
Bivalvia
(Anomiidae)
Enigmonia aenigmatica (Chemn.)
Enigmonia rosea Gray
(Arcidae)
Anadara auriculata (Lamk.)
Anadara cuneata (Reeve)
Anadara granosa (L.)
Barbatia fusca (Brug.)
Striarca lacerata (Brug.)
Striarca pectunculiformis (Dunker)
Striarca sculptilis (Reeve)
Striarca tenebrosa (Reeve)

(Asaphidae)
Sanguinolaria sp.
(Corbiculidae)
Geloina erosa (Sol.)
(Diplodontidae)
Diplodonta cumingii Hanley
(Glaucomidae)
Glauconome rugosa Hanley
Glauconome straminea Reeve
Glauconome virens (L.)
(Isognomonidae)
Isognomon ephippium (L.)
Isognomon isognomon (L.)
(Laternulidae)
Laternula truncata (Lamk.)
(Macridae)
Caecella horsfieldi Gray
(Mytilidae)
Brachydontes rostratus (Dunker)
Modiolus albicostus Lamk.
Modiolus aratus (Reeve)
Modiolus auriculatus (Krauss)
Modiolus metcalfei (Hanley)
Modiolus philippinarum (Hanley)
Modiolus senhausi (Reeve)
Mytilus viridis (L.)
Septifer sp.
(Ostreidae)
Crassostrea spp.
(Pholadidae)
Martesia striata (L.)
(Teredinidae)
Bankia rochi Moll.
Teredo edax (Hedley)
Teredo mannii (Wright)
Teredo thoracites Gould
(Trapeziidae)
Trapezium sublaevigatum (Lamk.)
(Veneridae)
Anomalocardia squamosa (L.)
Dosinia rustica Romer
Gafrarium divaricatum (Gmelin)
Meratrix meratrix (L.)
Paphia hiantinus (Lamk.)
Paphia luzonica (Sowerby)
Veneridae gen. indet.

Cephalopoda

Cephalopoda spp. indet.

Gasteropoda

(Achatinidae)

Achatina fulica Bowdich
Subulina octona (Brug.)

(Ampullariidae)

Pila scutata (Mousson)

(Assiminaeidae)

Assiminaea brevicula Pteiff.
Assiminaea ?nitida
Assiminaea sp. 3 (flattened)
Assiminaea sp. 4

(Cerithiidae)

Cerithium patulum Sow.

(Elobiidae)

Auriculastra subula
Auriculastra s. 2
Cassidula aurisfelis (Brug.)
Cassidula faba (Mencke)
Cassidula mustelina (Desh.)
Cassidula quadrasi Hidalgo
Cylindrotis quadrasi (Moell.)
Ellobium aurisjudae (L.)
Ellobium aurismalchi (Muller)
Ellobium aurismidae (L.)
Laemodonta octanfracta (Jones)
Laemodonta punctigera (Adams)
Laemodonta typica (Adams)
Melampus singaporensis Pfeiff.
Pythia scarabaeus
Pythia trigona (Trosch.)

(Iravadiidae)

Fairbankia bombayana
Iravadia reticulata Brandt

(Hydrobiidae)

Clenchiella microscopica Nev.
Clenchiella sp. 2
Sencera sp.

(Littorinidae)

Littorina carinifera Mencke
Littorina melanostoma Gray
Littorina scabra (L.)
Littorina undulata Gray

(Marginellidae)

Marginella corusca Reeve

(Muricidae)

Chicoreus capucinus (Lamk.)

(Nassidae)

Nassarius olivaceus Brug.

(Neritidae)

Nerita birmanica Philippi
Nerita planospira Anton
Neritina violacea (Gmelin)

(Onchidiidae)

Onchidium aberrans Semper
Onchidium ambiguum Semper
Onchidium vaigiense Qu. & Gaym.

Peronia grisea (Plate)
Peronia tumida (Semper)
Peronina alta Plate
Platevindex lutea (Semper)
Platevindex stuxbergi (Waterh.)
Platevindex n. sp.
Semperoncis fossor n. gen. n. sp.

(Planorbidae)
Indoplanorbis exustus (Desh.)

(Potamididae)
Cerithidia alata Sow.
Cerithidia cingulata (Gmelin)
Cerithidia djadjariensis (Martin)
Cerithidia microptera (Kiener)
Cerithidia obtusa Lamk.
Cerithidia quadrata Sow.
Cerithidia sp. indet.
Telescopium telescopium (L.)
Terebralia sulcata (Born)

(Stenothyridae)
Stenothyra polita Gray
Stenothyra sp. 2
Stenothyra sp. 3
Stenothyra sp. 4

(Thiaridae)
Melanoides riqueti (Grat.)

(Vitrinellidae)
n. gen. nr. *Adeorbis*

NEMERTEA
Sp. indet. 1 (Gray)
Sp. indet. 2 (Stripes)
Sp. indet. 3 (red-brown)

PLATYHELMINTHES
Acoela spp. indet.
Polycladida
(Pseudoceridae) spp. indet.
(Stylochidae)
Limnostylochus borneensis Stum.
Fam. indet. sp. 1 (gray)
Fam. indet. sp. 2 (striped)

Rhabdocoelida
Catenulida spp. indet.
Gyratrix hermaphroditus
Macrostomum sp.

Porifera sp. indet.

PROTOZOA (Animal only, families not separated)
Ciliata
Kentrophorus sp.
Lacrymaria sp.
Loxodes sp.
Myelostoma sp.
Parablepharisma sp.
Plagiopyla sp.
Saprodinium sp.
Sonderia sp.
Tintinnopsis sp.

Mastigophora

Noctiluca miliaris Suriray

Sarcodina

Arcella sp.

Chaosidae indet. sp.

Difflugia sp.

Hartmanellidae spp.

Vahlkampfiidae spp.

(Forminiferida)

Ammonia sp.

Foram. sp. 2

Foram. sp. 3

Sipunculida

Phascolosoma lurco (Selenka & de Man)

Phascolosoma n. sp.

VERTEBRATA

Amphibia

(Bufonidae)

Bufo melanostictus Schneider

(Ranidae)

Rana cancrivora Gravenhorst

Aves

(Accipitridae)

Haliaeetus leucogaster

Haliaster indus

(Alcedinidae)

Alcedo atthis

Halcyon chloris

Halcyon coromanda

Pelargopsis capensis

(Anatidae)

Anas platyrhychos domesticus

(Ardeidae)

Butorides striata

(Chloropseidae)

Chloropsis sonnerati

(Columbidae)

Ducula aenea

Ducula bicolor

Ptilinopus jambu

(Cuculidae)

Cacomantis merulinus

(Muscicapidae)

Cyornis rufigastra

(Nectariniidae)

Nectarinia calcostetha

(Pachycephalidae)

Pachycephala cinerea

(Pandionidae)

Pandion haliaetus

(Picidae)

Dinopium javanense

Pictus vittatus

(Pittidae)

Pitta moluccensis

(Phasianidae)
  Gallus gallus domesticus
(Ploceidae)
  Passer montanus
(Pycnonotidae)
  Pycnonotus goiaver
  Pycnonotus plumosus
  Pycnonotus zeylandicus
(Rallidae)
  Amaurornis phaenicurus
(Scolopacidae)
  Tringa hypoleucos
(Strigidae)
  Ketupu ketupu
  Ninox scutulata
  Otus bakamoena
(Timaliidae)
  Trichastoma rostrata

MAMMALIA
(Canidae)
  Canis familiaris
(Cercopithecidae)
  Macaca fascicularis
(Felidae)
  Felis domesticus
(Hominidae)
  Homo sapiens
(Muridae)
  Rattus rattus diardii
(Pteropodidae)
  Macroglossus lagochilus
  Pteropus vampyrus
(Sciuridae)
  Callosciurus notatus
(Suidae)
  Sus scrofa

PISCES
(Antennariidae)
  Antennarius commersoni Cuv.
(Apogonidae)
  Apogon amboinensis Blkr.
  Apogon frenatus Val.
  Apogon hyalosoma Blkr.
  Apogon sangiensis Blkr.
(Ariidae)
  Arius gagorides (C. & V.)
  Arius macronotacanthus Blkr.
  Arius polystaphylodon Blkr.
  Arius thalassinus (Ruppel)
  Arius venosus C. & V.
  Ostiogeneiosus militaris (L.)
  Ariidae gen./sp. indet.
(Balistidae)
  Monacanthus chinensis (Bloch)
(Batrachoididae)
  Batrachus sp.

(Belonidae)
Tylosurus crocodilus (Les.)
Tylosurus strongylurus (van Hass.)
(Bothidae)
Pseudorhombus arsius (H. Buch.)
(Carangidae)
Alectis indica (Rupp.)
(Centropomidae)
Chanda commersoni C.& V.
Chanda gymnocephala (Lac.)
Chanda interrupta (Blkr.)
Chanda kopsii (Blkr.)
Chanda nalua (H. Buch.)
Chanda urotaenia Blkr.
Lates calcarifer (Bloch)
(Chaetodontidae)
Parachaetodon ocellatus (C. & V.)
Platax batavianus C. & V.
(Chirocentridae)
Chirocentrus dorab (Forsk.)
(Cichlidae)
Saurotherodon mossambica (Peters)
(Clupeidae)
Harengula fimbriata (C. & V.)
Harengula perforata (Cant.)
(Cyprinidae)
Oryzias javanicus (Blkr.)
Panchax panchax (Hamilton & Buchanan)
(Dorosomidae)
Dorosoma chacunda
(Eleotridae)
Bostrichthys sinensis (Lac.)
Butis butis (H. Buch.)
Butis melanostigma (Blkr.)
Eleotris fusca (Bloch & Schn.)
Eleotris insulindica (Blkr.)
Eleotris melanosoma Blkr.
Hypsoleotris modestus (Blkr.)
Ophiocara porocephala (C. & V.)
Oxyleotris marmoratus (Blkr.)
Oxyleotris urophthalmus (Blkr.)
Prionobutis koilomatodon (Blkr.)

(Engraulidae)
Stolephorus indicus (van Hass.)
Stolephorus tri (Bl.)

(Ephippidae)
Drepane punctata

(Gobiidae)
Acentrogobius caninus (C. & V.)
Acentrogobius caverensis (Blkr.)
Acentrogobius chlorostigmatoides (Blkr.)
Acentrogobius cyanomos (Blkr.)
Acentrogobius ? globiceps (Harm.) (as "kranjiensis" Herre)
Acentrogobius janthinopterus (Blkr.)
Acentrogobius ornatus (Ruppell)
Acentrogobius puntang (Blkr.)
Acentrogobius reichei (Blkr.)
Acentrogobius viridipunctata (C. & V.)

Acentrogobius sp. 1
Acentrogobius sp. 2
Acentrogobius sp. 3
Bathygobius fuscus (Ruppell)
Boleophthalmus boddarti (Pallas)
Brachygobius ? kabilensis
Brachygobius sua (Smith)
Brachygobius xanthomelas Herre
Ctenogobius sp.
Ctenotrypauchen microcephalus (Blkr.)
Glossogobius biocellatus (C. & V.)
Glossogobius giurus (H. Buch.)
Gobioterus chuno (H. Buch.)
Gobiopterus variegatus (Peters)
Oligolepis acutipennis (C. & V.)
Oxyurichthys microlepis (Blkr.)
Oxyurichthys papuensis (C. & V.)
Periophthalmodon schlosseri (Pallas)
Periophthalmus chrysospilos Blkr.
Periophthalmus malaccensis Eggert
Periophthalmus vulgaris ceylonensis Eggert
Pseudapocryptes lanceolatus (Bloch & Schn.)
Scartalaos viridis (H. Buch.)
Sicyopterus macrostetholepis (Blkr.)
Stigmatogobius borneensis (Blkr.)
Stigmatogobius hoevenii (Blkr.)
Stigmatogobius javanicus (Blkr.)
Stigmatogobius poicilostoma (Blkr.)
Stigmatogobius romeri (Weber)
Stigmatogobius sadanundio (H. Buch.)
Tamanka ubinensis Herre
Trypauchen vagina (Bloch & Schn.)
"Vaimosa" avicennia Herre
"Vaimosa" jurongensis Herre

Gobiidae indet. (Kranji sp. 7)
Gobiidae indet. (Kranji sp. 8)
Gobiidae indet. (Kranji sp. 13)

(Hemirhamphidae)
Dermogenys pusillus van. Hass.
Hemirhamphodon pogonognathus Blkr.
Hemirhamphus far (Forsk.)
Hemirhamphus gaimardi C. & V.
Hemirhamphus marginatus (Forsk.)
Zenorchopterus buffoni (C. & V.)
Zemorchopterus dispar (C. & V.)
Zemorchopterus ectuntio (H. Buch.)

(Labridae)
Halichoeres hyrtli (Blkr.)

(Leiognathidae)
Gazza minuta (Bloch)
Gerres abbreviatus Blkr.
Gerres oyenae (Forsk.)
Gerres punctatus C. & V.
Leiognathus brevirostris (C. & V.)
Leiognathus dussumieri (C. & V.)
Leiognathus equulus (Forsk.)
Leiognathus fasciatus Lac.
Leiognathus ruconius (H. Buch.)

(Lethrinidae)
Lethrinus nebulosus (Forsk.)

(Lutianidae)
Lutianus vitta (Q. & G.)
(Megalopidae)
Megalops cyprinoides (Brouss.)
(Mugilidae)
Mugil coeruleomaculatus Lac.
Mugil cunnesius C. & V.
Mugil dussumieri C. & V.
Mugil planiceps C. & V.
Mugil seheli Forsk.
Mugil tade Forsk.
Mugil troscheli Blkr.
Mugil vaigiensis Q. & G.
(Mullidae)
Upeneus sulphureus C. & V.
Upeneus tragula Richards
(Pahlostethidae)
Ceratostethus bicornis (Regan)
(Platycephalidae)
Platycephala indica (L.)
Platycephala scaber (L.)
Thysanophrys punctatus C. & V.
(Plotosidae)
Plotosus anguillaris (Bloch)
Plotosus canius (H. Buch.)

(Pomacentridae)
Abudefduf sp.
(Pomadascyidae)
Pomadascys maculatus (Bloch)
(Poecilidae)
Poecilia sphenops (Val.)
(Psettodidae)
Psettodes erumei (Bloch)

(Scatophagidae)
Scatophagus argus (Bloch)
(Sciaenidae)
Otolithes argenteus C. & V.
Sciaena dussumieri (C. & V.)
(Serranidae)
Epinephalus tauvina (Forsk.)
(Siganidae)
Siganus canaliculatus (Park.) Blkr.
(Sillaginidae)
Sillago sihama (Forsk.)
(Sphyraenidae)
Sphyraena jello C. & V.
(Syngnathidae)
Syngnathus djarong Blkr.
(Synodontidae)
Saurida tumbil (Bloch)

(Tetrodontidae)
Sphoeroides oblongus (Bloch)
Tetrodon fluviatilis H. Buch.

(Theraponidae)
Pelates quadrilineatus (Bloch)
(Toxotidae)
Toxotes chatareus (H. Buch.)
Toxotes jaculator (Pall.)

REPTILIA
(Boidae)
Python reticulatus (Schneid.)
(Colubridae)
Acrochordus granulatus (Schneid.)
Boiga cynodon (Boie)
Boiga dendrophila (Boie)
Cerberus rhynchops (Schneid.)
Chrysopelea chrysochlora
Fordonia leucobalia (Schleg.)

(Crocodilidae)
Crocodilus porosus
(Gekkonidae)
Lepidodactylus lugubris (D. & B.)
Gekkonidae indet.
(Scincidae)
Lygosoma atrocostatum (Lesson)
(Varanidae)
Varanus dumerili (Schlegel)
Varanus salvator (Laurenti)
(Viperidae)
Trimeresurus purpureomaculatus (Gray)
Trimeresurus wagleri (Boie)

ALGAE AND EUCHLORPHYTIC PHYTOPLANKTON
Bacillariophyceae (Diatoms)
(Biddulphiidae)
Biddulphia sp.
Ceratulina sp.
Ditylum sp.
(Chaetoceraceae)
Chaetoceros sp.
(Coscinodiscaceae)
Coscinodiscus asteromphalus Ehr.
Coscinodiscus concinnus Smith
Coscinodiscus gigas praetexta Jan.
Cosc. janischii arafurensis Grun.
Coscinodiscus jonesianus Ost.
Coscinodiscus oculo-iridis Ehr.
Coscinodiscus radiatus Ehr.
Coscinodiscus sp.
Hemidiscus hardmannianus
Planktoniella sp.

(Fragillariaceae)
Thalassiothrix frauenfeldi Grun.
Thalassiothrix nitzschioides Grun.
(Leptocylindraceae)
Leptocylindricus danicus Cleve
Guinardia flaccida (Cast.)
(Melosiraceae)
Melosira sp.

(Naviculaceae)
Navicula spp.
Pleurosigma spp.
(Ntizschiaceae)
Amphora sp.
Nitzschia closterium W. Sm.
Nitzschia seriata Cleve
(Rhizosoleniaceae)
Rhizosolenia sp.
(Skeletonemaceae)
Stephanopyxis sp.
(Surirellaceae)
Surirella sp.
(Tabellariaceae)
Licmophora ?abbreviata Agardh
(Thalassiosiraceae)
Lauderia borealis Gran.

Chlorophyta
(Capsosiphonaceae)
Capsosiphon fulvescens
(Caulerpaceae)
Caulerpa verticillata Agardh
(Cladophoraceae)
Cladophora nitida Kutz.
Lola gracilis (Kutz.)
Urospora sp.
(Halicystidaceae)
Derbesia fastigata Taylor
Genus indet.
(Pleurococcaceae)
Pleurococcus naegelii
(Ulvaceae)
Enteromorpha sp.
Ulva sp.

Chrysophyta
Dinoflagellida
Ceratium furca
Ceratium trichoceros
Ceratium sp. 3
Peridinium sp.

Rhodophyta
(Delesseriaceae)
Caloglossum leprieurii (Mont.) Ag.
(Rhabdionaceae)
Catenella impudica (Mont.) Ag.
(Rhodomelaceae)
Bostrichium moritziana (Sond.) Ag.
Laurencia cf. *microladia*
Gen./sp. indet.

Bryophyta
Hepaticae
?*Microlepidozia* sp.
Musci
?*Calymperiopsis* sp.
Fissidens crassinervis
Leucobryum sp.

Pteridophyta
Filicales (Ferns)
(Dennstaedtiaceae)
Acrostichum aureum L.
Acrostichum speciosum Willd.
Asplenium nidus L.
Elaphoglossum decurrens Desv.
Humata heterophylla (Sm.) Desv.
Humata parvula Wall.
Humata repens (L. fils) Diels.
Lindsaya borneensis Hk.
Nephrolepis acutifolia (Desv.) Chr.
Vittaria elongata Sw.
(Grammitidaceae)
Ctenopteris moultoni
Pityrogramma calomelanos (L.) Link.
(Hymenophyllaceae)
Hymenophyllum denticulatum Sw. (?misd.)
Hymenophyllum serrulatum (Presl.)
(Polypodiaceae)
Drymoglossum piloselloides (L.) Presl.
Phymatodes scolopendria (Burm.) Ch.
Polypodium microphyllum
Pyrrhosia angustata (Sw.) Ching
Pyrrhosia varia (Kaulf.) Far.
Selliguea heterocarpa Bl.

Lycopodiales
Lycopodium taxifolium Sw.
Selaginella willdenovii (Desv.) Bak.

Psilotales
Psilotum complanatum Sw.
Psilotum flaccidum Wall.

Spermatophyta
Dicoteledons
(Acanthaceae)
Acanthus flexicaulis
Acanthus ilicifolius
(Annonaceae)
Xylopia sp.
(Apocynaceae)
Cerbera manghas L.
Cerbera odollam Gaertn.
(Araliaceae)
Heptapleurum avenae Seem.
(Asclepiadaceae)
Dischidia benghalensis Colebr.
Dischidia collyris Wall.
Dischidia nummularia Bl.
Dischidia rafflesiana Wall.
Finlaysonia obovata Wall.
Hoya coronaria Bl.
Hoya obtusifolia
Sarcolobus globosus Wall.
(Bignoniaceae)
Dolichandrone rheedei Seem.
Boraginaceae)
Cordia mossambica

(Combretaceae)
Lumnitzera littorea (Jack.)
Lumnitzera racemosa Willd.
Terminalia catappa L.
(Euphorbiaceae)
Breynia reclinata
Excoecaria agallocha L.
Glochidion littorale Bl.
Sapium indicum Willd.
(Ficoidaceae)
Sesuvium portulacastrum L.
(Gesneraceae)
Aeschynanthus lobbiana Hk.
(Goodeniaceae)
Scaevola taccada Roxb.
(Guttiferae)
Garcinia bankana Miq.
(Lauraceae)
Cassytha filiformis L.
(Lecythidaceae)
Barringtonia conoidea (Griff.)
Barringtonia inclyta (Miers.)
(Leguminosae)
Caesalpinia nuga (L.) Ait.
Cynometra ramiflora L.
Dahlbergia torta Grah.
Derris heterophylla
Derris uliginosa Benth.
Derris trifoliata Lour.
Inocarpus fagiferus (Park.) Fosb.
Intsia ibjuga (Colebr.) O.K.
Pongamia pinnata (L.) Merr.
Pterocarpus indicus L.
Xylocarpus granatus
Xylocarpus moluccensis
(Malpighiaceae)
Tristellateia australasica Riel.
(Malvaceae)
Hibiscus tiliaceus L.
Thespesia populnea Corr.
(Melastomaceae)
Medinilla hasseltii Bl.
Medinillopsis sessiliflora Cogn.
Melastoma malabathricum
Ochthocharis borneensis Cog.
Ochthocharis javanica Bl.
Pogonanthera reflexa Bl.
(Meliaceae)
Carapa obovata Bl.
(Moraceae)
Ficus diversifolia Bl.
Ficus binnendyckii
(Myrsinaceae)
Aegiceras corniculatum (L.) Blanco
Ardisia humilis Vall.
Ardisia littoralis
Myrsine sp. (?esculenta Buch. Ham.)
(Myrtaceae)
Eugenia myrtifolia Roxb.

(Rhizophoraceae)
- Brugueira cylindrica (L.)
- Brugueira eriopetala
- Brugueira gymnorhiza (L.)
- Brugueira parviflora (Roxb.)
- Brugueira sexangula (Lour.)
- Ceriops decandra (Griff.)
- Ceriops tagal (Perr.)
- Pellacalyx sp.
- Rhizophora apiculata Bl.
- Rhizophora mucronata Poir. in Lamk.

(Rubiaceae)
- Canthium didymum Roxb.
- Randia sp.
- Scyphiphora hydrophyllacea Gaertn.
- Timonius finlaysonianus Wall.

(Rutaceae)
- Merope angulata (Willd.) Sw.

(Sapindaceae)
- Allophyllus cobbe (L.) Raeusche

(Sonneratiaceae)
- Sonneratia alba J. Sm.
- Sonneratia caseolaris (L.) Eng.
- Sonneratia ovata Backer

(Sterculiaceae)
- Heritiera fomes Buch. Ham.
- Heritiera littoralis Ait.

(Ternstroemiaceae)
- Adinandra miquelii King

(Tiliaceae)
- Brownlowia argentata Kurz
- Borwnlowia tersa (L.) Kosterm.

(Verbenaceae)
- Avicennia alba Bl.
- Avicennia lanata
- Avicennia marina (Forsk.) Vierh.
- Avicennia officinalis L.
- Clerodendron inerme

Gymnospermae

(Podocarpaceae)
- Podocarpus polystachyus

Monocotyledones

(Araceae)
- Cryptocoryne ciliata Fr.

(Cyperaceae)
- Cyperus malaccensis Lam.
- Fimbristylis ferrugineus Vall.
- Scirpodendron costatum King

(Flagellariaceae)
- Flagellaria indica L.

(Graminaceae)
- Paspalum distichum Burm.

(Orchidaceae)
- Adenoncos sumatrana
- Appendicula lucida Ridl.
- Bulbophyllum apodum Hk.f.
- Bulbophyllum avicella Ridl.
- Bulbophyllum blumei (Lindl.)

Bulbophyllum botryphora Ridl.
Bulbophyllum concinnum Hk.f.
Bulbophyllum ovalifolium
Bulbophyllum vermiculare Hk.f.
Dendrobium flavidulum Ridl.
Dendrobium gemellum Lindl.
Dendrobium pensile Ridley
Dendrobium salaccensis
Dendrobium spurium
Erium floribunda Lindl.
Erium obliqua Lindl.
Microsaccus javanensis Bl.
Phreatia minutaflora Lindl.
Polystachya flavescens
Rhenanthera histrionica Ridl.
Schoenorchis perpusillus Hk.f.
Taeniophyllum obtusum
Thelasis carinata

(Palmaceae)

Cyrtostachys lacca Becc.
Nypa fruticans Wurmb.
Oncosperma tigillaria

(Pandanaceae)

Pandanus odoratissimus L.

PUBLICATIONS OF THE
SOUTH CHINA SEA FISHERIES DEVELOPMENT AND COORDINATING PROGRAMME

WORKING PAPERS

SCS/74/WP/1	Rabanal, H.R. The potentials of aquaculture development in the Indo-Pacific Region. Manila, South China Sea Fisheries Programme, 1974. 34p.
SCS/74/WP/2	Crutchfield, J.A., D.A. Lawson and G.K. Moore. Malaysia - Legal and institutional aspects of fisheries development. Manila, South China Sea Fisheries Programme, 1974. 27p.
SCS/74/WP/3	Marr, J.C. Republic of Vietnam - Legal and institutional aspects of fisheries development. Manila, South China Sea Fisheries Programme, 1974. 20p.
SCS/74/WP/4	Larsson, S.O.R., G.C.A. Van Noort and E.O. Oswald. Malaysia - A report on artisanal fisheries of Peninsular Malaysia with particular reference to Kuala Besut. Manila, South China Sea Fisheries Programme, 1975. 58p.
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SCS/75/WP/6	Tussing, A.R. Fishery development perspectives. Sub-Region V: South China Sea. Manila, South China Sea Fisheries Programme, 1975. (IPFC/74/Sym/7). 23p.
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SCS/75/WP/8	Peterson, C.L., K.J. Rosenberg and A.C. Simpson. Regional - Trip reports of chartered purse seine vessels Royal Venture and Southward Ho covering voyages I and II. Dec. 1-13, 1974 and Jan. 5 - Feb. 3, 1975. Manila, South China Sea Fisheries Programme, 1975. 37p.
SCS/75/WP/9	Oswald, E.O. and R.E.K.D. Lee. Regional - A proposal for a live bait pole-and-line tuna fishing survey in the South China Sea and adjacent waters. Manila, South China Sea Fisheries Programme, 1975. 38p.
SCS/75/WP/10	Rosenberg, K.J. and A.C. Simpson. Regional - Trip reports of chartered purse seine vessels Royal Venture and Southward Ho covering voyage 3. 9 February to 26 March 1975. Manila, South China Sea Fisheries Programme, 1975. 28p.

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