Aquatic Ecosystem Health and Management Society

Taylor & Francis
Taylor & Francis Group

Sustainable utilization and management of Mangrove ecosystems of Malaysia

V. C. Chong

Institute of Biological Sciences, University of Malaya, 50603 Kuala Lumpur, Malaysia; E-mail: chong@um.edu.my

Mangrove ecosystems of Malaysia are found largely on the west coast of Peninsular Malaysia, the southern coast of Sarawak and the eastern coast of Sabah. Malaysian mangroves are largely of the river-dominated type built on large deltaic plains, but intergrades of river-dominated and tide-dominated settings, drowned valley settings and carbonate settings are also found. Mangrove resources are exploited by humans for coastal protection, forestry products, fisheries, wildlife, agriculture, aquaculture, settlement, urban and industrial development, and ecotourism. Very often this exploitation is unsustainable, particularly when mangroves are converted for agriculture, aquaculture, urban, and industrial development. The overall loss in mangrove area due to these reasons is about 111,046 hectares or 16 percent, from 1973–2000. In spite of an exemplary management plan implemented for the Matang mangrove forest reserve, mangrove forests in the various states are unequally managed because there are conflicting interests due to management policies that are largely sectoral in nature. While sustainable management policies and guidelines are in place, it is still crucial how the State governments, which have power over land matters, implement Federal policies regarding mangrove conservation.

Keywords: resource use and impacts, economic value, management issues, mangals

Introduction

Mangroves are trees, shrubs, palms or ferns found above mean sea level in the intertidal zone of coastal and estuarine environments (Duke, 1992). Most are associated with soft muddy sediments found in sheltered tropical coasts such as bays, estuaries and lagoons. Mangrove trees and their environment have also been collectively referred to as 'mangroves' or 'mangal'; used in this sense, the term thus refers to the mangrove habitat or ecosystem which includes all its physical, chemical and biological components. Mangrove ecosystems are unique quite unlike any terrestrial or aquatic ecosystems in that they straddle terrestrial, freshwater and marine environments. They are regularly inundated by tides, flushed by freshwater and are waterlogged most of the time.

Mangroves are the principal source of primary productivity in such areas providing food, as well as shelter and nursery areas for a variety of terrestrial and marine fauna. Surplus production from mangrove forests includes timber harvests used for poles and charcoal production, and a variety of materials for thatching, fishing, fodder, tanning leather and medicine. As physical structures, mangrove forests act as buffers against tropical storms and coastal erosion. Unfortunately, this valuable resource is under increasing pressure from overexploitation, development and pollution. Loss of mangrove area worldwide has been drastic. The loss of mangrove forests in Thailand, Philippines and Vietnam has exceeded 60% (Chong and Sasekumar, 2002). In Malaysia, although the overall loss amounts to about 16%, some states had lost as much as 30-70% of their original areas (Chan et al., 1993). In spite of its reknown Matang Mangrove Forest Reserve which has been sustainably managed as a production forest for more than a century, more is desired for Malaysia's remaining mangrove forest reserves to be utilized and managed on a

Aquatic Ecosystem Health & Management, 9(2):249–260, 2006. ISSN: 1463-4988 print / 1539-4077 online
DOI: 10.1080/14634980600717084

Table 1. Mangrove forest area and reserves in Malaysia; [a] = Tan and Basiron (2000); [b] = Chan et al. (1993); [c] = Ooi (1996).

Region	State	Total Length of Coastline (km)[c]	Gazetted Forest Reserve (ha)[a]	Stateland (ha)[a]	Total (ha)	Density (ha km^{-2})	Gazetted Reserves[b]
Peninsular	Perlis	20	0	20	20	1.0	0
Malaysia	Kedah	148	7,248	400	7,648	51.7	11
	Penang	152	451	500	951	6.3	1
	Perak	230	43,500	150	43,650	189.8	21
	Selangor	213	15,090	4,500	19,590	92.0	15
	Negri Sembilan	58	454	200	654	11.3	3
	Melaka	73	166	100	266	3.6	2
	Johor	492	17,832	6,500	24,332	49.5	10
	Pahang	271	2,675	2,000	4,675	17.3	11
	Terengganu	244	1,295	1,000	2,295	9.4	1
	Kelantan	71	0	100	100	1.4	0
East	Sarawak	1035	73,000	59,000	132,000	127.5	11
Malaysia	Sabah	1743	328,658	12,719	341,377	195.9	26
	Labuan	59	0	0	0	0.0	0
	Total	4,809	490,369	87,189	577,558	120.1	112

sustainable basis. This chapter focuses on the mangrove ecosystem of Malaysia, outlining its characteristics and resources, how the resources are utilized, and finally examining threats and management issues.

Mangrove distribution and settings

Malaysia's mangroves presently cover 577,558 ha, with 341,377 ha (59%) located in Sabah, 132,000 ha (23%) in Sarawak and 104,181 ha (18%) in the peninsular part of Malaysia (Tan and Basiron, 2000; Table 1). The mangrove forests of peninsular Malaysia are mainly located on its west coast facing the Malacca Straits, while mangrove forests on its east coast facing the South China Sea are small and mainly restricted to river mouths. In the state of Sabah, mangrove forests are largely found on its east coast facing the Sulu and Sulawesi Seas, while in Sarawak state they are largely found at the river mouths of the Sarawak, Rajang and Trusan-Lawas Rivers (Figure 1).

Mangroves in Malaysia are largely river-dominated mangroves (Thom, 1982) where luxuriant development is observed in major deltas such as the Merbok, Matang, Klang and Rajang deltas. Tides range from mesotidal

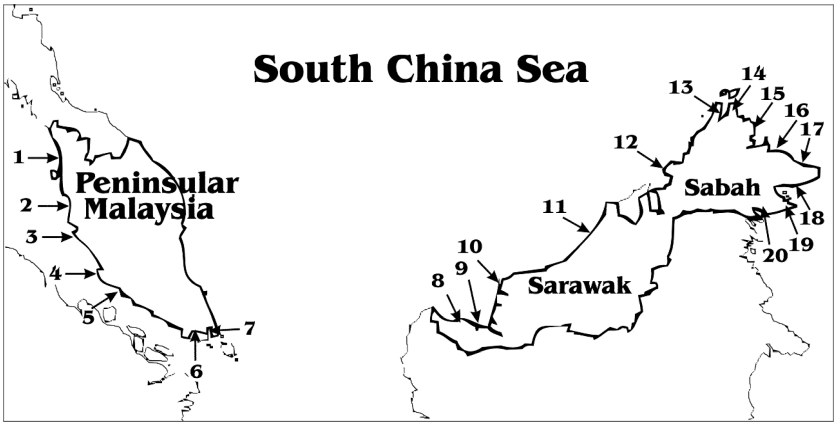

Figure 1. Map of Malaysia showing some of the major mangrove forest reserves in Peninsular Malaysia, Sarawak and Sabah. 1 = Merbok; 2 = Matang; 3 = Rungkup and Bernam; 4 = Klang; 5 = Sepang and Lukut; 6 = Pulai; 7 = Sungai Johor; 8 = Sungai Sarawak; 9 = Kampung Tian; 10 = Rajang; 11 = Kuala Sibuti; 12 = Menumbok; 13 = Kudat and Marudu Bay; 14 = Bengkoka; 15 = Sungai Sugut & Sungai Paitan; 16 = Trusan Kinabatangan; 17 = Kuala Segama and Kuala Maruap; 18 = Lahat Datu; 19 = Segarong and Semporna; 20 = Umas-Umas, Tawau and Batumapun.

Table 2. Area (ha) change and percentage lost/gain of mangrove forest reserves by state (from 1980–2000). No mangrove reserves in Perlis and Kelantan, except stateland mangrove forests. Sources, [a] = Chan et al. (1993); [b] = Tan and Basiron (2000).

Region	State	Forest Reserve			±%	Conservation area (ha)[a]
		1980[a]	1990[a]	2000[b]		
Peninsular	Perlis	0	0	0	0	
Malaysia	Kedah	9,037	8,034	7,248	−19.8	
	Penang	406	406	451	11.1	
	Perak	40,869	40,869	43,500	6.4	42
	Selangor	28,243	21,983	15,090	−46.6	320
	Negri Sembilan	1,352	1,061	454	−66.4	
	Melaka	77	314	166	115.6	
	Johor	25,619	16,697	17,831	−30.4	26
	Pahang	2,496	2,032	2,675	7.2	56
	Terengganu	2,982	954	1,295	−56.6	
	Kelantan	—	—	—	0.0	
East	Sarawak	44,491	36,992	73,000	64.1	385
Malaysia	Sabah	349,773	316,460	328,658	-6.0	4840
	Total	505,345	445,802	490,368	-3.0	5,669

(e.g., Matang) to macrotidal (e.g., Klang), with strong freshwater flow. The Matang mangrove forest reserve is built on deltaic sediments brought down from three river basins, and major portions of the reserve lie on seven deltaic islands separated by many distributaries or waterways. Similarly, major mangrove forests in Klang occur in eight major deltaic islands formed by sediments brought down by the Klang and Langat rivers. Large areas of mangroves fringing the coastal embayments of Sabah are of the drowned river valley type which provides sheltered environments within which mangrove forests develop on muddy substrates, for example in Marudu and Labuk Bays. The northeastern mangrove of Langkawi Island represents the carbonate setting type where terrestrial sediment supply is low and the mangrove trees grow on sandy peat substrates trapped amongst limestone karsts.

Watson (1928) recognised five major types of mangrove forest zones in peninsular Malaysia, based on the dominant species which form almost pure stands from the seafront into the hinterland: (i) the *Avicennia - Sonneratia* type (on pioneer shore), (ii) *Bruguiera cylindrica* type; (iii) *Bruguiera parviflora* type, (iv) *Rhizophora* type, and (v) *Bruguiera gymnorhiza* type (on landward margin).

Resource utilization and impacts

The loss of Malaysia's mangrove forest area from 1973 to 2000 has been estimated at 111,046 ha or 16% for Malaysia by Chong and Sasekumar (2002). But this figure is not reflective of changes in the various states which actually show substantial losses as well as gains (Table 2). States which show overall losses of their reserves during the last two decades include Kedah, Johor, Selangor and Negri Sembilan. Melaka and Sarawak have substantially increased their reserves recently.

Unsustainable human uses of mangrove and overexploitation of its natural resources are the chief reasons for the damage and loss of mangrove habitats.

Coastal erosion

Mangrove forests fringing the shoreline are used, usually not intentionally, as natural barriers against surge storms, protecting settlements located further inland. However, the ability of mangroves to protect shorelines is not infallible once the coastal mangrove belt is disturbed. As early as the 1950s until as late as the 1980s, earthen dykes were build by the Department of Irrigation and Drainage along the west coast of the peninsula to reclaim coastal mangroves so as to create more agricultural lands as well as to protect them from tidal inundation. A 200 metre width of mangrove belt was then considered sufficient to reduce wave energy, as was later confirmed by modeling work under the National Coastal Erosion Study carried out by the Economic Planning Unit in 1985 (EPU, 1985). The study indicates that mangroves attenuate waves by

obstructing them with roots and trunks as long as the trees are sufficiently close to each other and as tall as the incoming wave. Coastal erosion usually starts with the lowering of the mudflat in front of the *Avicennia* plants. The possible reasons are unclear but at Sungai Burung, there seems to be a 20-year cycle of accretion and erosion (Othman, 1992). *Avicennia* plants with surface roots easily topple down as erosion propagates towards the *Rhizophora* and *Bruguiera* zones. At these zones the rate eventually slows down since these species have deeper roots and the soil is more compact. When the next accretion cycle returns the *Avicennia* plants recolonize the mudflats. Thus, the multispecies mangrove forest acting as a system retards erosion. In spite of the 200-metre buffer zone and the predictions from hydrodynamic modeling, coastal erosion including the dyke still occurs because the reclamation has damaged the natural system by destroying the more inland *Rhizophora* and *Bruguiera* zones. The current guideline is a setback of 400 metres from the seaward edge of the mangrove to be left as a buffer zone (Ooi, 1996).

Erosion of mangrove-fringed river banks occur in several places where boat traffic is heavy, as by large fishing boats in Kuala Kedah, Merbok river, and Sangga Besar river, and by passenger ferries that ply the channel through Klang Island. In Kuala Kedah, this type of erosion has caused serious damage to settlement properties. In Tanjung Piai increasing shipping traffic in the Johor Straits, since the recent opening of the port of Tanjung Pelepas, has had a devastating effect on the coastal mangroves. The wave action by large ships and tankers undercuts the fringing *Rhizophora* trees which eventually topple down, and has eroded at least 15 m of the coastline over the period.

Agriculture

The expansion of the agricultural sector in the 1960s led to a rapid demand for land to plant cash crops in the coastal plains. The conversion of mangrove forest land to arable land as described above is viewed as one of the major alternatives. As a result, extensive tracts of coastal mangroves were cleared for planting rice, coconut, cocoa and oil palm during the last four decades. Mangrove forests converted in this manner saw the greatest loss in Kedah, Selangor and Sarawak during the early years. Selangor suffered the greatest loss where about 7,500 ha or 30% of its mangrove area had been excised, primarily for planting coconut and oil palm. Kedah had 1,500 ha of its Ban Merbok mangroves converted for rice planting, whereas Sarawak Mangrove Reserve lost 4,000 ha (Chan, 1987).

Aquaculture

Coastal pond culture is rapidly developing since the late 1970s due to stagnating fisheries catches, lucrative market demand for prawns, the success stories of overseas prawn farming, and government policy to promote it. The species commonly cultured are mainly tiger prawn (*Penaeus monodon*), white prawn (*P. merguiensis*), barramundi (*Lates calcarifer*) and mangrove snappers (*Lutjanus* spp.). The post-1980 period has seen a dramatic increase in prawn ponds at the expense of mangrove forests. Coastal pond areas in Malaysia were estimated to increase at the rate of 170 ha yr^{-1} from 1980 to 1995 (Chong, 1998). Total pond surface area for brackish-water farming is presently in the region of 8,826 ha (DOF, 2001). In Johor, some 3,500 ha of mangroves were used or alienated for aquaculture (Choo, 1996). Aquaculture is further invading former mangrove lands where rice farming had failed as in Kedah where some 100 ha were reconverted for tiger prawn farming. Unfortunately there has been no critical evaluation of the sustainability of pond culture resulting from mangrove conversion to justify further pond development. An analysis of brackish water pond production in relation to three other types of coastal aquaculture has shown that prawn pond productions are low (Table 3), indicating suboptimal utilization of space by pond culture as compared to, for instance, fish cage culture, and that it is only sustained by the high price of prawns (Chong, 1998). Despite government tax incentives and pioneer status given to prawn culture, production has fallen short of expectation, with many ponds either not producing or abandoned. At present the government has taken a very strong stand on the issue of converting new mangrove forests for aquaculture, and has passed a moratorium on such use. It is generally now accepted that from both economic and environmental points of view, there is no good reason for converting mangroves into aquaculture ponds.

Table 3. Productivity and economic values of four major brackish-water aquaculture systems from 1988–1995. Source, Chong (1998).

Culture System	Productivity (tones ha^{-1} yr^{-1})		Economic Value (RM ha^{-1} yr^{-1})
	Mean	Range	
Pond culture	2.1	1.43–2.82	41,036
Cage culture	86.86	70.60–103.63	1,280,403
Mussel culture	277.2	125.39–536.02	146,764
Cockle culture	11.77	6.48–21.10	4,620

Considered more compatible to the mangrove ecosystem, floating fish cage culture have presently become more important since the early 1990s. Fish cages increased by about 5,000 cages annually from 1982–1995 in Malaysia, where cage culture is carried out in sheltered bays and estuaries in Penang, Perak, Selangor, Johor and Sabah (Chong, 1998). Impacts on mangroves are variable but not severe in terms of water quality and eutrophication (Alongi et al., 2003; Wong, 2003).

Settlement and urban development

Increasing coastal populations and the demand for land have caused large areas of mangroves to be cleared or degraded. Traditional fishing villages, such as Kuala Perlis, Kuala Kedah, Kuala Sepetang and Kuala Selangor, many of which are built on cleared mangrove forests, are expanding rapidly. The port of Klang, built on former mangrove land, has grown to be the largest port in Malaysia, and with it is the increasing need for more space and port facilities. As a result, North Port was built from the excision of 255 ha of the coastal mangroves, and another 32 ha of the Pulau Lumut Mangrove Forest Reserve (PLMFR) similarly make way for the new West Port on the island of Lumut. Land reclamation for settlement and agriculture in late 1950s had earlier removed about 1,300 ha from this forest reserve, and with an additional loss of 2,300 ha for an industrial park on the island, the PLMFR of 4,349 ha is currently extirpated. In southeastern Penang some tens of hectares of mangroves make way for Penang's international airport and adjacent industrial estate. In Kuching, Sarawak, vast areas of mangroves are recently filled in for urban and other development uses.

Forestry

About 70% the mangroves which are gazetted as mangrove reserves are managed by state forestry departments for pole, firewood and charcoal production. These reserves are managed based on a rotation cycle of 20 to 30 years depending on the state. At the end of the cycle the mangrove trees are clear felled and allowed to regenerate. In Sarawak and Sabah vast areas of mangroves had been denuded by the wood chip industry. In Sarawak, a single wood chip plant consumed 15,000 ha of mangroves in 25 years, while in Sabah, two similar companies in their 15-year operation consumed 70,000 ha of mangroves in 15 years (Chan et al., 1993). These operations are now regarded as economically and ecologically unsound and have ceased.

Fisheries

Since mangroves function as nursery or habitat areas for largely small or juvenile fishes, commercial fisheries inside mangrove swamps are relatively unimportant, with the exception of crabs (*Scylla* spp.) and *Acetes* fishing which are small-scale operations. In the Johor River estuary, empang fishing for prawns and larger species of fish is destructive and encourages growth overfishing (Chong and Sasekumar, 2002). Empang is operated by staking a long fishing net with fine mesh size to surround an area of the river bank below the outer fringe of the mangrove forest. On the ebb run, prawns and fish coming out of the mangroves are caught in the net. The valuable catch are retrieved when the river bank is exposed while leaving behind thousands of young fish. Despite its destructiveness, empang fishing being a native fishing method is not banned.

Fish that nurture in mangroves are however mainly exploited off shore. Studies indicate that on the average 50% of the commercially exploited fish species in west peninsular Malaysia used mangrove habitats in some way (Jothy, 1984; Sasekumar et al., 1994), while more than 90% of the commercial prawn species used mangroves as nursery areas (Chong et al., 1990, 1994).

Ecotourism

Mangrove ecotourism in Malaysia is relatively under-developed. However, mangrove habitats offer a range of recreational activities that include nature photography, birdwatching, wildlife observation, nature education, recreational fishing and boating. The Kuala Selangor Nature Park in Selangor is a fine example of a nature-cum-recreational park where destructive activities are prohibited. The park had an annual visit of about 40,000 visitors in 1996 (Leong, 1999). Ecotourism is seen as one of the ways to win public support for conservation and sustainable utilization.

Pollution

Except for anecdotal records, there are few studies on pollution in Malaysian mangroves. Sementa and Kapar mangroves in Selangor were severely polluted by oil palm effluents in the 1970s. Die-backs of mangrove trees in the Sepang River estuary were observed in early 1990s due to point source outfalls from pig farms. Such organic pollution from agriculture, agro-industry

and manufacturing industries into rivers largely ceased when the EQA and its later amendments were introduced and enforced.

The Matang mangrove waters are assessed to be slightly polluted with a water quality index (WQI) of 60 to 80 by the Department of Environment (DOE, 1997). Pollution is attributed to nearby industrial parks where the main types of industries are textile factories, distilleries, leather tanning factories, rubber-based factories, food industries, electrical components industry, edible oil refineries, palm oil mills, rubber mills and piggeries (Lee, 1993). The river water quality indicated non-compliance of the interim WQ standards (Type I), for coliforms, total suspended solids, ammoniacal nitrogen, Cd, Hg, Pb and Cu in Sepetang River, Matang (Table 4). In human settlements on mangrove areas, such as the fishing villages of Pulau Ketam (Klang), Bagan Sangga Besar and Kuala Sepetang (Matang), where there is a poor system of garbage disposal, mangrove waterways serve as regular dumping sites for

Table 4. Marine water quality parameters recorded in Matang (Sungai Sepetang) and Dinding (Sungai Manjung) mangroves and Interim Standards for Marine Water Quality (Malaysia) (from Chong et al., 1999).

Water/ Sediment Parameters	Sg. Sepetang (Matang), DOE (1997), Kuala Sg. Sepetang		Sg. Manjung (Lumut), DOE, Kuala Sg. Manjung		Interim Standards for Marine Water Quality (Malaysia) (River water)#		
	Min.	Max.	Min	Max.	Type I	II	III
Physico-Chemical parameters							
Temperature (C)	28	31	30	32			
Salinity (‰)	7	22	23	25			
Dissolved oxygen (mg l^{-1})	2.4	3.2	4.4	6.3	(7)	(5–7)	(<3–5)
Ph	6.72	7.7	8.1	8.2	7.5–8.4	7.3–8.8	6.5–9.0
Nutrients and Organics							
Total Organic Carbon (mg l^{-1})	0.00	0.00	0.00	0.00			
Ammoniacal Nitrogen (mg l^{-1})	0.07	0.26	0.13	0.16	(0.1)	(0.3)	(0.9)
Nitrate Nitrogen (mg l^{-1})	−2.00	0.09	−2.00	0.04			
Total Nitrogen (mg l^{-1})	0.25	1.48	0.33	0.90			
Phosphate (mg l^{-1})	0.00	0.00	0.00	0.00			
Total Suspended Solids (mg l^{-1})	170.00	390.00	330.00	370.00	50	50	150
Oil & Grease (mg l^{-1})	−2.00	9.00	−2.00	7.50	(ND)	(7.00)	
Detergents (Mbas) (mg l^{-1})	0.00	0.00	0.00	0.00		(0.5)	(5.0)
Presumptive Coliform, 44° C(MPN/100ml)	0.00	2400.00	0.00	1609.00	(100)	(5000)	(50000)
Faecal Coliform (37° C)	0.00	50.00	0.00	0.00	(10)	(100-400)	(5000)
Heavy Metals							
Cadmium (mg l^{-1})	−0.200	0.010	−0.200	0.010	0.005	0.1	0.1
Chromium (mg l^{-1})	0.020	0.070	−0.200	0.070	0.1	0.5	0.5
Mercury (mg l^{-1})	−0.200	0.001	−0.200	0.001	0.0005	0.001	0.001
Lead (mg l^{-1})	−0.200	0.170	−0.200	0.180	0.05	0.1	0.1
Arsenic (mg l^{-1})	0.001	0.007	−0.200	0.006	0.05	0.1	0.1
Nickel (mg l^{-1})	−0.200	−0.200	−0.200	2.000	0.1		
Copper (mg l^{-1})	−0.200	0.020	−2.000	−0.200	0.01	0.1	0.1

Type I For the conservation of marine aquatic resources and safe utilisation by humans (includes salt field, food processing, desalination, fisheries and aquaculture and marine park (conservation area).

Type II For recreation.

Type III For industrial processing, harbour, port, oceanic exploitation and development.

Interim standards for river water quality.

ND = Not detectable.

'−2.00,' '−0.200' = not measured.

Table 5. Total economic value of mangrove ecosystems (83,259.1 ha) in west coast of Peninsular Malaysia. Values in terms of US$ (1995 prices). Extracted from MPP-EAS (1999).

Use Values	Gross Benefits	Net Benefits	Assumptions
Direct use			
Charcoal and Poles	28,641,130	8,592,339	$344/ha; 30% net return
Fish and prawns (push net only)	5,099,344	1,496,148	29.34% net return
Mud crabs	4,224,720	1,239,533	29.34% net return
Tourism	35,301,858	21,181,115	$424/ha; 60% net return
Subtotal	73,267,052	32,509,135	
Indirect use			
Nursery role (inshore and offshore fish and prawns)	343,220,013	67,717,309	19.73% net return
Carbon sequestration	150,698,971	150,698,971	$1,810/ha
Protection from erosion	207,659,742	207,659,742	$221,333.74/km; 938.22km
Subtotal	701,578,726	426,076,022	
Option value			
Biodiversity value	1,248,887	1,248,887	$15/ha
Non-use values			
Existence value	919,180,464	919,180,464	$11,040/ha
Total	$1,695,275,129	$1,379,014,508	

solid wastes including sewage. Matang waterways are believed to be polluted by herbicides and pesticides, which are used heavily in the surrounding rice fields and oil palm plantations. Silviculture operations in Matang use the herbicide Vespar® to kill *Acrostichum* ferns (Gan, 1995).

Economic value of mangroves

Table 5 outlines the economic valuation of the west coast Peninsular Malaysia's mangroves (83,259 ha; MPP-EAS, 1999). All non-market and net market values derived from mangrove products and services amounted to about US$1.38 billion for this mangrove formation. On a unit hectare basis, this amounts to US$16,563 annually.

Mangrove Management

Forestry legislation and policy

The National Forestry Policy of 1978 (revised, 1992), aims to ensure that forestry resources, including mangroves, are utilized sustainably and managed in an orderly manner. The specific objectives of the NFP are (1) to create sufficient forest areas as Permanent Forest Estates (PFE) that will ensure sound climatic and physical conditions, safeguard water supplies, soil fertility and environmental quality, and mitigate damage caused by floods and erosion (Protective Forests), a supply of forestry products in perpetuity for economic purposes (Productive Forests), and conservation of forest areas for recreation, education, research and biodiversity protection (Amenity Forests); (2) to manage the PFE with adoption of sound forest management practices so as to maximize the social, economic and environmental benefits; (3) to pursue a sound programme of development of the PFE through sustainable practices in order to achieve maximum productivity; (4) to ensure that other forest resources not in the PFE are efficiently utilized for local industry through wise planning in order that maximum benefits will be derived (from Chan et al., 1993).

Mangrove forests come under the jurisdiction of State Governments. Each state is empowered to enact their own forestry laws and to formulate forestry policies independently. The executive authority of the Federal Government only extends to the administration of matters relating to research and development, education and training, forestry-based industries development and provision of advice and technical assistance.

The National Forestry Council (NFC) serves as a forum for Federal and State authorities to discuss and resolve matters relating to forestry issues, administration and management. Because State Forest Enactments and Rules for respective states are varied, the

National Forestry Act was instituted to ensure that all States prepare and implement proper forestry management plans. In Sabah and Sarawak, forestry activities are regulated separately by several State enactments or ordinances, including protection of national parks and wildlife in the latter case. Sabah implements the objectives of the NFP. The NFP was revised in 1992 to improve federal and state levels coordination, increase awareness of biodiversity conservation and sustainable management, and seeks to create sufficient PFE to support rational land use. It also requires all the State Forestry Departments to reclassified the PFE into one or more of the following functional classes: (i) timber production forest under sustained yield, (ii) soil protection forest, (iii) soil reclamation forest, (iv) flood control forest, (v) water catchment forest, (vi) forest sanctuary for wildlife, (vii) virgin jungle reserved forest, (viii) amenity forest, (ix) education forest, (x) research forest, and (xi) forest for federal purposes.

Management of mangrove and its resources is also covered under other legislations which include the Land Conservation Act, National Land Code, Wildlife Act, Environmental Quality Act, National Park Act, Wood-based Industries Enactment, and Fisheries Act. Malaysia as a producing member country of the International Tropical Timber Organization (ITTO) is fully committed to achieve sustainable forest management in the overall context of sustainable development. Recently endorsed or proposed policies which have a regulatory nature on mangrove utilization and management, include the National Biodiversity Policy, National Environmental Policy, National Wetland Policy (in preparation; Ministry of Science, Technology and Environment; MOSTE, 1997), and Integrated Coastal Zone Management Policy (in preparation; Economic Planning Unit, EPU). Malaysia is signatory to a number of international agreements and conventions related to mangrove biodiversity, sustainable development and conservation. These include ratification of the United Nations Convention on the Law of the Sea in 1982, Rio Declaration on Environment and Development in 1992, Convention of Biodiversity in 1994, the Ramsar Convention on Wetlands in 1994, International Tropical Timber Agreement (ITTA) in 1995, the ASEAN Agreement on Conservation of Natural Resources in 1995 and the Convention on International Trade in Endangered Species (CITES) in 1997. Malaysia adopted the ITTO's Guidelines for the Sustainable Management of Natural Tropical Forests in 1994 and ITTO's Criteria for the Measurement of Sustainable Tropical Forest Management in 1998.

Management practices

The best managed mangrove forests on a sustainable basis occurred in the Matang Mangrove Forest Reserve of the state of Perak. It has been systematically managed on a sustained basis for fuelwood and poles since 1908. Since then no more than 3% of the original areas has been lost; in fact recent assessment indicates gains of about 1,500 ha of forests due to accretion (Gan, 1995). The silviculture system was initially based on a rotation age varying from 20 to 40 years, with a fixed number of seed trees maintained in the logged-over areas for regeneration. Since 1950 this system was changed to a fixed rotation age of 30 years at the end of which all trees were cleared cut without retention of seed plants. Ten-year working plans prepared by Noakes (1952), Dixon (1959), Mohamed Darus (1969), Haron (1981), Gan (1995) and Azahar Muda (2003) then followed successively. Retention of seed plants was however reintroduced after the first rotation cycle in 1979, but the method was again dropped after 1990 and clear felling was reintroduced. Matang's Working Plan for mangrove utilization and management has the main objective to maximize production of greenwood for pole and charcoal wood production both for sustained local consumption and export. In maintaining the mangrove forests for this purpose the plan also has the objectives to protect the shoreline from erosion; to protect and conserve the forests as functioning nursery areas and wildlife habitats; to provide forest areas for conservation, research, education and training; and to promote sustainable ecotourism.

In the state of Selangor, mangroves in the Klang Islands are managed solely for economic profits from the production of piling poles, charcoal, woodchips and fishing stakes, and for this reason *Rhizophora apiculata* and *R. mucronata* forests are preferred for regeneration (Soo, 1979). There is no proper working plan as for the Matang mangroves, but since 1957 the rotation based on a clear-felling system has been fixed at 25 years when most of the *Rhizophora* stems achieve a diameter of 5 to 6 inches. The system does not practice intermediate thinnings and enumeration of stand volume of wood, but there is replanting of blank areas with *Rhizophora* seedlings usually 2 years after felling. Wood production was low.

The state of Sarawak also has an interesting history of mangrove management that dates back to 1915 when the Sarawak Forest Department was first established and three large tracts of mangrove forests were reserved in the First, Fifth and Sixth Divisions (Chai and Lai, 1984). Mangroves were then also managed

for firewood, charcoal and poles, including tannin and nipah sugar production for domestic consumption. Ten-year working plans based on a 15 year (for charcoal) and 20 year (firewood) cycles were only established since 1953, with the main objectives of orderly exploit and produce mangrove timber to satisfy local demand as well as export, and to ensure regeneration (natural and artificial) and conservation. From 1969 woodchip demand for the pulp and rayon industries in Japan caused large scale exploitation that reached 300,000 tonnes or 20% of the total production in 1976, while demand for fuel wood decreased and licenses to produce it instead converted to woodchip production (Chai and Lai, 1984).

As far as mangrove management in the state of Sabah is concerned, there was no working plan of any sort, past or present. Timber exploitation for charcoal and firewood and its management appears to be ad hoc with the result that excessive logging and woodcutting had occurred in some forest reserves in the past and which were considered worse off than unmanaged stateland forests (Phillips, 1984). The state's woodchip industry consumed an estimated 70,000 ha of mangroves over 15 years since 1970 (Chan et al., 1993). Despite an ill-defined management system, Sabah has the highest number of gazetted conservation areas with a total area of 4,840 ha.

Management problems and issues

There are a total of 112 mangrove forest reserves, of which 75 are located in peninsular Malaysia, 26 in Sabah and 11 in Sarawak (Chan et al., 1993). Recent gazettement of mangrove forests includes the Tanjung Piai mangroves (526 ha) as part of the recently declared Tanjung Piai National Park in Johor, but degazettement includes reserves in Langkawi as well as the Pendas River mangroves in Johor. Stateland forests occur outside forest reserves and are not managed for sustained timber production. These forests are subject to pressures of alienation and conversion for development purposes.

Competing jurisdictions

Few State governments readily give up valuable state lands for conservation purposes without economic returns or revenue that are needed for state development. Indeed, faced with pressures to develop, States often alienate mangrove forest lands, including reserves, for developmental purposes. For instance, degazettement of PFE in Peninsular Malaysia, has seen losses of about 17% from 1980 to 1990, and 4% from 1990 to 2000 (see Table 2).

Currently, there are 11 gazetted conservation forests or protected mangroves covering 5,670 ha and constituting only about 1% of Malaysia's mangroves. The total conserved mangrove area in Malaysia is much less than the area of 30,000 ha proposed by Ong and Gong (1991) for the benefits of posterity. A minimum self-sustaining area for each conserved area is necessary to preserve genetic material and it should have a surrounding buffer zone against encroachment (Ong, 1995).

Partial or inadequate jurisdiction

Although the socioeconomic benefits gained by coastal communities through sustained forestry production are substantial, these direct benefits are in fact much lower in comparison to the indirect benefits provided by fisheries (Salleh and Chan, 1987; MPP-EAS, 1999). Fisheries management is under the purview of the Department of Fisheries but neither agency is responsible for the health of the swamp's waters since management and enforcement of water quality standards is under the Department of Environment. Thus, the sectoral division of management responsibilities for the various components of the mangrove ecosystem is often more an obstacle to effective management of the mangrove ecosystem.

Aquaculture development

The New Agriculture Policy (1991–2010; NAP) targets further expansion of the aquaculture sector for the future. To achieve the goals of the policy, the Fisheries Department has formulated the Aquaculture Development Action Plan (ADAP) which identifies the major thrust areas for expansion: cage culture, shrimp farming in former agricultural land and recirculation or raceway systems. Suitable aquaculture development areas (ADA) are identified, zoned or demarcated, and presented to state authorities for land alienation. Although the Fisheries Department has identified some 20,000 ha of aquaculture development areas, mostly former mangrove land that cannot be gainfully farmed, there has been resistance from farm owners to part with their land in Kerpan, Kedah. If such lands remain unavailable, new land including mangroves may have to be alienated. In Malaysia, the ADAP provides only the guidelines for sustainable aquaculture development, and in matters concerning land use these cannot be enforced. Hence, state legislative measures appear necessary to promote best management practices.

Viewed as environmentally friendly, fish cage culture is expected to expand markedly. Hindrance to this expansion could be the availability of suitable sheltered sites of reasonable water quality.

With respect to mangrove clearing for aquaculture, an important regulatory and legal instrument is environmental impact assessment (EIA, 1997), a set of criteria for evaluating various environmental impacts. Mangrove clearing of more than 50 ha requires an EIA under the Environmental Quality Act. In spite of this, as Choo (1996) pointed out, there are legal loop-holes as ponds could still be dug in stages to avoid contravening the act.

Biodiversity and productivity

The selective silviculture of more valuable mangrove species (e.g., *Rhizophora apiculata*) in production forests leads to almost monospecific forest stands. The loss of biodiversity as a result of the management regime as applied to Matang forests for 90 years may have decreased mangrove productivity (Gong and Ong, 1995), although this is not clearly established (Gan, 1995).

Matured forests have been observed to support more birds (Siti Hawa et al., 1995) and small mammals (Yoneda et al., 1997), as compared to regenerating forests which are more open. The unexploited dryland mangroves and mangroves by the riverbanks are frequented by relatively more species of birds and mammals.

Sustainable forestry management in Malaysia

Following the rapid emergence of the aquaculture sector particularly during the 1980s, the Department of Fisheries requested the now defunct Malaysian National Mangrove Committee (NATMANCOM) to provide a set of management guidelines for brackishwater aquaculture in mangrove areas. These guidelines are presently used as criteria for EIAs, but they are not strictly followed (Choo, 1996). For instance, the 'graded' selection order for pond sites does not prevent mangrove reserves from being degazetted and becoming stateland forests.

The Coastal Resources Management Project (CRMP), funded by USAID for a coastal resources management plan specifically for south Johor, addressed the problems of sectoral jurisdictions over coastal resources. It is the first pilot study towards adoption of an integrated multisectoral approach in Malaysia. The CRMP provided a comprehensive set of recommendations pertaining to mangrove land usage. The study advocated no more conversion of mangrove forest reserves and that further development of aquaculture and agriculture should cease in existing mangrove areas. Instead, non-conversional aquaculture should be encouraged such as cage and raft cultures in mangrove waterways. Also, forestry working plans should be developed for the existing mangrove forest reserves in Johor, while mangroves fronting coastal bunds and erosion-prone areas should be gazetted as protective forest reserves.

The CRMP was followed up by the development of a comprehensive 10-year integrated management plan (2000–2009) for the Johor mangroves, following a two-year study from 1997–1999 by the Forestry Department and the Danish Cooperation for Environment and Development (DANCED). The study identifies 19 key mangrove areas totalling 26,912 ha in Johor. Agricultural development is viewed as the main threat to the Johor's west coast mangroves. The southern coast mangroves are sheltered mangroves and are under substantial pressure from large-scale development projects, including those for new harbours, marinas, resorts and a power plant. On the east coast, mangrove forests are small and isolated but are threatened by agricultural and urban reclamation. The plan proposes three management categories:

(i) Biodiversity conservation and nature tourism—large mangrove areas for biodiversity conservation and with potential for nature tourism. These areas could be legally designated national or state parks. The number of mangrove forests proposed in this category is 3, covering 2,389 ha (9%).
(ii) Sustainable Use Forestry—relatively large areas managed for commercial production of forestry products as well as for conservation purposes; such activities are also compatible with tourism, recreation and fisheries. Certain pockets of old growth forests within the area should be set aside as permanently protected biodiversity reservoirs, for example, as nesting sites for large birds, and as temporary refuges for animals during the logging process. This category comprises of existing Forest Reserves. The number of forests proposed is 4, covering 16,933 ha (63%).
(iii) Protection Forests—which include the remaining mangroves to serve some of the following functions: biodiversity conservation, fisheries, shoreline protection, recreation, nature education and urban green spaces. Some of these areas could

serve as sanctuaries in urban environments. The bulk of such diverse sites, and present Stateland Forests, would be legally classified as Forest Reserves for protection. Twelve forests are proposed with a total area of 7,590 ha (28%).

The management plan advocates avoidance of the use of mangroves for agriculture, aquaculture and urban development, but recognizes that if in certain situations a project cannot be relocated, then pockets of mangroves should be preserved inside the reclaimed areas. To satisfy the basic local community needs, specific Community Forests could be created from the above categories, to cater for the needs of the local community.

Recognizing the need for conserving mangrove forest ecosystems worldwide in view of their importance, the World Bank recently commissioned the formulation of a global, voluntary Code of Conduct for Sustainable Management of Mangrove Forest Ecosystems, with the objectives to arrest the recent and rapid destruction of coastal mangroves, to improve their management, and to conserve their biodiversity (Macintosh and Ashton, 2002). The Code identifies key linkages and coordination needs among government departments, NGOs, local communities and other stakeholders, and recommends key legislation and enforcement mechanisms required for sustainable mangrove uses and management. The Code is intended as a general guide or support for States since it is recognized that each has its own issues and priorities, and may already have in place conservation programmes. The Code also recognizes that the objectives and their implementation could only be achieved through capacity building especially in areas of financial and technical assistance, technology transfer, training and scientific cooperation. The Code provides guidance on the improvement of legal and institutional frameworks for sustainable management, and the promotion of food security, sustainable livelihoods of depending coastal communities, trade of mangrove products in conformity with local and international rules, and research on mangrove genetics, biodiversity and environment.

In conclusion, because the mangrove ecosystem is inextricably linked to elements of both land and sea, holistic, integrated coastal zone management is necessary in order to resolve multiple use conflicts. However, granted the long entrenched sectoral governance of resources and the environment, it will take sheer political will to effect a paradigm shift in the management of Malaysia's coastal resources within the context of such a management plan.

References

Alongi, D. M., Chong, V. C., Dixon, P., Sasekumar, A., Tirendi, F., 2003. The influence of fish cage aquaculture on pelagic carbon flow and water chemistry in tidally dominated mangrove estuaries of peninsular Malaysia. Mar. Environm. Res. 55, 313–333.

Azahar Muda Nik Mohd. Shah Nik Mustafa, 2003. A Working Plan for the Matang Mangrove Forest Reserve, Perak: the third 10-year period (2000-2009) of the second rotation (Fifth Revision). State Forestry Department, Perak.

Chai, P. P. K., Lai, K. K., 1984. Management and utilization of mangrove forests in Sarakwak. pp. 785–795. In: E. Soepadmo, A. N. Rao, D. J. Macintosh (Eds.), Proceedings of the UNESCO Asian Symposium on Mangrove Environment—Research and Management, University of Malaya, Kuala Lumpur, Malaysia.

Chan, H. T., 1987. Status Report: Malaysia, In: R. M. Umali (Ed.), Mangroves of Asia and the Pacific: Status and Management, Technical Report of the UNDP/UNESCO Research on Training Pilot Programme on Mangrove Ecosystems in Asia and the Pacific, Philippines.

Chan, H. T., Ong, J. E., Gong, W. K., Sasekumar, A., 1993. Socio-economic, ecological and environmental values of mangrove ecosystems in Malaysia and their present state of conservation. In: B. F. Clough (Ed.), *The Economic and Environmental Values of Mangrove Forests and their Present State of Conservation in the South-East /Pacific Region*, pp. 41–82. Japan International Association for Mangroves, Okinawa, Japan.

Chong, V. C., 1998. Coastal aquaculture development in Malaysia and its environmental impacts, pp. 1–17. Workshop on Aquaculture and its Environmental Problems in the Southeast Asian Countries: 1998 March 27–28: Japan International Research Center for Agricultural Sciences, Tsukuba.

Chong, V. C., Sasekumar, A., 2002. Coastal habitats (mangroves, coral reefs and seagrass beds) of the ASEAN region: Status, utilization and management issues. Fish. Sci. 68(1), 566–571.

Chong, V. C., Sasekumar, A., 2002. Fish communities and fisheries of Sungai Johor and Sungai Pulai Estuaries (Johor, Malaysia). Malay. Nat. J. 56(3), 279–302.

Chong, V. C., Sasekumar, A., Lim, K. H., 1994. Distribution and abundance of prawns in a Malaysian mangrove system. pp. 437–445. In: S. Sudara, C. R. Wilkinson, L. M. Chou (Eds.), Proceedings, Third-ASEAN-Australia Symposium on Living Coastal Resources, Vol. 2 Research Papers. 1994 May 16–20: Chulalongkorn University, Bangkok, Thailand.

Chong, V. C., Sasekumar, A., Leh, M. U. C., D'Cruz, R., 1990. The fish and prawn communities of a Malaysian coastal mangrove system, with comparisons to adjacent mud flats and inshore waters. Estuar. Coast. Shelf Sci. 31, 703–722.

Chong, V. C., Sasekumar, A., Low, C. B., Muhammad Ali, S. H., 1999. Physico-chemical environment of the Matang and Dinding Mangroves (Malaysia). pp. 115–121. In: K. Kiso, P. S. Choo (Eds.), Fourth JIRCAS Seminar on Productivity and Sustainable Utilization of Brackish Water Mangrove Ecosystems. 1998 December 8–9: Penang, Malaysia: Japan International Research Center for Agricultural Sciences, Japan.

Choo, P. S., 1996. Aquaculture development in the mangrove. In: M. Suzuki, S. Hayase and S. Kawahara (Eds.), Sustainable Utilization of Coastal Ecosystems. Proceedings of the Seminar on Sustainable Utilization of Coastal Ecosystems for Agriculture, Forestry and Fisheries in Developing Regions, pp. 63–72.

JIRCAS Working Report No. 4: Japan International Research Center for Agricultural Sciences, Tsukuba.

Dixon, R. G., 1959. *A Working Plan for the Matang Mangrove Forest Reserve, Perak (First Revision 1959)*. Forest Department, Perak, Malaysia.

Duke, N. C., 1992. Mangrove floristics and biogeography. In: A.I. Robertson and D.M. Alongi (Eds.), *Tropical Mangrove Ecosystems*, Coastal and Estuarine Studies 4, pp. 63–100. American Geophysical Union, Washington.

DOE (Department of Environment), 1997. Malaysian Environmental Quality Report 1997. Department of Environment, Ministry of Science, Technology and Environment, Malaysia.

DOF (Department of Fisheries), 2001. *Annual Fisheries Statistics 2001, Vol. 1*. DOF, Malaysia.

EIA (Environmental Impact Assessment), 1997. Detailed EIA Lekir Coastal Development (Land Reclamation and Deep Water Terminal) at Manjung District, Perak Darul Ridzuan. Desa Kilat Pte. Ltd. and Perunding Utama Pte. Ltd. Malaysia.

EPU, 1985. National Coastal Erosion Study: Phase 1. Report submitted by Stanley Consultants, Inc., Jurutera Konsultant (SEA) Pte. Ltd. and Moffatt and Nichol, Engineers to the Government of Malaysia: Economic Planning Unit, Malaysia.

Gan, B. K., 1995. *A Working Plan For The Matang Mangrove Forest Reserve, Perak (Fourth Revision)*. State Forestry Department of Perak, Malaysia.

Gong, W. K., Ong, J. E., 1995. The use of demographic studies in mangrove silviculture. Hydrobiologia 295, 255–261.

Haron, H. A., 1981. *A Working Plan for the Second 30-year Rotation of the Matang Mangrove Forest Reserve, Perak. The First 10-year Period, 1980–1989.* State Forestry Department, Perak, Malaysia.

Jothy, A. A., 1984. Capture fisheries and the mangrove ecosystem. In: J. E. Ong and W. K. Gong (Eds.), *Productivity of the Mangrove Ecosystem: Management Implications*, pp. 121–128. Science University of Malaysia, Penang.

Lee, H. K., 1993. Environmental management of the Sepetang River Basin. pp. 1–14. In: A. Sasekumar (Ed.), Proceedings of a Workshop on Mangrove Fisheries and Connections. 1991 August 26–30: Technical Committee on ASEAN-Australia Marine Science Programme on Living Coastal Resources, Kuala Lumpur.

Leong, L. F., 1999. Economic Valuation of the Mangrove Forest in Kuala Selangor, Malaysia. M.Tech. (Environmental Management) thesis, Institute of Postgraduate Studies, University of Malaya, Kuala Lumpur.

Mohamed Darus, H. M., 1969. *Rancangan Kerja Bagi Hutan Simpanan Paya Laut Matang Perak (Pindaan Yang Kedua 1969),* State Forestry Department, Perak, Malaysia (in Malay).

MOSTE Ministry of Science, Technology and the Environment, 1997. *Assessment of Biological Diversity in Malaysia.* MOSTE, Malaysia.

MPP-EAS, 1999. Total Economic Valuation: Coastal and Marine Resources in the Straits of Malacca. MPP-EAS Technical Report No.24, GEF/UNDP/IMO, Philippines.

Noakes, D. S. P., 1952. *A working plan for the Matang Mangrove Forest Reserve, Perak*. Forestry Department, Federation of Malaya.

Ong, J. E., 1995. The ecology of mangrove conservation and management. Hydrobiologia 295, 343–352.

Ong, J. E., Gong, W. K., 1991. Mangroves. In: R. Kiew (Ed.), *The State of Nature Conservation in Malaysia*, pp. 22–28. Malayan Nature Society, Kuala Lumpur.

Ooi, C. A., 1996. Coastal erosion management in Malaysia. pp. 1–12. In: A. Sasekumar (Ed.), Proceedings of the 13th Annual Seminar: Impact of Development and Pollution on the Coastal Zone in Malaysia 1996 October 26.: Malaysian Society of Marine Sciences, Petaling Jaya, Malaysia.

Othman, M. A., 1992. Value of mangroves in coastal protection. Hydrobiologia 285, 277–282.

Phillips, C., 1984. Current status of mangrove exploitation, management and conservation in Sabah. pp. 809–820. In: E. Soepadmo, A. N. Rao, D. J. Macintosh (Eds.), Proceedings of the UNESCO Asian Symposium on Mangrove Environment—Research and Management, 1997 July 30–31.: University of Malaya, Kuala Lumpur, Malaysia.

Salleh, M. N., Chan, H. T., 1987. Sustained yield forest management of the Matang mangrove. In: R. M. Umali (Ed.), Mangroves of Asia and the Pacific: Status and management. Technical Report of the UNDP/UNESCO Research on Training Pilot Programme on Mangrove Ecosystems in Asia and the Pacific, Philippines.

Sasekumar, A., Chong, V. C., Lim, K. H., Singh, H. R., 1994. The fish community of Matang mangrove waters. pp. 457–464. In: S. Sudara, C. R. Wilkinson, L. M. Chou (Eds.), Proceedings, Third-ASEAN-Australia Symposium on Living Coastal Resources, Vol. 2: Research Papers, Research Papers 1994 May 16–20.: Chulalongkorn University, Bangkok, Thailand.

Siti Hawa, Y., Azman, B. S., Burhanuddin, M. N., 1995. Field study on bird population in the Matang mangrove forest reserve, In: *Reseach on Conservation of Wetland Biodiversity in Tropical Asia*, pp. 74–88. Department of Wildlife and National Parks, Malaysia, and Japan Wildlife Research Center.

Soo, N. P., 1979. Management and harvesting of Klang Mangrove Forests. pp. 85–91. In: P. B. L. Srivastawa, A. Manap Ahmad, G. Dhanarajan, I. Hamzah (Eds.), Symposium on Mangrove and Estuarine Vegetation in Southeast Asia. 1978 April 25–28.: Biotrop Special Publication No. 10., Bogor, Indonesia.

Tan, K. H., Basiron, N. M., 2000. Conservation, development and management of mangrove resources in Malaysia: Issues, challenges and opportunities. Paper presented at the International Symposium on Protection and Management of Coastal Marine Ecosystems, 2000 December 12–13, Bangkok, Thailand: UNEP/EAS EMECS.

Thom, B. G., 1982. Mangrove ecology: a geomorphological perspective. In: B. F. Clough (Ed), *Mangrove ecosystems in Australia, structure, function and management*, pp. 3–17. ANU Press, Canberra.

Watson, J. G., 1928. Mangrove Forests of the Malay Peninsula. Malayan Forest Records No. 6, Singapore, China.

Wong, S. C., 2003. Effects of Fish Cage Culture on the Water Quality of the Matang Mangrove Estuaries, Peninsular Malaysia. M.Tech thesis, Institute of Postgraduate Studies, University of Malaya, Kuala Lumpur.

Yoneda, M., Sukigara, S., Burhanuddin, M. N., Azmin, M. R., Norizan, A., 1997. The status of mammals in the Matang mangrove forest reserve, In: *Reseach on Conservation of Wetland Biodiversity in Tropical Asia.* pp. 49–68. Department of Wildlife and National Parks, Malaysia, and Japan Wildlife Research Center.