Mangrove Ecosystem of Malaysia: Status, Challenges and Management Strategies

A. Latiff and I. Faridah-Hanum

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A. Latiff (✉)
Faculty of Science and Technology, Universiti Kebangsaan Malaysia,
43600 Banji, Selangor, Malaysia
e-mail: latiff@ukm.my

I. Faridah-Hanum
Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

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Abstract Unlike other types of forests which are more spatially widespread and can be found on varied soil types, the mangrove swamp forests are restricted to sheltered coasts, islands, lagoons, estuaries and rivers on muddy substrates. As an ecosystem it is an important habitat for diverse wildlife, including fishes, shells and microbes and a number of specialized plant forms. It is also of great socio-economic importance as a hydrological regulator, playing an important role in flood mitigation, buffering against saline intrusion and waves. It is also an important source for fuelwood, timber resources and provides a variety of produce used by local inhabitants. Despite these values, mangrove swamp forests are rapidly being cleared, degraded and transformed to other land-uses, especially for agriculture, aquaculture, resettlement, industrial and ecotourism infrastructures. In view of the recognized values, it is urgent that more suitable areas are protected for not only the biodiversity conservation purposes but also as a special and unique forest type. In Malaysia, a working plan for the Matang mangrove forest reserve, Perak (fifth revision) provides a comprehensive overview of the management and conservation of the mangrove ecosystem in Malaysia, which could also be a model for other mangrove areas in other states for their protection and management. In the long term, systematic and holistic planning represent the best means of achieving sustainable mangrove swamp forest management by incorporating conservation principles and forestry objectives.

1 Introduction

In Malaysia, the mangrove ecosystem has been an important resource for the coastal, estuarine and to a certain extent, the riverine communities. These communities have either been living within the mangrove swamp forests or at the fringes of inland mangroves and have been depending on it for their livelihood and socio-economic well-being(Lugo and Snedaker 1974). The mangrove swamp's aquatic resources have been important sources of fishes, shells and other gastropods for the fishermen, and the forests have been providing fuelwood, poles and other building materials for the local communities. In particular, all parts of *nipah* palms (*Nypa fruticans*) have been providing products to those communities all over the country (Latiff 2009). According to Chan (1987), such social-economic forestries and fisheries have been coexisting harmoniously for generations and have minimal impact on the ecosystem. However, with the recent resurgence of interests in aquaculture and agriculture, many areas of the inland mangrove forests had paved ways for these economic activities with some concomitant loss to the mangrove biodiversity, in general.

As the Forestry Departments realized the importance of mangrove resources to the communities, they began to take steps in forest protection and conservation by allocating some mangrove swamp forests as forest reserves, such as Virgin Forest Reserves, and effectively managed them based on good forestry management

Table 1 Extent of mangrove forest reserves (in ha) in Malaysia (Anon. 2003)

State	Total area	Note
Johor	21,180	Much of the mangrove forests both in east, south and west coasts of Johor are experiencing disturbances both from the natural hazards and socio-economic development and exploitation, especially in the Sungai Pulai area
Kedah	8,355	It is now reported that only 8,034 ha is left, mostly on the mainland at Sungai Merbuk; those of Langkawi Island experienced some forms of disturbances and exploitation. However, the mangroves of Kilim-Kisap area have been exploited for ecotourism
Perlis	Not available	There are patches of mangrove forest in the area of Kuala Perlis; possibly they are in stateland and not allocated as forest reserve
Negeri Sembilan	204	In 1994, it was reported that only 879 ha were left, but those in Sungai Linggi and Port Dickson areas were very disturbed. Much of the forests have been lost to socio-economic development
Pahang	3,916	The mangroves in the state are well-preserved, especially in the Sungai Kuantan and Sungai Rompin areas
Perak	40,683	Those in the Matang Forest Reserves, which now covers about 40,466 ha, are very well managed, but those in Bagan Datok areas are very disturbed as they are not allocated as forest reserves
Pulau Pinang	870	Very little is left but well-managed both on the mainland and island
Selangor	19,503	Recently, it has been reported that only 15,090 ha are left and those in Kuala Selangor and the islands off Port Kelang are well-managed
Kelantan	Not available	There are patches of mangrove forests in estuaries and their river banks in the state lands at the river mouth of Sungai Kelantan
Terengganu	1,822	There are patches of mangrove forests in estuaries and their river banks, and those in the area of Sungai Kemaman are well-managed
Melaka	80	There are patches of mangrove forests in estuaries and their river banks
Sub-total	97,517	In 1994, it was reported that 105,537 ha were present but after about 10 years only 97,517 were left
Sabah	340,689	Most of the mangrove forests are well-protected; only a small degree has been exploited. Those at Sunai Sugut and Sungai Kinabatangan are very rich in species diversity. There are also mangroves in sheltered river mouths and lagoons of some off-shore islands
Sarawak	126,400	Most of the mangrove forests are well-protected in the estuaries and banks of Sungai Sarawak, Sungai Rejang
Grand total	564,606	At the time of this writing the authors believe the total area of the mangrove forests has been somewhat diminished both by natural and human-induced activities

practices. The total extent of the mangrove forests reserves has been estimated to be about 580,000 ha of which 77.8 % is considered productive (Chan 1987). However, in Peninsular Malaysia about 105,537 ha is categorized under Permanent Forest Reserves and about 90 % of these occur on the more sheltered west coast while only 4 % occur on the more exposed east coast of Peninsular Malaysia (Table 1).

2 Biological Characteristics

2.1 Vegetation and Flora

The mangrove vegetation is evergreen and simple in physiognomic structure of two to three storeys varying from 5–25 m in height, depending on age and localities (MacNae 1968) and Snedaker (1978) (Tomlinson 1986; Ball 1988; Clough 1992; (Chapman 1975); Duke 1992; Smith 1992). The emergent layer usually consists of very few tall trees, and the canopy is comparatively even and closed, except where there are gaps, either natural or man-made. The understorey layer is poorly defined and merging with the ground layer which is devoid of growth except saplings. The principal mangrove species are characterized by special roots such as stilt roots and pneumatophores and also by their viviparous propagule habit. Several authors such as Wyatt-Smith (1960), Liew (1980), and Chai (1982) reported about 31 plant species which are exclusively found in the mangrove swamp forests, while a total of 51 species are non-exclusive or associates. However, Japar Sidik (1994) reported that Malaysia has 38 exclusive, 57 non-exclusive and nine associate mangrove species. The preliminary assessment of flowering plants of Matang Forest Reserves was made by Shamsul et al. (2005) and those of other areas were given by Norhayati et al. (2005) and Wan Juliana et al. (2010). Accounts of lower plants are very scarce, those of ferns and mosses for Matang Forest Reserves, for example, were reported by Jaman and Maideen (2005) and Damanhuri et al. (2005), respectively.

The vegetation of the mangrove forest is simple in structure thus the floristic composition is also low compared to other forest types. However, as an ecosystem the mangrove swamp forest is rich in flora and fauna. The perception among scientists is that the mangrove flora, structure, above ground biomass and net productivity on the west coast differ very much when compared with that of the east coast of Peninsular Malaysia, or even with those of Sabah and Sarawak. However, some studies showed that it is otherwise and some specific differences are observed. It has been found that the mangrove flora of Peninsular Malaysia's east coast mangroves is poorer in distribution and zonation is not obvious. This is probably because the east coast mangroves are exposed to larger waves of the South China Sea as compared to those in the west coast which are sheltered and confined within the Straits of Malacca. Early in the last century, Watson (1928) classified the mangroves in Peninsular Malaysia into five vegetation types based on species composition and dominance. They are *Avicennia-Sonneratia* type, *Bruguiera cylindrica* type, *Bruguiera parviflora* type, *Rhizophora* type and *Bruguiera gymnorhiza* type. A better and more comprehensive classification is given by Chai (1982) which included the inland mangroves. However, classification of the mangrove types of Terengganu is very commendable as it used aerial photography in addition to ground-truthing (Mohd. Lokman and Sulong 1990; Sulong and Ismail 1990). If recent techniques are employed to reclassify the mangrove types in Malaysia, it might put Watson's (1928) classification in a better perspective. This is important as in many localities the dominance of certain mangrove species has changed over the years due to habitat degradation, loss of species and exploitation.

There have been numerous studies on the flora of the mangrove forests, though the number of species is small compared to other ecosystems. The most recent are those of Wan Juliana et al. (2010) who illustrated and described the full mangrove flora of Langkawi Archipelago, Nilus et al. (2010) who illustrated the mangrove flora of Sabah and Azmil et al. (2012) who produced the checklist for the mangroves of Pulau Pangkor, Perak. Phang et al. (2005; 2007) discussed the enormous diversity of seaweed including that of mangroves. In Langkawi Islands and Sabah and probably elsewhere, *Caulerpa* spp., which in the former locality are found in the Sungai Kilim and Sungai Kisap, are edible as salad.

2.2 Fauna

Berry (1972) broadly categorized the animal communities in the mangroves into two components, namely, the aquatic and the terrestrial. The former consists of fishes, crabs, snails, worms and the bivalves, whilst the latter consists of insects (including the fireflies), birds (including the migratory species), lizards and monkeys. The mangroves of Pulau Langkawi, Matang, Port Kelang and Kukup are known for fishery, and those of Kampung Kuantan, Kampung Belimbing (Selangor), Sungai Kerian (Penang) and Matang (Perak) harbour fireflies which attracted ecotourists. The mangroves of Kuala Merbuk (Kedah), Kukup (Johor) and Kuala Gula (Perak) are equally known for supporting migratory birds.

The general fauna of the Matang mangroves was reported by Sasekumar (2005), but the specific avifauna was given by Noramly (2005), mammals by Shahrul Anuar et al. (2005) and fishes by Chong (2005) and Amiruddin et al. (2005). There are reports on fireflies (Zaidi et al. 2005), mudskippers (Faridah et al. 2005), zooplankton (Ooi et al. 2005) and others. It has been argued many times that the mangrove fauna excluding the fishes and shells have been underestimated in their value and significance to the overall mangrove biodiversity. Both the terrestrial and aquatic birds are indeed very important in the ecology and well-being of the mangrove habitats because these birds are predators of fishes and other invertebrates. The herpetofauna are poor except for a few species of mangrove vipers and lizards. However, the insect diversity, particularly the butterflies and macroinvertebrates, are quite high (Zaidi and Azman 2005; Zaidi et al. 2005).

2.3 Microorganisms

There are very few studies on the microorganisms in the mangroves except that of Kuthubutheen (1984) and Alias et al. (1995) who reported the phylloplane fungi on a few species of mangroves. The microscopic fungi and lichens are quite well represented in the mangrove forests but not studied and reported, as far as the authors know. The authors were also informed of other studies, especially the degradation of

mangrove leaf litter by microbes which is important in nutrient recycling in the habitat. One of the most noticeable macroscopic fungi in the mangroves is the species of *Ganoderma,* which in recent years have been claimed to be medicinal. The checklist of mangrove and marine fungi was prepared by Siti Aisyah Alias (2007)who reported a total of more than 234 species identified and an additional 68 species unidentified. The ascomycetes were the largest group discovered followed by deutromycetes and basidiomycetes.

3 Exploitation of Mangrove Forests

3.1 Timber Extraction

Mangrove forests are quite an important source of timber and non-timber products but insignificant compared to the timbers of the lowland and hill dipterocarp forests which produce the heavy and hard wood timbers. The timbers of mangroves are harvested and converted to charcoal and pole production for mainly domestic market (Amir 2005). Among the non-timber products are a few medicinal plants, aquatic vertebrates and invertebrates, vinegar and *nipah* attaps. In the past the mangrove forests were exploited for the above products, amongst others, but today the aquatic invertebrates and fishes are among the productive resources. Aquaculture such as for fishes and prawns have proven more economical. However, in the last decade the mangrove services have been further exploited, especially for nature recreation and ecotourism activities. Some mangrove areas in Langkawi Island, Matang, Kuala Selangor, Lumut, and Kuantan have attracted entrepreneurs to start both recreational and ecotourism products. Awang Noor (2005) and Amir (2005) have summarized both the goods and services of mangrove forests, including the environmental values. The former discussed extensively the economic value of mangrove forests.

3.2 Mangrove Stocking

Ashari et al. (2005) discussed the management of stocks at Matang since 1904, which employed different rotations from period to period. Presently, Matang practices a 30-year rotation period but Johor practices a 20-year rotation period. The gross volume and basal area either increased or decreased due to the different regimes of thinning and rotation. Some studies had suggested the rotation period may be reduced to a 22-year period for optimal productivity. Juliana and Nizam (2005) had also described the mangrove structure and above-ground biomass as indicators of mangrove stocking and carbon sesquestration. In general, mangrove stocking is adequate for the supply of poles and wood for the local markets, either for construction and charcoal factories. In particular, the mangroves of Matang, Perak are managed like a commercial plantation on a 30-year rotation to supply produce for the local economic demands.

3.3 Mangrove Forest Conversion

3.3.1 Agriculture

In the state of Selangor, for example, the extent of mangrove forests in 1975 was 39,695 ha and by the year 1999 only 15,090 ha were left, a reduction of about 62 %, and much have been lost to land conversion to oil palm cultivation and aquaculture activities. The areas affected were the forest reserves of Kuala Sepang, Banjar Selatan, Teluk Gadong, and Jugra, among others (Haliza et al. 2005). Cultivation of oil palm in Malaysia has been the most profitable of all the agricultural crops and a vast amount of lands, including those of inland mangroves, have been lost to oil palm plantation. Pulau Carey, Selangor had substantial mangroves in the past but now the whole island is cultivated with oil palm. The authors believe similar trends also occur in other states, particularly Perak, Kedah, Negeri Sembilan, Sabah and Johor. In terms of productivity and economic benefits oil palm plantations are many times more economical than mangrove forests. In the next decade it is perceived that much of the mangrove swamp forests in Sarawak will be converted to oil palm plantations too as the state tries to eradicate poverty among the rural communities and empower them as settlers depending on the plantation.

3.3.2 Aquaculture

Fish and prawn cultures have been proven to be economically more profitable, especially for oversea markets. Similarly, many estuaries and rivers have been the sites for fish cultures, especially in the Kilim-Kisap area of Langkawi, Matang and Kuala Selangor. The prawn cultures have been developed somewhat inland but still in the mangrove forests. In Selangor, for example, aquacultures have significantly depleted mangrove areas in Kuala Bernam and Jugra (Haliza et al. 2005). Ong (1982) had already warned about the proliferation and expansion of aquaculture industries in Malaysia as the demand for fishes and other aquaculture produce are on the increase due to the popularity of seafoods. The conversion of mangrove areas to aquaculture farms not only was prominent in Selangor but also in almost all other states, notably in Langkawi, Perak, Johor, Sarawak and Sabah.

3.3.3 Resettlement

As the inland mangrove forest areas are converted to other land-use, especially the oil palm plantation, a small area in Selangor, about 412 ha of the mangrove forest, also gave way for resettlement of indigenous communities as in Kuala Sepang (Haliza et al. 2005). Similarly, in Langkawi some areas were converted to fish landing ports, and the mangroves of the Malut area were cleared, developed and later abandoned. However, this conversion to settlement area is insignificant.

4 Impacts on Mangroves

4.1 Pollution

Both the pollution in the estuaries and rivers has its sources in the inland industrial and agricultural activities and other land-use patterns upstream. Historically we have judged the quality of water in the mangrove areas by its foul smell and dark colour as being affected by pollutants. In Matang in particular, sediments from the developing town of Taiping flowed into the mangrove areas, making the muddy sediments sandy. Activities such as aquaculture, cockle harvesting, navigation and river settlement also contribute to river and estuarine pollution. Mohd. Kamil et al. (2005) have shown that the water quality of the Matang mangroves has deteriorated in the past few years, to cite an example. Almost all rivers in Malaysia which originate from the hinterland carrying loads of pollutants will pass through belts of mangroves on both sides of the rivers and estuaries. The authors wonder what would be the short-term and long-term effects of these pollutants, especially the grease and heavy metals, on the biodiversity of the mangrove areas downstream. There are not many studies on this aspect to discern.

5 Mangroves of Malaysia

5.1 Langkawi Islands

5.1.1 Floristic Composition

Pulau Langkawi has an exceptional natural settings and beautiful landscapes that attract both naturalists, scientists and tourists alike. The mangrove forests of the Kilim-Kisap areas in particular are testimony to the above statement. In addition, the mangrove forests there are found on the shallow limestone substratum, making them one of the most outstanding features in Peninsular Malaysia, and possibly in the world. The mangrove ecosystem is both dynamic and fragile and is very sensitive to both natural stochastic events and human activities. Though they provide many essential services such as storm protection, erosion control, waste-water clean-up, and forest products, they are consistently subjected to conversion to other land-use purposes of greater economic returns. Wan Juliana et al. (2010) described and illustrated a total of 76 species of mangroves trees (45 %), shrubs (25 %), ferns (9 %), climbers (9 %), herbs (7 %) and bryophytes (5 %) in 58 genera and 35 families. Out of the total 76 species, 32 are exclusive, 33 are non-exclusive and 11 are associate mangrove species. Comparatively, the mangrove forests in the Langkawi islands have a high diversity of mangrove plants in Peninsular Malaysia.

In 1980, the total mangrove area of the Langkawi Islands was 3657.67 ha and, about 11 years later, the extent of the mangroves area was reduced by 11.85 % to

3270 ha. Some of the mangrove areas had been earmarked for aquaculture ponds, chalets, navy facilities and other uses. Norhayati and Latiff (2001) had estimated the density of mangroves in a 1 ha plot as being 849 per ha, and the stands belonging to nine species and four families. The most dominant species is *Rhizophora apiculata* with an important value of 50.2 and tree density of 557 /ha, while the total above ground biomass was estimated at 115.07 t/ha.

5.1.2 Threats and Conservation

It is estimated that in 1988 there was a total of 4,165.29 ha of mangroves, in the year 1993 there were 3,902.85 and by the year 1999 there was a total of 3,764.97 ha. This means that between 1988 and 1999, a total of 400.32 ha or 36.39 ha per year were lost to other land-uses. From another study, in a period of five years (1988–1993) 6.3 % of the total mangrove areas were deforested, and in the next interval (1993–1999), a further 3.53 % were deforested. These activities coincided with the fact that Pulau Langkawi was declared as a free-trade zone in 1985.

As stated by Norhayati and Latiff (2001), the estimated above-ground biomass of mangroves in Pulau Langkawi 115.07 t/ha. Using this figure it could be estimated that the total amount of biomass lost in the last 11 years (1988–1999) was 46,064.82 tonnes. From 1988 to 1993 a total of 129.69 ha were lost, with only 26 % to agriculture (33.09 ha), and between 1933 and 1999, a total of 128.54 ha were lost, 23.94 ha to agriculture and 15.75 ha to aquaculture. The threats and management of the mangroves of Langkawi in particular has been discussed by Latiff (2012).

5.2 Mangroves of Selangor

5.2.1 Floristic Composition and Biomass

Soepadmo and Pandi Mat Zain (1989) surveyed the mangroves of Sementa, Selangor where 32 species of plants were found. The dominant species were *Avicennia alba* and *Sonneratia alba* in the *Avicennia* zone. In the mixed *Rhizophora* zone, the dominant species were *Rhizophora mucronata* and *R. apiculata*, and in the *Bruguiera* zone, *Bruguiera cylindrica* and *B. parvifolia*. The total number of stems differed from zone to zone, ranging from 4189 /ha in the *Avicennia* zone to 13,290 /ha in the *Bruguiera* zone, and the above-ground biomass ranged from 124.53 t/ha in the former zone and 150.78 t/ha in the latter zone. That of Kuala Selangor, to a certain extent, has been conserved with the establishment of a Nature Park.

5.2.2 Threats and Conservation

Nik Mohd. Shah et al. (2005) provided an excellent description of the management and conservation of mangroves in Selangor. In the year 2003 a total of 14,897

ha existed in the state, which fall under the categories of production forest, soil conservation forest, wildlife conservation forest and Virgin Jungle Reserves. Since 1920 most of the mangrove forests were allocated as Permanent Forest Reserves, and the first working plan was prepared in 1922 and the last one was for 2006–2015. The case of the Kuala Selangor mangroves illustrates the various threats faced and how management strategised their *in situ* conservation. Some pristine patches were developed as a nature park, those along the Sungai Selangor at Kampung Kuantan and Kampung Belimbing were developed for recreation and ecotourism as fireflies occur there, and rehabilitation and restoration were conducted where the mangroves were depleted by natural causes. However, with the construction of the Selangor Dam, some effects on the population of *Sonneratia caseolaris* along the Sungai Selangor have been observed. The threats and management of mangroves in Selangor has been discussed by Haliza et al. (2005).

5.3 Mangroves of Johor

Johor has a total of 20,533 ha of mangrove forests which are mostly found in Sungai Pulau Forest Reserve, Sungai Johor Forest Reserve, Sungai Santi Forest Reserve and Sungai Lebam Forest Reserve, and the first working plan for the state was developed in 1941. The latest integrated management plan (2000–2009) was developed primarily to conserve and manage the forests through sustainable regime to ensure that they contribute to the state and national economy and environmental stability. The threats to the present mangrove forests come from various sources. For example, large scale development projects for infrastructure, urban development, industries and harbours in and around Bandar Nusajaya would definitely affect the existing environment of the mangroves. In addition, the proposed petrochemical plant and the Iskandar Corridor development would also pose possible threats (Che Hashim et al. 2005; Maimon et al. 2008).

5.4 Mangroves of the East Coast of Peninsular Malaysia

5.4.1 Floristic Composition and Biomass

Soepadmo and Pandi Mat Zain (1989) surveyed the mangroves of Kuala Kemaman and Kg. Pantai Tinggi, Kemaman, Terengganu where only 24 species of plants are recorded. The dominant species were *Rhizophora apiculata* and *Bruguiera gymnorrhiza*. The total number of stems at Kuala Kemaman Forest Reserve was 5,340 /ha and the above-ground biomass was 199.13 t/ha, whereas those of Kampung Pantai Tinggi were 3,281 /ha and 163.10 t/ha, respectively. Mohd. Lokman and Sulong (2001) described the vegetation and flora of the mangroves of Terengganu.

There are other surveys and floristic studies on the mangroves of the other east-coast states of Kelantan, Pahang and Johor. However, those of Kelantan are situated on the statelands, and hence not protected. Furthermore, they occur in small patches at the river mouths and stand structure and composition is rather poor. There were some studies but neither published nor reported for reference. Those in Pahang are comparatively richer, especially in the Kuantan and Rompin districts.

5.4.2 Threats and Conservation

The mangroves in the east coast states of Peninsular Malaysia, particularly those in Terengganu and Pahang are not-well sheltered by lagoons and rivers, unlike those in the west coast states. Hence they are not as diverse and widely distributed. However, they are also threatened by similar factors such as strong waves, especially during the monsoon, small-scale agriculture, aquaculture, resettlements and construction of infrastructures, especially those in Setiu, Dungun and Kemaman, Terengganu (Gong et al. 1984). For the state of Terengganu in the last five years five compartments of Kuala Kemaman Forest Reserves were gazetted as Virgin Jungle Reserves. This exercise augurs very well for mangrove conservation in Peninsular Malaysia.

5.5 Mangroves of Sabah

Tangah (2005) stated that Sabah has about 316,024 ha of mangrove forests in the forest reserves and about an additional 25,000 ha are outside the reserves. Much of them are still pristine and not exploited for commercial purposes. A review of the past and current status of the mangrove forest management was conducted by Kugan (2003) who revealed that the state had embarked on production of chipwood and bark from mangrove trees on a commercial scale in the early 1970s. However, the insignificant contribution to the state's revenue and the damaging extraction method employed prompted the state government to discontinue it in 2001. The challenges that the state government had embarked were to store the timber stocks, to arrest the competing land-use, to diversify resource utilization, to maintain a healthy mangrove ecosystem and increase efforts in conservation (Liew 1980). Fatimah et al. (2012) illustrated the case of mangroves in the Kota Marudu area where the communities were engaged in both the conservation efforts and resource exploitation to eradicate poverty in the area.

5.5.1 Threats and Conservation

As stated earlier much of the mangroves in Sabah are still intact in their natural state. Several years ago the state government decided to exploit for rayon and only recently the project had been terminated. The authors do not foresee pertinent threats to the

Sabah mangroves as the demand for their exploitation is not significant. However, when the resources of the lowland dipterocarp forests of Sabah diminish there is the possibility the timber resources of the mangroves will be tapped.

5.6 Mangroves of Sarawak

According to the national figures, Sarawak has about 126,400 ha of mangroves. However, according to Marajan (2005), based on satellite imagery of the 740 km long coastline, some 142,693 ha are covered with mangrove forests. This illustrates very well that up-to-date techniques such as aerial photography and satellite imagery could enhance the inventory of resources. However, only about 48 % is under permanent forest reserves, the remainder are within the stateland. Similar to Sabah, Sarawak also went for chipwood and charcoal production for export and the annual production had been substantial. The poles and other non-wood products were for domestic use. The management plans were written in the 1950s and the main objectives were to satisfy the domestic demand for poles, firewood and charcoal and to export the surplus.

5.6.1 Threats and Conservation

The authors foresee pertinent threats to the Sarawak mangroves will occur in the next decade as the demand for their land conversion and exploitation of the rich resources are becoming more apparent (Ashton and McIntosh 2001). However, like Sabah when the resources of the lowland dipterocarp forests and peat swamp forests of Sarawak diminish, there is the possibility the timber resources of the mangroves will be tapped too.

6 Management and Conservation

The Departments of Forestry in Malaysia, as custodians and managers of the mangrove forests, are all committed to conservation of biodiversity which emphasize both the protection and sustainable utilization of the resources. In Malaysia, the basis and concept that underlines the practice of sustainable forestry is to set aside adequate natural forest lands, including mangrove forests, as Permanent Forest Estates (PFE) that are strategically located throughout the country. There are two types of PFEs, namely, the production and protection forests. While the cutting cycle for hill mixed dipterocarp forest is 25 years, that for peat swamp forest is 45 years and for the mangroves it is between 20 and 30 years and is kept unamended. The management and conservation of mangrove forests are discussed under the following sub-headings.

6.1 Sustainable Forest Management

All states in Malaysia are committed to forest conservation including the mangrove forests except those without substantial areas such as Kelantan, Melaka, Perlis and Pulau Pinang. While the rate of exploitation is higher in the states of Peninsular Malaysia, Sabah and Sarawak are beginning to demonstrate the value of both conservation and utilization of mangroves for their states' revenue in the near future. These commitments are illustrated by Shaharuddin et al. (2005), Marajan (2005) and Tangah (2005). It is presumed in the next decade that both the states of Sabah and Sarawak will embark on mangrove exploitation to give added value to their mangrove forests, in addition to more serious efforts in conservation. Sustainable mangrove forestry in Malaysia may prove as the way forward in ensuring a balance between exploitation and conservation by all states. The need for more studies and research to develop more products has also been discussed (Ibrahim and Husin 2005; Ong 2005; Latiff 2005).

6.2 Minimising Impacts and Promoting Wise Use of Resources

The keys to conservation are to protect the mangrove resources *in situ* and when the need to utilize the resources for economic purposes arises steps must be taken to minimize the impacts to the ecosystem. As the mangrove ecosystem is very fragile any form of disturbances no matter how small could possibly create long-lasting impacts. As stated by Kugan (2003) the harvesting of mangroves for woodchips in Sabah had critically damaged the mangrove vegetation so that the production was stopped by the state government after about 30 years of exploitation. The Environmental Impact Assessment regulation in Malaysia is already in place for land conversion and other prescribed activities.

6.3 Enhancing Biodiversity Management

The existence of a unique ecosystem diversity, rich species diversity, flora and fauna is well documented in the mangrove ecosystem. The mangroves of Malaysia are rich both in terms of flora and fauna (Aldrie and Latiff 2008). Some of the species have been exploited and utilized while some hold potential for the future economic benefits of the communities concerned. Once again the key is mangrove forest conservation to ensure the conservation of species and subsequent use of their genetic diversity. There is an urgent need though to strengthen both the institutional and research capacity to address this important issue. The Department of Forestry in all states is committed to conserve mangroves in their respective states, hence the capacity for research must be further strengthened.

6.4 Strengthening Mangrove Virgin Jungle Reserve

The Virgin Jungle Reserves (VJR) within the permanent forest reserves are established for the purpose of stock holdings of important habitats and species of forestry important for future silviculture, education and research. Strengthening the present VJRs would certainly ensure mangrove forest conservation in the country. The state of Terengganu in particular should be commended for establishing five new VJRs in the Kuala Kemaman Forest Reserves and the state of Perak for well-managed mangroves at Matang.

6.5 Enhancing Public Awareness

The public is the ultimate benefactor of mangrove conservation; hence to enhance public awareness on the importance of this ecosystem is the most important assurance for future generations. A step has been taken by the Malaysian Nature Society in establishing a mangrove Nature Study Centre supported by a private company in Terengganu. School children and university students are taken to the centre to do nature studies on the ecology of the mangrove flora and fauna. The local community in Setiu, Terengganu, with the assistance from WWF Malaysia and the Universiti Malaysia Terengganu, has also shown similar commitment by embarking on mangrove replanting. In fact, the 2004 tsunami had created the impetus in creating public awareness on the importance of the mangroves. Many states had embarked on mangrove tree planting in the last five years, some with great success and some with minor failures.

7 Functions of Mangroves

As sinks for waste-water borne pollutants
It has been shown that mangrove soils and roots could trap and immobilize heavy metals and nutrients from waste water originating from the hinterland. Hence it is believed that mangroves could function as a purifier of pollutants (Conley et al. 1991; Ambus and Lowrance 1991). This function has been taken for granted such that many inland factories and industries pollute the upstreams and pollutants flow downstream through the mangroves to the sea.

As a sediment removal system
As water flows slower in streams and rivers of mangrove areas than that of non-mangrove rivers, sediments tend to settle down to the bottom and that which flows outwards towards the sea is sediment-free (Wolanski 1995). As observed in Matang, Perak much of the muddy substratum had become sandy and this affected the cockle production which ultimately brought adverse implications to the cockle farming.

Coastal erosion prevention

The strong roots and buttress systems of the mangrove plants form a natural buffer between the land and sea. They also tend to break strong wind and wave actions. This had been proven in 2004 when a tsunami struck the coasts of the Langkawi Islands, Kedah and Perak. If not for this buffer effect much more damage to the estuaries and rivers would have occurred. In addition, mangroves also contribute to land-building through accretion (Othman 1994).

Recreational areas

Today mangrove areas are capable of generating some economic returns through boating, bird watching, jungle trekking, and other recreational activities. Kampung Kuantan and Kampung Belimbing in Kuala Selangor are known to attract eco-tourists as fireflies synchronizing light emitting become the attraction at night. In Lumut, Perak some recreational facilities have been constructed and developed to attract local visitors and tourists.

Education

As mangrove forests contain salt-tolerant plants and animals, they could play an important role in educating the public, especially school children on ecology. An excellent example is the Kuala Selangor Nature Park that has conducted many education programmes for the school children and the public at large by the Malaysian Nature Society. The area is about 95 ha and a total of 157 species of birds and 13 species of plants are present in the park.

8 Development of a Management Plan

Mangrove swamp forests are always under serious threats of various forms notably from conversion to other land-uses especially aquaculture and agriculture. Razani Ujang (1982) stated that between 1955 and 1980, a total of 10,500 ha of mangrove swamp forests have been converted and Selangor alone had lost about 7,500 ha or about 30 % of the total mangrove areas in the state. The state of Kedah including Pulau Langkawi is no exception. About 1,500 ha of the Sungai Merbok mangrove area had been converted to rice fields but those areas remained idle because of the acid sulphate soils that don't favour successful rice farming.

The problem lies in the difficulty in recognizing the indirect and direct benefits of the mangrove swamp forests. Since the mangrove ecosystem is an interphase between terrestrial and marine environments, there exists competition for various economic interests. Major industries in sectors such as forestry, fisheries and agriculture could claim mangroves as their administrative domain, and the policy that is best for one is detrimental for another. This is observed as happening in many states such as Perak and Selangor. Hence, trade-offs between alternative development and resource use must be examined more carefully and comprehensively. Current economic analysis can assist to identify the problem of using the cost-benefit approach to solve problems associated with a decision on coastal resource use, such as mangroves.

8.1 Matang Mangrove Forest

The Matang mangrove forest is taken here as a model for sustainable management because not only is it always claimed to be the best managed mangrove forest in Malaysia and probably also in the world but also it has a long history of management, as a first working plan was drawn in 1904 (Gan 1995). This is supported by Muda et al. (2005) who detailed the management system by introducing zoning, rotation, yield estimation and regulation as well as sound silvicultural practices (Hossain 2004).

9 Research and Development

Hamdan et al. (2012) outlined the various aspects of research and development of mangroves in Peninsular Malaysia with a focus on the rationale for rehabilitation and restoration of the health of mangroves. The policy and the role of various legislation in the country is quite clear but yet as shown by Haliza et al. (2005) in the case of the mangroves in Selangor, there are many conflicts on the ground with respect to implementation of legislations (e.g. National Forest Act 1984) and the various master plans at the local government level. Just like any other forest types, mangrove forests are also subjected to sustainable forest management and the states that adopted this are Perak, Johor, Selangor and Kedah where mangrove forests are very extensive. The objectives of sustainable management are to produce fuelwood, charcoal and poles, to protect the riverine and coastline ecosystems and to practice conservation (Ong 2003).

10 Mangrove Ecotourism

The initiative taken in Langkawi island and Kota Marudu, Sabah by the various authorities and stake-holders in promoting sustainable mangrove ecotourism is very commendable and it should be a model for other protected areas. Visitors and tourists were taken by boats to not only observe the beauty of mangrove vegetation, flora and fauna but also the activities of the local communities in small-scale exploitation of mangrove resources. These activities are both educational for the visitors and tourists and profit making for the local communities.

11 Challenges

Among the present and future challenges are:

a) To conserve adequate areas of riverine and coastal zones covering all forest types for the appropriate species. Of particular significance is the conservation of the *nipah* areas which are mostly outside the forest reserves. The species has been acclaimed as one of the important multi-purpose ones but conservation is not

in sight, though exploitation has been minimal. There have been surveys and discussion on the possibility of converting the *nipah* sugar to biofuel.

b) To protect the coastal and estuarine ecosystems. The disaster of the tsunami of 2004 has probably taught us some important lessons of what the mangroves could do to protect the estuarine areas in particular. Likewise there are also many coastal areas which have been eroded by sea.
c) To introduce up-to-date and workable management regimes. The states of Perak, Johor, Sabah and Sarawak have updated their management plans to suit possible change in policy of exploitation and management.
d) To handle the land conversion issues. Both the local and state governments must adhere to the existing laws and regulations to ensure that land conversion issues are addressed in an appropriate manner in the future.

12 Management Strategies

The management strategies employed amongst others are:

a) To maintain and propagate the most productive forest subtypes, e.g. *Rhizophora* forest. Surveys as conducted by the Forestry Department Terengganu (Mohd. Lokman and Sulong (2001) are excellent examples to recognize the mangrove types and subtypes by zones. This classification would help the various state governments to manage their resources efficiently.
b) To encourage the propagation of other forest types and subtypes. Where the existing mangrove types have suffered damage efforts should be taken to undertake rehabilitation and restoration of mangrove belts.
c) To introduce high quality mangrove species, e.g. X*ylocarpus* species. In the past no efforts have been taken to improve the quality of mangrove species either by genetic selection or propagation.
d) To conserve all riverine and coastal mangroves. As stated above all inland mangroves in statelands, especially the *nipah* belt, should be conserved.
e) To create and maintain adequate mangrove wildlife. Where evidence is shown that there has been depletion or loss of certain animal species efforts should be taken to enrich the population.

To achieve the above strategies, all parties especially the Forestry Departments of all states, non-government organisations, schools, universities, research institutes and other stake-holders must agree to prioritise conservation and maintain sustainable timber production through management zoning, felling rotation, and best silvicultural practices. Understanding the ecology and biogeography of the mangroves are the key to successful management (Hamilton and Snedaker 1984).

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