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THE ECONOMIC AND ENVIRONMENTAL VALUES OF MANGROVE FORESTS AND THEIR PRESENT STATE OF CONSERVATION IN THE SOUTH-EAST ASIA/PACIFIC REGION

ITTO/ISME/JIAM Project PD71/89 Rev.1 (F)

Project Coordinator
B.F. Clough

International Tropical Timber Organization

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JIAM Japan International Association for Mangroves

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Technical Report of the Project

The Economic and Environmental Values of Mangrove Forests and their Present State of Conservation in the South-East Asia/Pacific Region

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Preface

Between 1983 and 1989, two major UNDP/UNESCO Regional Projects on Mangrove Ecosystems were implemented in Asia and the Pacific as part of the COMAR (Coastal and Marine Sciences) programme of UNESCO. The first of these projects, Research and Training Pilot Programme on Mangrove Ecosystems (RAS/79/002), ran from 1983 to 1986; the second, Research and its Application to Mangrove Ecosystems Management (RAS/86/120), was carried out from 1987 to 1989. These two projects had as their major common goals the rational management of mangrove ecosystems to ensure ecological and economic sustainability. Both placed considerable emphasis on educating policy makers, coastal zone managers and the community-at-large of the ecological and environmental importance of mangrove ecosystems, and of their socio-economic values and benefits, both to local communities and in the national interest.

The report of the first of these two projects (RAS/79/002), published in 1986, provides the most recent assessment of the condition of mangrove ecosystems in Asia and the Pacific. Since then, however, mangrove ecosystems in Asia and the Pacific have continued to be overexploited and/or annexed for a range of other land uses under the guise of economic development.

Recognizing that there has been a further significant decrease in the area of mangrove forest in Asia and the Pacific since 1986, the International Tropical Timber Organisation (ITTO) agreed to support a re-assessment of the state of conservation and utilization of mangrove ecosystems in the region, to be carried out by the International Society for Mangrove Ecosystems (ISME) and the Japan International Association for Mangroves (JIAM). Two projects were initiated. The first, covering Indonesia, Malaysia and Thailand, was implemented by ISME and is the subject of this report. The second, covering the western Pacific and implemented by JIAM, is the subject of a report by JIAM that is incorporated in the present volume for ready reference; it was prepared by M. Jaffar.

Implementation of the present project, The Economic and Environmental Value of Mangrove Forests and their Present State of Conservation in the South-East Asia/Pacific Region, formally commenced in October 1991, and a preliminary workshop was held in Bangkok in November 1991 to consider the original project document (Appendix I), to identify the major objectives and outcomes of the project, and to decide the manner in which the project was to be implemented. The report of that workshop may be found in Appendix II.

From the outset it was recognized that given the financial constraints of the project and its relatively short duration it would not be feasible to make a comprehensive assessment of the state of conservation and management of mangrove ecosystems throughout southeast Asia. It was therefore decided that the project should focus on Indonesia, Malaysia and Thailand, three countries that arguably have the most comprehensive set of data on their mangrove ecosystems, and which have a long history of mangrove utilization and management. Strong arguments were advanced that the combined experience of these three countries in monitoring and managing their mangrove ecosystems might provide useful models and examples, both good and bad, for the development of sound sustainable management practices by other countries of the region. With this in mind, it was agreed at the Bangkok workshop that Indonesia, Malaysia and Thailand should provide up-to-date reports on the status, utilization and management of their mangrove ecosystems, in a form that would satisfy the following primary objectives:

1. To assess, as quantitatively as possible, the present status of mangroves, their utilization and their management.
2. To identify, and quantify where possible, the environmental, ecological and socio-economic values of mangroves.
3. To provide guidelines for sustainable management of mangrove ecosystems that take into account their environmental, ecological and socio-economic values.

4. To provide a model for the acquisition, storage and analysis of inventory data and other information on mangrove ecosystems that is required for the development of sound management policies and plans.

This technical report is the final report for the project. It includes the Country Reports submitted by Indonesia, Malaysia and Thailand, as well as the summary report of the Project Coordinator, which includes a set of guidelines for sustainable management of mangrove ecosystems. No doubt the latter could be improved upon, but in the meantime it is hoped that the guidelines will be useful to policy makers and coastal zone managers. This final report also contains a description of the database developed during the project. While the database requires further development, it will in its present form provide a model for the kind of information that should be collected to assess the current status of mangroves in countries not covered by the present project.

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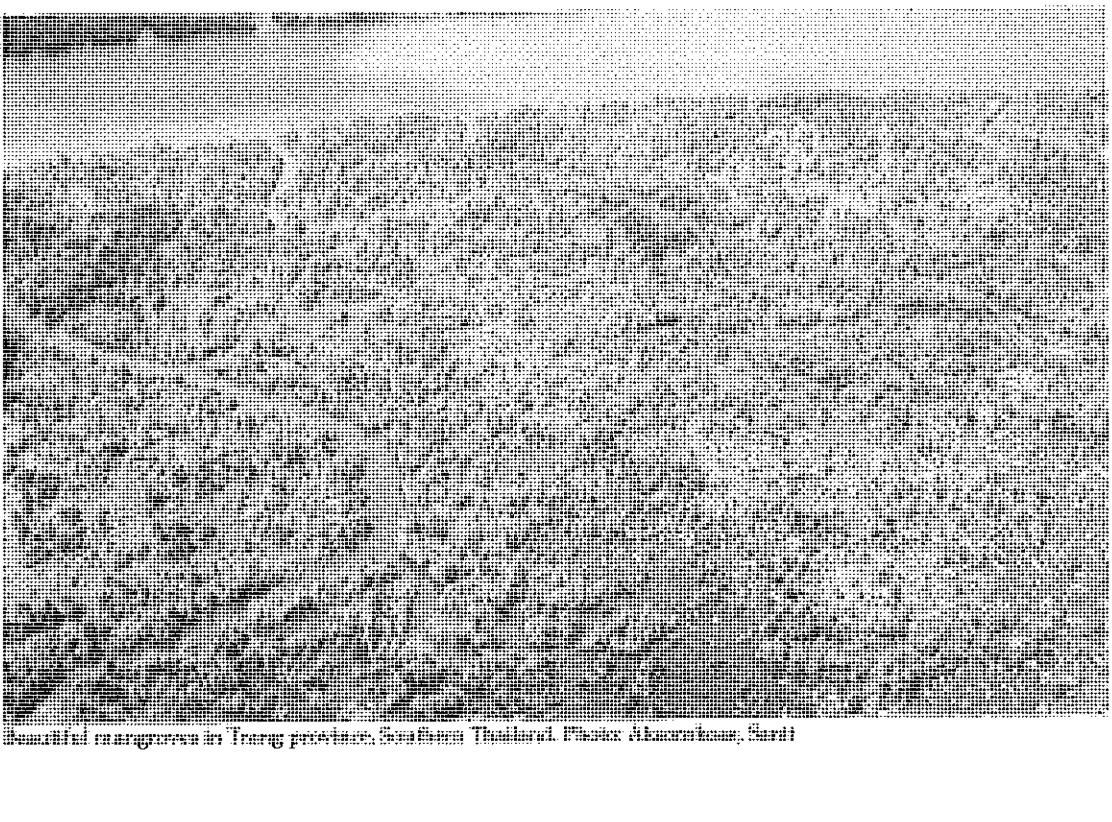
Contents

List of Figures

List of Tables

Mangrove forests have been converted to shrimp farm at Ban Don Bay, Surat Thani Province, Southern Thailand. Photo: Aksornkoae, Sanit



Beautiful mangroves in Trang province, Southern Thailand. Photo: Aksornkoae, Sanit

The status and value of mangrove forests in Indonesia, Malaysia and Thailand: Summary

B.F. Clough

Introduction

Coastal dwellers have traditionally used mangrove areas in a sustainable manner for centuries. In more recent times, however, rising human population pressure and the drive for economic development in coastal areas has resulted in the loss, degradation or overexploitation of mangroves in many parts of the world. These pressures are particularly acute in some countries of the Indo-Pacific region, and less so in others.

The last comprehensive assessment of the status of mangroves in South-East Asia and the Pacific was published in 1986. This present assessment aims to provide a more up-to-date and quantitative evaluation of the status, use and value of mangrove ecosystems in Indonesia, Malaysia and Thailand. It is based primarily on information provided by each of these countries in their Country Reports.

Distribution, extent and loss of mangroves

Indonesia

Indonesia is estimated to have about 4.25 million ha, of which the Province of Irian Jaya accounts for almost 3 million ha (69%). Other provinces with significant areas of mangrove include Riau (276,000 ha) and South Sumatra (195,000 ha) on the island of Sumatera, and East Kalimantan (266,000 ha).

Of the 4.25 million ha of mangrove in Indonesia, approximately 608,000 ha (14%) are designated as conservation area and 733,000 ha (17%) for log production. The area designated as conservation area presumably includes those areas set aside as coastal buffer zone, as well as areas set aside for wildlife protection (591,000 ha; Indonesian Country Report). The status and use of the remaining 69% (2.9 million ha) of Indonesia's mangroves is not clear. Almost 3 million ha of Indonesia's mangroves (69% of the total) are found in Irian Jaya. Further transmigration from other more densely populated regions of Indonesia to Irian Jaya may pose a threat to this large area of mangroves.

Indonesia has implemented a policy to establish a mangrove greenbelt to maintain coastal stability. The width of this coastal buffer zone varies from one area of coastline to another depending on the tidal range. The formula used to determine the width of the buffer zone is: Width of mangrove greenbelt (m) = maximum tidal range (m) x 130.

Malaysia

Malaysia is presently estimated to have 641,000 ha of mangrove forest remaining, of which 446,000 ha (70%) is gazetted as mangrove forest reserves that are managed for sustainable forestry production as part of the Permanent Forest Estate. The remaining 195,000 ha (30%) is Stateland mangroves, which come under the jurisdiction of the respective State Governments. About 57% of Malaysia's mangrove forests are found in Sabah, 26% in Sarawak, and 17% in Peninsula Malaysia.

From 1980 to 1990, the area of mangroves in Malaysia decreased from 505,300 ha to 445,800, a loss of 59,500 ha or almost 12%. This corresponds to an annual rate of loss of about 6,000 ha yr^{-1}, similar to the average rate of loss in Thailand over the period 1960-1990. More than 50% of the loss in area between 1980 and 1990 occurred in Sabah where mangroves have been clearfelled for the woodchip industry. Although the woodchip plants in Sabah were closed down some years ago, their operation over a period of about 15 years is estimated to have consumed about 70,000 ha of mangrove (Malaysian Country Report). Since clearfelling for woodchips is incompatible with the national policy of sustainable forestry production from mangrove forest reserves, it is assumed that most of the loss in mangrove area in the State of Sabah occurred in Stateland mangroves which fall under the jurisdiction of the State Government. A similar woodchipping plant in Sarawak is estimated to have clearfelled about twice its allocation of 15,000 ha over 25 years, and is now reported to have run out of mangrove forest.

In Peninsular Malaysia, the greatest losses in area between 1980 and 1990 have occurred in the States of Johor (a loss of 9,000 ha or 35%) and Selangor (a loss of 6,000 ha or 22%). In the State of Terengganu on the east coast of Peninsula Malaysia, a total of 2,000 ha (68% of the total mangrove area) was lost between 1980 and 1990. The loss in mangrove area along the southern coast of Johor (Peninsula Malaysia) has been due chiefly to alienation for pond culture of shrimp and for agriculture.

Thailand

The total area of mangrove in Thailand has decreased by more than 50% since 1960, when the area of mangrove is estimated to have been about 360,000 ha (Fig. 1). The rate of decrease is estimated to have been about 4,000 ha yr^{-1} from 1960 and 1975, about 6,300 ha yr^{-1} between 1975 and 1980, and more than doubling to about 13,000 ha yr^{-1} between 1980 and 1986 (Thai Country Report). The area of mangroves remaining in 1991 has been estimated to be 174,000 ha. Alienation for aquaculture accounted for about 64% and coastal development about 26% of the decrease in mangrove area in the period up to 1986. It is reasonable to assume that these two activities have been mainly responsible for the continuing loss in mangrove area since 1986.

The Government of Thailand has now placed a moratorium on the further alienation of mangrove areas and has instituted an ambitious programme of reforestation of degraded mangrove areas with the objective of increasing the mangrove area to about 370,000 ha by 1996, roughly equivalent to the area that existed in 1960. The success of these initiatives is likely to depend on the extent to which the moratorium on illegal cutting and the further removal of mangroves can be enforced, since this seems to have been difficult to control in the past. According to the mangrove land use plan prepared by the Government for the targeted area of 370,000 ha by 1996, approximately 40,000 ha (11%) is proposed to be designated as Preservation Zone (protected areas for nature and/or environmental conservation), 200,000 ha (54%) as Economic Zone A (areas to be utilized and managed for sustainable long-term yield of forest resources), and 130,000 ha (35%) as Economic Zone B (areas in which other development may be allowable after consideration of its environmental impact).

Patterns of use and socio-economic values

Utilization and management of mangrove ecosystems can be broadly divided into two categories, sustainable and non-sustainable. Sustainable uses are those that maintain the basic ecological functions of the mangrove ecosystem and adjacent ecosystems, do not degrade environmental quality, and provide long-term socio-economic benefits to future generations. Examples of sustainable use include national or nature parks, conservation reserves, the provision of nursery areas and maintenance of fisheries stocks, and management for sustained timber production over a number of rotations. Conversion of mangrove areas for aquaculture, agriculture, urban and industrial development, and other activities that result in the over-exploitation, degradation or destruction of mangrove areas are considered to be non-sustainable uses of the mangrove ecosystem.

In Indonesia, Malaysia and Thailand, mangrove areas have traditionally provided food and many other materials needed for the subsistence and livelihood of local villagers. Artisinal and other subsistence fisheries in and adjacent to mangrove forests provide a major source of food, while the mangrove trees themselves are used for firewood, boat building, housing and other constructional purposes, and yield a range of other products that sustain the daily life and culture of the local people. The socio-economic values of these activities are difficult to quantify. There is as yet no widely accepted methodology for assessing the environmental, cultural and socio-economic values of mangroves, in part because conventional economic indicators do not necessarily provide an adequate description of the contribution of mangrove ecosystems to the daily life and culture of people who have traditionally used mangrove areas. The case studies of Lal (1990) in Fiji, and Aksornkoae (1984) and Wechakit (1987) in Yeesarn Village, Thailand (see Thai Country Report), provide two specific examples where an attempt has been made to evaluate some of the socio-economic values of mangroves to local people.

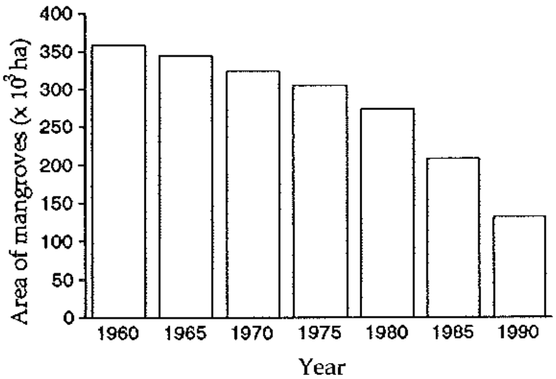


Fig. 1. Estimated change in mangrove area in Thailand during the period 1960-1990, based on data provided in the Country Report

Forestry

Wood from mangrove forests is used widely throughout South East Asia for charcoal production. Species of the family Rhizophoraceae, mainly *Rhizophora apiculata, R. mucronata* and *Bruguiera parviflora*, are particularly favoured for making charcoal because of their hard, dense timber, claimed by some to produce the best charcoal in the world. Perhaps the best known example of sustainable use of mangrove wood for charcoal and other forest products is the Matang mangrove forest area in the Malaysian State of Perak, where mangrove forests have been managed silviculturally since early this century to produce timber, charcoal and firewood. The literature documenting the management of the Matang mangrove forest is extensive (see, for example, Watson, 1928; Noakes, 1952; Dixon, 1959; Ong, 1978; Haron, 1981; Ong, 1982). With a total of about 41,000 ha of managed forest, 1,000-1,300 ha of the Matang mangroves are now cut annually on a 30 year rotation. Two thinnings are carried out, the first at 15 years and the second at 20 years. Poles cut during thinning are used for construction, and in some cases for firewood. Gross revenue from charcoal and other timber products has been estimated at about US$6 million (Ong, 1978; see also Malaysian Country Report). Extraction and processing of timber from the Matang mangrove forest has been estimated to provide employment for a direct workforce of about 1,400 people and an indirect workforce of a further 1,000 (Ong, 1978; see also Malaysian Country Report). In addition to forest products, the Matang mangrove forest also supports an extensive capture fisheries industry employing an estimated 10,000 persons, and yielding a total annual revenue from fisheries of US$12-30 million (Tang *et al.*, 1981; see also Malaysian Country Report). However, the net economic return from both fisheries and forestry in the Matang mangroves is somewhat less than these figures, since costs have not been taken into account.

Silvicultural practices such as rotation time, coupe size, minimum tree size and thinning strategies vary from one Malaysian State to another, but rotations are seldom less than 25 years.

Charcoal is also a major product from mangrove forests in Thailand. According to figures given in the Country Report from Thailand, charcoal production from mangrove forests increased steadily between 1970 and 1984, production in the latter year being about 415,000 m^3 (≅ 282,000 tonnes) with a value (in 1984) of 565 million baht (≅ US$22.5 million at present exchange rates). More than 90% of the charcoal produced from mangrove forests in 1984 was derived from forests managed by the Royal Forest Department, private plantations accounting for the remainder. More recent figures are not yet available.

In Thailand, rotations of 15 years or less are usually used for plantations, with no intermediate thinning; rotations of 30 years are used for natural mangrove forest (i.e. that allowed to regenerate naturally following cutting). Based on the very limited data available, the silvicultural practices for plantations in Malaysia and Thailand appear to give similar yields. Wechakit (1987), for example, reported an average standing dry biomass of 151 t ha^{-1} for a 12 year old stand of *Rhizophora apiculata* in the Thai province of Samut Songkram, whereas Ong *et al.* (1984) estimated the standing dry biomass to be 300 t ha^{-1} in a 25 year old stand of the same species in the Matang mangrove forest of Peninsula Malaysia. The total yield from two rotations of 12 years each in Thailand would therefore be about the same as that from one rotation of 25 years in Malaysia. Similarly, the total yield from two 15 year rotations is likely to be similar to that of one 30 year rotation. This is a very simplistic and crude comparison, which does not take into account the additional yield derived from thinnings in the silvicultural practice adopted at Matang. Nor does it take account of likely differences in growth rate due to climatic or soil conditions. However, there may be other advantages, as well as disadvantages, of short rotations. One benefit is that concessionaires granted concessions by the

Royal Forest Department, or private owners, are able to obtain a more regular income from the same area of mangroves. This may be an advantage under some socio-economic conditions. On the other hand, this could be offset by the higher cost of replanting associated with short rotations. There is presently insufficient information to evaluate the relative merits of these different silvicultural strategies.

In Indonesia, charcoal is produced mainly in the Riau province of Sumatra. About 22,000 tonnes was produced in 1983, valued at US$1 million (Indonesian Country Report). Charcoal kilns have also been reported in West Kalimantan, but no data on production are available. It is not known whether silvicultural practices are used in the production of mangrove wood for charcoal in Indonesia.

Commercial extractive forestry operations are not carried out in Thailand or Peninsula Malaysia. However, large areas have been clearfelled for woodchips in the Malaysian states of Sabah and Sarawak. In Sabah an estimated 70,000 ha was cleared for woodchips over a period of about 15 years between 1970 and the mid 1980s, providing employment for about 1500 people, and yielding an annual revenue of about US$5 million (Liew, 1980; cited in the Malaysian Country Report). In Sarawak, as much as 30,000 ha may have been clearfelled for woodchips, providing employment for about 700 workers and an annual revenue estimated to be US$3 million.

Presently, commercial logging of mangrove forests in Indonesia is being carried out in Sumatra, Kalimantan and Irian Jaya, mainly for export to Taiwan and Japan. Comprehensive statistics for sawlog production are not available, but an estimated 383,000 m^3 was exported (presumably from the whole of Indonesia) in 1978 (Burbidge and Koesoebiono, 1980; cited in the Indonesian Country Report). From 1981 to 1983, a further 85,300 m^3 of sawlogs were exported annually from Riau province in Sumatra, and in 1989 West Kalimantan produced 45,800 m^3 of sawlogs. The revenue from sawlog production is not known.

Mangrove forests in Indonesia have also been cut for woodchips and pulp since 1979, when 70,000 m^3 of woodchips were exported from East Kalimantan. Since then the export of woodchips and pulp from Indonesia has risen to an estimated 257,500 m^3 in 1990 (Simbolon, 1991; cited in the Indonesian Country Report). A further area of 137,000 ha of prime mangrove forest in Irian Jaya has been leased for woodchip production.

Extractive exploitation of mangrove forests for sawlogs and woodchips is not sustainable, even in Indonesia which has the largest area of mangroves of any country in the world. Large scale clearing of mangrove forests of the kind involved in harvesting for sawlogs and woodchips can be expected to have major long-term ecological, environmental and socio-economic impacts. These include, amongst others, an increase in coastal erosion, a deterioration in coastal water quality, loss of nursery areas, and a reduction in coastal capture fisheries. Moreover, the revenue from such activities chiefly accrues to large companies or a few individuals; the local people are seldom adequately compensated for the long-term loss of their traditional livelihood and culture.

Mangrove products are used widely for building houses in coastal villages. Many such villages in Indonesia, Malaysia and Thailand are constructed entirely from mangroves, *Rhizophora* and *Bruguiera* species being mainly used for the supporting structures, and *Nypa* palm thatching for the roof and walls. The nibong palm, *Oncosperma tigillaria*, is also widely used in Indonesian coastal villages for stilts and walkways between dwellings.

In most rural coastal villages, fuelwood derived from mangroves is still a major source of energy. Uncontrolled illegal cutting of mangroves for fuelwood is a major cause of mangrove forest degradation in some coastal areas of Thailand and Indonesia.

Experience from the Matang mangrove forest in Peninsula Malaysia has shown that with good multiple-use management practices it is possible to maintain sustained forest and fisheries production without compromising the ecological and environmental values of the ecosystem. For Matang, the total annual revenue from forest products has been reported to be in the order of US$6 million (Ong, 1978), and from fisheries in the order of US$12-40 million (Tang *et al.*, 1981). Both industries together are estimated to provide direct or indirect employment for about 12,500 people. The main drawback of plantation silviculture is the reduction is species diversity, since most plantations are monocultures. This can be offset to some extent by the retention of selected areas of virgin mangrove forest as reserves.

Capture fisheries

While it is well known that a number of commercially important fish and shrimp species utilize or are dependent on mangrove areas for at least part of their life cycle, it is difficult to quantify the connection between fisheries catches and mangroves. Only in the case the large mudcrab, *Scylla serrata*, which is largely confined to mangrove areas, can the connection be demonstrated unequivocally. This species is caught extensively in all three countries for local and, to a lesser extent, export markets. Wong *et al.* (1984) reported a landing of 152 tonnes from a relatively small area of mangroves on the east coast of Peninsula Malaysia, worth an estimated US$125,000 to the local fishermen. Although quantitative data from elsewhere are not readily available, the widespread availability of mudcrabs in local markets indicates qualitatively the commercial importance of this species.

Artisinal and commercial fishing activities are carried out widely in mangrove estuaries. Commercial bagnet fishing in Malaysian mangrove estuaries is reputed to be highly lucrative. About one-third of the commercial fish and shellfish landed in Peninsula Malaysia in 1981 were mangrove associated species, representing a catch of about 209,000 tonnes estimated to be worth about U$250 million annually (see Malaysian Country Report). Artisinal fishing in Segara Anakan lagoon at Cilicap in Indonesia, with an area of 4,000 ha and surrounded by some 14,000 ha of mangroves, produced an annual average of 356 tonnes of fish in the period 1976-1982.

Raft, cage and bottom culture

The culture of grouper (*Epinephelus* spp.) and sea bass (*Lates calcifer*) in floating cages, and mussels and oysters in cages or on poles has been practised in Malaysian mangrove estuaries for many years, and is now almost ubiquitous. Choy (1991) recently reported figures for production of sea bass from cage culture in the waterways of the Matang mangrove forest area in Peninsula Malaysia. In 1990, a total of 26 tonnes of sea bass, worth about US$96,000, was produced by 72 fishermen from an estimated 2,528 cages, providing a gross return of about US$1,330 per fisherman. This practice, which is ecologically compatible with sustainable management of mangroves, is now gaining popularity in Indonesia and Thailand.

Culture of the blood cockle, *Anadara granosa*, on the mudflats adjacent to mangroves is common in many parts of Malaysia. The state of Perak has approved about 3,000 ha of land for cockle culture. Of this, 1,373 ha are in the district of Larut Matang where, in 1990, 48 operators produced 11,385 tonnes of cockes valued at about US$2 million. This activity yielded an annual gross return of about US$41,000 per operator, or about US$1,460 per annum.

Blood cockles and other molluscs (including horse mussel, green mussel and oysters) are also cultivated on a limited scale in Thailand, mainly in the provinces of Rayong, Chantaburi, Chumporn, Phang-nga, Krabi and Satun. According to Department of Fisheries statistics, production fluctuated widely during the period 1978-1982 (see Table 11 in the Thai Country Report). In Indonesia, cockles and oysters are cultured on a limited scale in Jakarta Bay.

Pond culture

The rearing of fish in brackish water ponds has been practised in Indonesia for centuries. In recent times it has become much more widespread and more intensive, as is also the case in Malaysia and Thailand. The present area of ponds in Indonesia is estimated to be about 285,000 ha, mainly in Java, Sumatra and Sulawasi. Formerly milk fish (*Chanos chanos*) was the only species grown in fish ponds, but about 70% of the ponds are now used for culture of tiger prawns (*Penaeus monodon*). Attempts are now also being made to grow *Lates calcarifer* and *Tilapia mossambica* in brackish water ponds. Details of farming techniques are given in the Indonesian Country Report.

Ponds for intensive culture of mainly tiger prawn (*Penaeus monodon*) have been constructed in or adjacent to mangroves in most coastal Malaysian states. Statistics show that in 1987, 600 ha of aquaculture ponds in Johor yielded 245.3 tonne of tiger prawn, which at that time was 80% of the total brackish pond production of Peninsular Malaysia. Reliable statistics on the present area of coastal aquaculture projects in Malaysia were not available for this report.

Similarly in Thailand aquaculture ponds for the culture of mainly shrimp have been constructed in or adjacent to mangroves, mainly in the provinces of Samut Sakorn, Samut Songkram, Samut Prakan, Surat Thani and Nakhon Si Thamarat. Statistics for 1982 indicate that 3,943 aquaculture farms occupying a total area of about 30,790 ha produced 10,090 tonnes of shrimp. Based on the reduction in mangrove forest area over the past decade in Thailand, much of which was converted for shrimp farms, the present area of ponds is likely to be much greater.

As pointed out earlier in this report, conversion of mangroves for aquaculture has been a major cause of the loss in mangrove area in Malaysia and Thailand over the past decade or so. However, mangrove areas are not the most suitable land for aquaculture because of their susceptibility to acid sulphate conditions. While this can largely be overcome by the application of lime, this reduces profitability. There are also a number of other problems, including the risk disease and algal blooms which can kill the shrimp and make the venture unprofitable. In consequence, there have been a number of reports of failed aquaculture projects that have been abandoned or lie idle. It is widely recognized that these activities are not compatible with sustainable management of mangrove ecosystems.

Agriculture, mining and other uses

In the past, considerable areas of mangrove have been converted for agriculture, mainly rice, coconut palm and oil palm. On the whole, conversion of mangrove areas for agriculture has not been particularly successful, owing mainly to the susceptibility of mangrove soils to acid sulphate conditions. The yield from grain crops such as rice are generally much lower on former mangrove than other soils, while the lifespan of coconut trees has been reported to be much shorter when grown on mangrove soils (see Indonesian Country Report). Despite the low success rate of agricultural ventures on converted mangrove soils, conversion of mangroves for agriculture appears to be continuing on a limited scale in all three countries.

Mining, mainly for tin, was formerly carried out in mangrove areas in Thailand, but this practice has decreased markedly in recent years. In Indonesia, only oil mining has been carried out directly in mangrove areas. However, tailings from mining for other materials in areas adjacent to mangroves often have a significant impact on the mangrove ecosystem.

Urban and industrial development, especially near to large cities, has been responsible for significant losses of mangroves locally. Population and development pressures are likely to lead to further alienation of mangroves for urban, industrial and port development adjacent to cities.

Mangroves are also used traditionally and commercially for a number of other products or purposes. These include the production of alcohol, mainly from *Nypa* palm; tannin for dyes, mainly from members of the family Rhizophoraceae; medicinal purposes; fishing gear and other items used in daily life by local dwellers.

In general, only a relatively small proportion of the total mangrove areas in Indonesia, Malaysia and Thailand have been specifically designated and set aside as national parks, nature reserves or amenity forests. Specific examples are described in more detail in the three Country Reports.

Ecological and environmental values

Mangrove ecosystems are recognized as having significant ecological and environmental values. However, it is difficult to quantify these because many of the critical experimental studies needed for this have not been done. Furthermore, while it is possible to generalise some of the ecological and environmental values, geomorphic, hydrologic and climatic differences often dictate the need for quite site-specific studies to identify the particular ecological and environmental values of a given area of mangroves.

Nursery areas

The qualitative importance of mangroves as habitat, nursery and source of food for both commercial fisheries species and other non-commercial fauna is now well established (e.g. Turner, 1977; Blaber, 1980; Blaber *et al*., 1985; Staples and Vance, 1985; Turner, 1986; Robertson and Duke, 1987; Robertson, 1988; Blaber et al., 1989; Blaber and Milton, 1990; Robertson and Duke, 1990a; Robertson and Duke, 1990b; Sasekumar, 10??; Mactintosh et al., 1991; and other references cited in these papers). While there is convincing evidence for the dependency of some commercial and non-commercial species on mangroves for at least part of their life cycle, there is nevertheless considerable spatial and temporal variability in use of specific mangrove areas by many species (Robertson and Duke, 1987). The reasons for this variability are not presently known. In some cases it may be due to differences between estuaries in the abundance of crab larvae or other sources of food, or hydrodynamic and hydrological factors. In other cases it may be associated with the presence or absence of other nearby habitats, such as seagrass beds, which provide shelter or sustenance at other stages in the life history of certain species of fish and shrimp.

Shoreline protection

Coastlines are naturally dynamic. Present coastal landforms and the bathymetry of estuaries, coastal lagoons and other nearshore waters reflect the constant interplay between tidal action, onshore wave action, nearshore ocean currents, and the input of freshwater and sediment from nearby rivers and streams, as well as episodic events such as severe storms and major flooding of coastal streams. Erosion, transport and deposition of sediment in coastal areas in response to persistent (i.e. not episodic) forcing factors follow well-established physical principles (Wolanski *et al.*, 1980; Wolanski *et al.*, 1990; Wattayakorn *et al.*, 1990).

Mangroves are opportunistic colonizers of suitable habitats, mainly along more protected coastlines. The occurrence and extent of mangrove forests locally is thus determined largely by the geomorphic and hydrodynamic processes that shape river deltas, estuaries and other coastal landforms. In general, therefore, mangrove forests do no play an active role in shaping coastal landforms. Once established, however, mangroves modify both the pattern and velocity of water flow in estuaries and thus influence erosion and sedimentation (Wolanski *et al.*, 1980; Wolanski *et al.*, 1990). In addition, the dense underground root system of mangroves, most of which lies just beneath the soil surface, binds the soil surface layers and minimises erosion. Erosion along the concave edges of mangrove-lined river meanders occurs chiefly by undercutting of the mangroves rather than by surface erosion. Even in this case, however, the rate of erosion is less in the presence of mangroves than it would be in their absence. Thus mangroves tend to play a more passive role in stabilising sediments that have been deposited by physical hydrodynamic forces, even in areas that are protected from strong wind and wave action. The extent of this influence varies from one area to another depending on the nature and magnitude of hydrodynamic forcing factors. Clearfelling of large areas of mangrove, or their removal along seaward margins may give rise to significant long-term changes in patterns of erosion and sedimentation, leading to siltation of estuaries and offshore coastal lagoons and necessitating regular dredging to maintain boat access.

It is often argued that mangroves mitigate the impact of cyclones, hurricanes and other severe storms in coastal areas. Fosberg (1971), for example, suggested that the effect of the hurricane and tidal wave that devastated Bangladesh in 1970 and claimed more than a hundred thousand lives may not have been so severe if large areas of mangrove had not been cleared to make way for rice paddies. It is difficult, however, to substantiate such claims quantitatively because of the lack of effective controls. Nevertheless, the circumstantial evidence tends to support these claims.

Nesting, stopover and feeding sites for migratory birds

In general, the use of mangrove areas as nesting, stopover and feeding sites for resident and migratory bird populations has not been as widely documented as that of the marine fauna, undoubtedly owing in part to the presumption that birds have little economic value. Nevertheless, there is increasing evidence that mangroves and their associated tidal mudflats are key nesting and foraging sites for many migratory bird species (see Malaysian Country Report). Silvius *et al.* (1987), for example, estimated a peak bird population of up to 60,000 individuals of at least 32 species on the west coast of Peninsula Malaysia, and calculated that a total of up to 400,000 waders visited this coastline annually.

The dependency of resident bird populations on mangroves, either for nesting sites or for foraging is not clear. In general, it appears that the majority of resident species utilise mangroves opportunitistically for foraging and in some cases for nesting (Schodde et al., 1982). Small numbers of one endangered species, the Chinese Egret (*Egretta eulophotes*), have been reported at two sites on the west coast of Peninsula Malaysia (see Malaysian Country Report).

The of mangrove ecosystems and their associated mudflats and waterways as nesting, stopover and feeding sites for migratory birds has been a somewhat neglected ecological value of these ecosystems. Limited data appear to be available for only a few specific mangrove areas.

Water quality

Most evidence suggests that mangrove systems act as a sink for dissolved nutrients rather than as a source of dissolved nutrients outwelling into adjacent coastal waters (Nedwell, 1974; Nedwell, 1975; Odum and Johannes, 1975 - cited by Hatcher et al., 1990; Clough et al, 1983; Nixon et al., 1984; Boto and Wellington, 1988). Mangrove ecosystems therefore probably play an important role in sequestering inorganic dissolved nutrients and other potential pollutants from coastal streams and rivers that would otherwise be discharged into neighbouring coastal lagoons, coral reefs and other nearshore ecosystems. Soil and foliar nutrient concentrations, and the growth rates of mangrove trees, are higher in areas enriched by external inputs of inorganic nutrients, particularly nitrogen and phosphorus, than in adjacent areas that do not receive external inputs (Onuf *et al.*, 1977; Boto and Wellington, 1983; Clough *et al.*, 1983). In this connection, it has been suggested that mangrove systems might be used as a tertiary treatment site for sewage to remove dissolved nutrients (Nedwell, 1974, Nedwell, 1975; Odum and Johannes, 1975 - cited by Hatcher et al. 1990; Clough et al., 1983), provided that the input of particulate organic carbon to the mangrove ecosystems is minimised (Clough et al., 1983; Saenger et al., 1983).

Primary and secondary production

The primary productivity of mangrove forests varies enormously across the wide range of localities and environments in which mangroves grow (Lugo and Snedaker, 1974; Clough, 1992). Under favourable conditions of persistent cloud cover, high rainfall and moderate soil salinities, typical of moist equatorial coastlines, the net above-ground primary productivity may be of the order of 20-40 tonnes dry matter ha^{-1} yr^{-1} (Ong et al., 1984; Clough, 1992). This high net primary productivity, which is comparable to that of many other kinds of forests, forms the basis of the utilization of mangrove forests for timber products. Most of the available data for above-ground net primary production relates specifically to managed monospecific stands of *Rhizophora* spp., which are the main species used for timber, firewood and charcoal production. However, limited data also exist for other species in natural stands of mixed species (Lugo and Snedaker, 1974; Putz and Chan, 1986; Devoe, 1992; Clough, 1992). The high net primary productivity of the trees themselves may be supplemented by primary production by other photosynthetic organisms, including plankton in the water column of mangrove waterways (*c* 4 t C ha^{-1} yr^{-1}; Ong et al., 1984) and benthic algae (Heald, 1971).

Leaf litter, fallen branches and other wood, dead roots, propagules, and organic exudates (mainly from mangrove roots) provide a rich source of carbon and other nutrients for an extremely large range of secondary consumer organisms across all trophic levels. Mangrove sediments support large bacterial populations (10^5 - 10^7 cells g^{-1} dry weight of soil; Alongi, 1989), which accounts for their high bacterial productivity (up to about 1.1 g C m^{-2} day^{-1}; Alongi, 1989). Counts of fungi, using the technique of dilution plating, range from 10^2 to 10^7 counts g^{-1} dry weight of soil (Alongi, 1989). Mangrove sediments also support significant populations of meiofauna (Alongi, 1989).

Microbes, fungi, meiofauna and macrofauna all play a major role in organic decomposition and nutrient regeneration in mangrove ecosystems. Of particular interest is the role of crabs, mainly sesarmids, which in some mangrove ecosystems are responsible for consumption and cycling of up to 80% of the litter fall (Robertson and Daniel, 1989). Geographic and topographic variation in the relative contribution of different secondary consumers to decomposition and cycling of organic detritus has been discussed by Hatcher *et al.* (1989).

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Draft guidelines for sustainable utilization and management of mangrove ecosystems.

Introduction

The contribution of mangroves to the environmental and ecological health of tropical coastlines is now widely acknowledged. In addition, mangroves supply a wide range of forest products, sustain important coastal capture and culture fisheries, and provide valuable socio-economic benefits to local indigenous human populations. Generally, however, it appears that the economic benefits of mangroves to national, regional and local economies are still much undervalued. In consequence, the destruction, degradation and mismanagement of mangrove areas remains widespread.

Several States have formulated national or regional management guidelines for the management of mangrove areas. However, these are often not widely known and seldom implemented. There is therefore a need for management guidelines that are more widely disseminated and more generally applicable. It is hoped that the present guidelines for utilization and management of mangroves will satisfy this need.

Mangroves grow at the interface between the land and the sea, where they are impacted upon by events and processes that occur both to their landward and seaward. The term "Mangrove Forest" conveys a misleading image that mangrove ecosystems stop at the margins of the vegetation, thereby excluding the estuarine and nearshore waters and mudflats, as well as the terrestrial hinterland, with which they are commonly associated. Given the close links and interdependence of mangroves with their neighbouring ecosystems, it is in fact difficult to identify the boundaries between them and their landward and seaward neighbours. In these guidelines, mangrove ecosystems are considered to include the area between the extreme highest and lowest tide level, including all parts of rivers and estuaries bordered by mangroves, and adjacent tidal mudflats, with the further provision that migratory fauna and traditional indigenous human inhabitants and users are regarded as an integral part of the ecosystem.

Since mangrove ecosystems are such an integral part of the coastal zone, their utilization and management should be considered within the framework of a broader coastal zone management strategy, in which equal attention is given to both nearshore areas and the terrestrial hinterland. Although this is beyond the scope of the present guidelines, it is nevertheless strongly recommended that they be implemented within such a framework.

The International Society for Mangrove Ecosystems (ISME) recently adopted a "Charter for Mangroves" that embodies a set of principles for the conduct of all activities related to mangrove ecosystems. These principles form the underlying philosophy of the present guidelines. The detail of the guidelines and specific recommendations represent a synthesis of material provided in the Country Reports from Indonesia, Malaysia and Thailand which form part of the ISME/JIAM/ITTO Regional Project entitled "Assessment of the Present State of Conservation and Management of Mangroves in South-East Asia and the Pacific". Material from other sources has also been included where acknowledged. The format for these guidelines broadly follows that of the ITTO Guidelines for the Sustainable Management of Natural Tropical Forests.

Policies & General Principles

- ☐ Rational management of mangrove ecosystems is essential to sustain essential environmental and ecological values, to provide for the livelihood and well-being of coastal populations, and to ensure sustainable development and the maintenance of national prosperity.

- ☐ States have a sovereign right and a responsibility to manage their mangrove areas in accordance with national goals and aspirations. Nevertheless, it must be acknowledged that mismanagement of natural resources, including mangrove areas, may lead to deleterious environmental and economic impacts both on neighbouring States, and on a regional and global scale. States should therefore be mindful of the impact on other nations of their national policies and strategies for the management of their mangrove areas.

- ☐ Sustainable management of mangrove and other coastal wetland ecosystems requires a strong and continuing political commitment at national, regional and local government levels.
- ☐ Policies and strategies for sustainable management of mangroves should be developed in the context of a national policy aimed at the sustainable use of all natural resources, both terrestrial and marine.
- ☐ A single agency should be assigned to provide overall coordination of all other agencies whose terms of reference and administrative responsibilities encompass mangrove ecosystems.
- ☐ A **National Mangrove Inventory** should establish the environmental, ecological, economic and socio-economic importance of all mangrove areas.
- ☐ Based on the findings of a National Mangrove Inventory, all mangrove areas should be assigned to one or other of the categories: Mangrove Conservation Reserve, Mangrove Forest Reserve, Mangrove Fisheries Reserve and Alienable Mangrove Land.
- ☐ Apart from Alienable Mangrove Land, all areas of mangrove should be kept and managed on a sustainable basis as **Permanent Mangrove Estate** to ensure the maintenance of essential environmental and ecological values and/or to secure their optimal contribution to national prosperity.
- ☐ Rational management goals should be set for each mangrove management unit, in accordance with the primary objectives for management of the category of mangrove land to which it has been assigned.
- ☐ The designation of mangrove areas for particular uses, the setting of management goals, and the formulation of strategies for achieving those goals should accomplished by consensus of those involved, including representatives from government, professional scientists, the private sector, the local population and special interest groups.
- ☐ Legal provisions need to be made for appropriate mechanisms of appeal by any party against policies or actions perceived to be in conflict with their interests.
- ☐ An agreed policy for mangroves should be supported by appropriate legislation that is consistent with legislation in related sectors. Laws and regulations should be enacted at the appropriate government level to support the agreed policy related to mangrove ecosystems.
- ☐ Mechanisms should be provided for regular revision of policy based on changing circumstances and the availability of new information.
- ☐ Adequate funding for research and monitoring should be provided

Categories of Mangrove Land

Following a national inventory, all mangrove areas should be allocated to one of the categories described below:

A. Permanent Mangrove Estate

The Permanent Mangrove Estate should encompass all mangrove areas that are to be kept and managed on a sustainable basis to maintain essential environmental and ecological values, and/or to secure their optimal contribution to national prosperity. Such areas should include:

1. Mangrove Conservation Reserve.

Protected areas of mangrove that are set aside for conservation, recreation and scientific studies. These would include:

a) **Fragile areas** to be kept as permant mangrove estate where perturbation would lead to unacceptable changes in:

- sediment transport or loading to nearshore areas
- deterioration in water quality
- increased erosion
- loss of protection from storms and storm surges.

b) **Conservation areas** set aside for plant and animal species and ecosystem preservation, such as:

- a representative sample of an ecosystem
- areas of high biodiversity
- areas linking or contiguous with other coastal wetland ecosystems
- areas of high conservation value as unique habitats for eco-tourism
- habitats for rare orendangered species of flora and fauna, including foraging and migratory species
- areas identified as of special value for scientific research
- areas identified as of special value as educational and recreational amenities

2. Mangrove Forest Reserve

Forest designated specifically for sustained production of timber, including firewood, charcoal production, poles, and other forest products. Areas of the mangrove palm, *Nypa fruticans*, designated for the production of sugar, alcohol, thatching and other products should be included in this category of the mangrove estate. Productive mangrove forest can and should be managed where possible with protection and/or nature conservation as recognized secondary objectives. In particular, multiple use management of productive mangrove forest should aim to provide for:

- a sustainable supply of forest products
- a sustainable nursery and feeding ground for coastal capture fisheries
- a suitable habitat for raft culture of oysters, mussels and fish in neighbouring estuarine waters
- a suitable habitat on adjacent intertidal mudflats for the culture of cockles and other benthic fauna of commercial significance

3. Mangrove Fisheries Reserve

Mangrove areas and their associated waterways, not already designated as Mangrove Conservation Reserve or Mangrove Forest Reserve, that have special value as nursery areas for capture fisheries, and/or for commercial raft culture of fish, oysters and other filter feeders. In the event that management as a forest reserve is incompatible with management strategies for fisheries reserve, one or other of the management strategies should be designated as the primary goal according to national, regional or local priorities.

B. Alienable Mangrove Land

Mangrove areas that have been designated in national or regional land use plans for possible future conversion to other uses. Alienable Mangrove Lands comprise those areas that could be converted to other uses such as pond aquaculture, agriculture, or reclamation for urban and industrial development without compromising unacceptably the attributes identified as being critical in designating the Permanent Mangrove Estate. Such areas might include, for example, the less productive forest areas or those of little value for either Mangrove Conservation Reserve or Mangrove Fisheries Reserve Nevertheless, these areas should be managed efficiently either as protected or production mangrove areas until required for conversion.

Guidelines for Sustainable Management and Utilization

General Recommendations

The general recommendations made below apply equally to activities in all mangrove areas irrespective of their categorical designation.

- ☐ Within the scope of the agreed general policies for sustainable management of mangrove ecosystems (Section I), appropriate specific management goals and practices should be identified and implemented for each mangrove management unit.
- ☐ Appropriate laws and regulations should be enacted and enforced to ensure compliance with agreed management policies and practices for each mangrove management unit.
- ☐ The best available technical and managerial advice should be made available to operators and concessionaires from an appropriate designated government authority. Agents of the designated authority should be responsible for enforcement of agreed management policies and practices.
- ☐ There should be a buffer zone between mangrove areas and any adjacent

development, the minimum width of which should be:

Industry:	1,000 m
Housing:	500 m
Tourist:	100 m

Pond Aquaculture: See specific recommendations under this section below

- ☐ An **Environmental Impact Assessment** and **Feasibility Study** should be required for all development projects involving the clearance of mangroves, and for development projects adjacent to mangrove areas.

- ☐ Development to the seaward, estuarine or riverine side of mangrove areas poses a high risk of altering the bathymetry and hydrology of adjacent mangroves, particularly where dredging and/or spoil deposition is involved. In general, such activities should not be permitted. In cases where such activities are proposed, a detailed study of water currents and sediment transport should be required to determine both the short term and long term consequences of the proposed activities. Where possible, use should be made of appropriate hydrological models.

- ☐ The construction of dams, barrages and other engineering works, as well as the clearing of land for agriculture and changing land use practices in upstream catchments, inevitably alters the delivery of fresh water and sediment to mangrove areas further downstream. An Environmental Impact Assessment which includes as assessment of the impact on mangrove ecosystems should be carried out before such activities are permitted.

- ☐ Strict pollution controls should be established and enforced for development adjacent to mangroves to prevent entry of any effluent discharge or waste into mangrove areas.

- ☐ Where necessary, effective physical barriers should constructed to minimise the runoff or leaching of wastes from disposal sites into adjacent mangrove areas. Particular attention should be given to preventing seepage of contaminated groundwater into mangrove areas.

- ☐ Mangrove areas fronting coastal bunds should be gazetted as Mangrove Conservation Reserves for protection against shoreline and riverbank erosion.

Pond Aquaculture

- ☐ Pond aquaculture should not be permitted within areas designated as Mangrove Conservation Reserve, Mangrove Forest Reserve or Mangrove Fisheries Reserve. The following recommendations are made with respect to priorities for the location of ponds and the minimum width of the buffer zone:

  - non-mangrove areas, with a minimum buffer zone width of 100 m between the pond site and mean high tide level;
  - mangrove areas previously reclaimed for other purposes, but now under-utilised, unproductive or abandoned; for example, areas reclaimed for agriculture that are no longer productive or utilised owing to acid sulphate or saline soils; a minimum buffer zone width of 100 m between the pond site and mean high tide level;
  - alienable mangrove areas available for conversion, with a minimum buffer zone width of 100 m between the pond site andthe mean high tide level;
  - to the landward of less productive Mangrove Forest Reserve, with a minimum buffer zone width of 100 m between the mangrove area and the pond;
  - to the landward of, but not in, productive Mangrove Forest Reserve or Mangrove Fisheries Reserve, with a minimum buffer zone width of 200 m;
  - should the use of existing mangrove areas be inevitable, ponds should be sited in the upper intertidal areas near the landward edge of the mangroves. These are considered to be less productive for forestry, of less significance as a nursery and fisheries habitat, and of lesser importance for coastal protection, than mid and low intertidal areas.

- ☐ With respect to the location of ponds and the width of buffer zones, and subject to the priorities outlined above, it is further recommended that:

- along accreting shorelines there should be a minimum 200 m wide buffer zone between the pond site and the seaward edge of the mangrove forest;
- along stable and eroding shorelines there should be a minimum 400 m wide buffer zone the pond site and the seaward edge of the mangrove forest;
- there should be a 50 m wide buffer zone along all rivers between the pond site and the riverbank;
- where ponds are constructed to the landward side of mangrove areas, there should be a minimum distance between adjacent projects of more than 4 times the length of the coastline occupied by the larger of the two projects; this recommendation is based on the fact that access to brackish water is likely to require the construction of a channel cut through the mangrove area.

☐ Ponds should be constructed with minimum excavation to minimise problems associated with acid sulphate soils.

☐ Pumping rather than tidal fluctuation should be used to regulate the water regimes of ponds.

Capture Fisheries

☐ While the relationship between mangroves and coastal capture fisheries is difficult to quantify, efforts should be made to establish the mangrove dependency and site specificity of coastal fisheries.

☐ Monitoring of fishing activity and fisheries catches should be carried out to ensure the sustainability of coastal fisheries. Monitoring activities should include:

- size and number of boats involved;
- number of subsistence and commercial fishermen;
- the species of fish caught, their size and their number;
- recruitment of juveniles.

☐ Based on the data obtained from monitoring activities, management plans should be developed and regularly revised to at least maintain and preferably to increase the catch from mangrove associated capture fisheries. In developing management plans, particular attention should be given to:

- regulation of fishing pressure and fishing techniques to ensure sustainability of coastal fisheries;
- an appropriate compromise between the needs of larger commercial fishermen and those of local subsistence fishermen;
- maintenance of nursery areas to ensure adequate restocking rates;
- the possibility of zoning specific areas for different end users and/or fishing techniques.

Raft and Cage Culture

☐ The culture of oysters, mussels, fish, shrimp and other suitable edible fauna in rafts and cages in mangrove waterways should be actively encouraged and promoted as a sustainable alternative to pond aquaculture.

☐ Rational management plans should be developed for each estuary to ensure:

- optimal density and spacing of rafts or cages;
- acceptable annual levels of commercial production;
- the maintenance of an acceptable level of water quality

Forestry

☐ Rational forestry management or working plans should be developed for each mangrove forest reserve. The needs for conservation and protection of critical habitats should be incorporated. Working plans should ensure that all field operations should include consideration of:

- the sequence of areas to be harvested annually (annual allowable cut;
- the size and shape of harvest coupes;
- areas to be excluded from harvesting for conservation purposes;
- harvest and extraction techniques;

- regenerative capacity and techniques, including the number and distribution of seed trees to be left, the need for manual replanting, availability and cost of propagating material, and the necessity and procedures for weed control during early stages of regeneration;
- establishment of seed stands;
- planning and implementation of planting programmes.

☐ Major forest harvesting projects should be subjected to environmental impact assessment and monitoring.

☐ Attention should be given to the aspirations and socio-economic needs of local communities to ensure employment opportunities and equity in the distribution of income from forestry operations.

Criteria for Designating Uses

The designation of any area of mangrove land as Mangrove Conservation Reserve, Mangrove Forest Reserve or Alienable Mangrove Land should be made only after careful consideration of all resource inventory and other information available. Specific criteria for assessment may vary from one country to another, and from one locality to another. However, the designation of mangrove areas for any particular use should include, where posssible, consideration of the following parameters:

☐ The extent and characteristics of the resource, including:

- location in relation to other coastal ecosystems;
- areal extent;
- stand structure and species composition;
- basic physical and chemical characteristics, including hydrologic and hydrodynamic conditions, climate, and soil characteristics;
- age and history of utilization and management;

☐ Ecological and environmental significance in terms of:

- coastal stability, protection against erosion, and land accretion;
- role as a nursery for coastal marine species, of both commercial and non-commercial value;
- significance as special examples of a unique ecosystem;
- significance as habitat for wildlife, and as foraging or migratory stop-over sites for rare or endangered birds;
- significance in maintaining coastal water quality and in regulating flood water.

☐ Their commercial significance and sustainability (both ecological and economic), including a cost/benefit analysis, in terms of:

- subsistence and commercial capture fisheries;
- commercial raft and cage culture of fish, shrimp and shellfish;
- bottom culture of cockles and other benthic species;
- forestry and forest products, including an assessment of potential for sustainable production over at least 3 rotations of 20 years or more (or 5 rotations of 12 years or more), depending on the designated end product (e.g. sawlogs, firewood, poles, charcoal);
- alternative forms of land use.

☐ Their socio-economic significance to local indigenous people in terms of:

- traditional values and forms of utilization;
- subsistence and dependency of local populations on mangrove ecosystems.

☐ The possible impact of a rise in sea level and expected changes in climate.

Condition, socio-economic values and environmental significance of mangrove areas in Indonesia.

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Introduction

The economic development that is currently being undertaken by the Indonesian Government forms an all out effort directed toward optimal and sustainable utilization of natural resources and living environment. Mangrove area constitutes one of the natural resources and it plays a very important role in the development of Indonesia. As such, its optimal and sustainable utilizations are now given the highest priority.

Mangrove area development is presently aimed to capture the maximum benefit through multifaceted utilization, while at the same time maintaining its sustainability. In other words, in the effort to get the maximum benefit, care should be taken that the resource remains ecologically in a state of equilibrium, harmonious and sustainable, so that it is capable of maintaining its function as human life support system.

Mangrove ecosystem is an important element in fishery and nature protection, especially wildlife and coastal area. It develops in the intertidal area along the low lying Indonesian coast. Like its terrestrial counterpart, mangrove ecosystems can provide a variety of invaluable benefits for the society at large if properly and wisely managed.

Mangrove ecosystem in Indonesia is estimated to cover an area of 4.25 million hectares. Even if it is only about 2% of the entire land territory, nonetheless its economic and environmental values should not be underestimated. Therefore, its presence must be maintained. Being a transition zone between terrestrial and marine ecosystems, the mangrove ecosystem has been known for long to have multiple functions and constitutes an important link in maintaining biological equilibrium in the coastal ecosystem. It has been utilized since long time in the past, either for its forestry products or for other non-forestry purposes.

This article is an attempt to provide information on the present condition, socio-economic value and environmental significance of mangrove area in relation to the national development of Indonesia.

General description

Area and distribution

Indonesian archipelago is composed of some 17,508 islands, with land area covering over 1.93 million km^2 and an estimated coastal line of more than 81,000 km. Mangrove habitats are found on all coastal areas, except those that are steep and rocky. The width of the forest varies from a few meters to several kilometers.

Data on the extent and distribution of mangrove areas in Indonesia were obtained by aerial and field surveys, using maps of 1:500,000; 1:100,000; and 1:50,000 scales.

This technique of observation covered only mangrove areas which have a width of 500 m and a length of at least 5 km along the coast. Thus, mangrove communities that are less than the above measurements as well as those that do not form a forest are excluded from the map.

Aerial photographing and mapping throughout Indonesia started in 1970 using updated technology and were completed in 1982, except for some areas that were always covered by cloud. Refinement of the maps and the data is underway.

Based on the results of aerial and field surveys, the Indonesian mangrove land covers a total area of 4,255,011 ha. It is distributed over all Indonesian provinces, except West Sumatra, Bengkulu (Sumatra) and Timor Timur. Table 1 and Fig. 1 show the distribution and extent of mangrove resources in Indonesian provinces. Unless undergoing human disturbance, the extent of mangrove areas may remain unchanged. As a result of the effort to maintain saline water behind

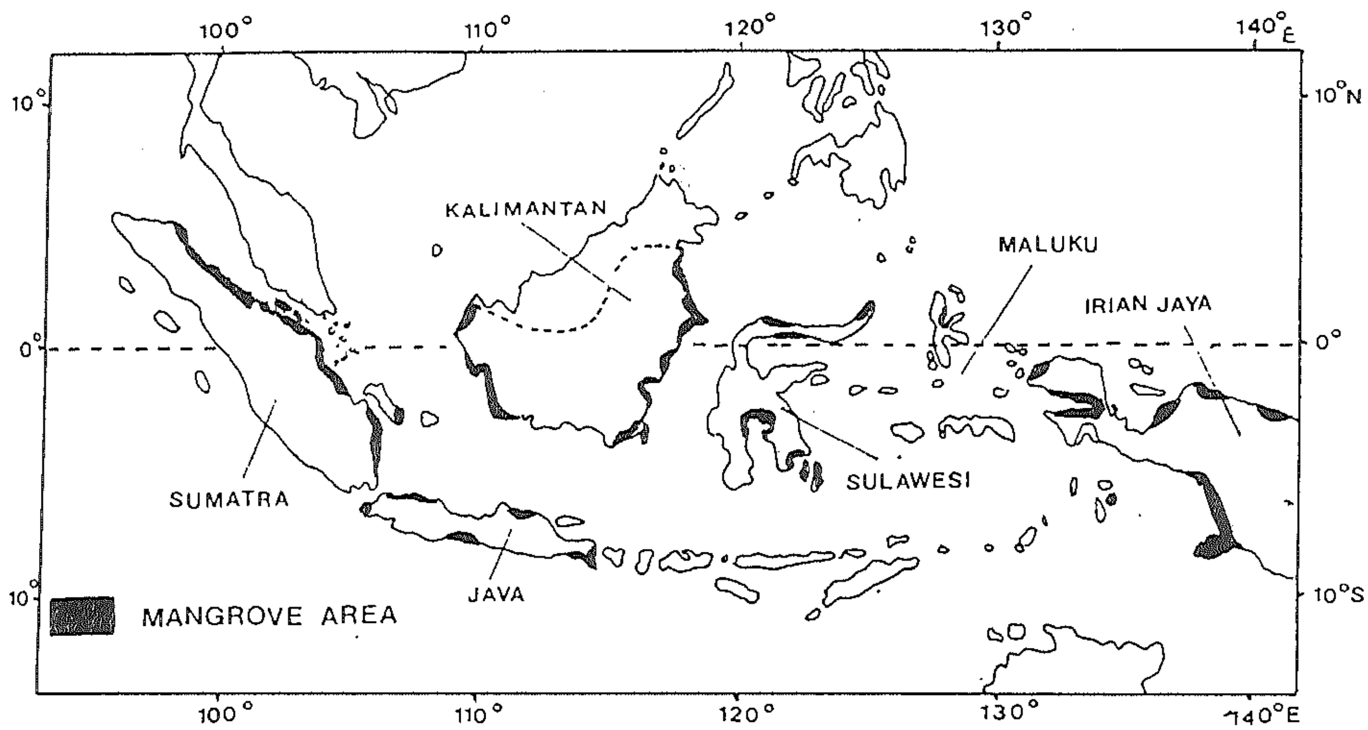

Figure 1. Distribution of mangrove areas in Indonesia (not to scale; slightly modified from Martosubroto & Naamin 1977)

mangrove forest, for example by converting the land behind mangrove forest into brackish water fishponds, while at the same time allowing coastal accretion processes to continue, the extent of mangrove land is likely to increase. This phenomenon may be seen e.g. in the north coast of Java and in Sulawesi. By contrast, conversion of mangrove land for agriculture will decrease mangrove forest land. This situation is happening for instance in Cilacap, Central Java.

Vegetation

The natural vegetation of mangrove forest consists of a variety of mangrove plants and nipah. Pure stand or associations may occur for some species.

Table 1. Areal distribution of mangroves in Indonesia (ha).

No.	Province	Total Area	Area for log production	Area for conservation
1	2	3	4	5
A. SUMATERA				
1	Aceh	54,335	31,000	15,150
2	North Sumatra	60,100		11,500
3	West Sumatra	-	-	-
4	Riau	276,000	123,000	60,000
5	Jambi	65,000	-	26,000
6	Bengkulu	-	-	-
7	South Sumatra	195,000	19,000	30,000
8	Lampung	17,000	-	1,000
B. KALIMANTAN				
9	West Kalimantan	40,000	39,000	-
10	Central Kalimantan	10,000	10,000	-
11	South Kalimantan	66,650	48,000	17,800
12	East Kalimantan	266,000	103,000	128,000
C. JAVA				
13	West Java	28,513	-	7,800
14	Jakarta	95	-	15
15	Central Java	13,576	-	1,000
16	Yogyakarta	-	-	-
17	East Java	7,750	-	2,430
D. NUSATENGGARA				
18	Bali	1,950	-	1,950
19	West Nusa Tenggara	3,678	-	2,500
20	East Nusa Tenggara	1,830	-	-
21	East Timor	-	-	-
E. SULAWESI				
22	North Sulawesi	4,835	-	1,000
23	Central Sulawesi	4,000	-	-
24	South East Sulawes	29,000	-	1,500
25	South Sulawesi	66,000	-	1,500
26	Moluccas	100,000	-	21,600
27	Irian Jaya	2,943,000	360,000	267,000
Total		4,254,312	733,000	597,745

* Forestry Department 1982

\+ Various sources

In a number of localities, pure stands of nipah occur, covering extensive areas. The dominant form of vegetation is governed by ecological factors, particularly the edaphic factors. For that reason, mangrove community is commonly classified as an edaphic-climax vegetation formation type.

On the basis of the dominant species, Indonesian mangroves take the form either as consociation or association (mixed stand). Five consociations are recognized, i.e. *Avicennia* consociation, *Rhizophora* consociation, *Sonneratia* consociation, *Bruguiera* consociation and *Nypa* consociation.

Their presence and condition are determined by ecological factors, such as tidal regime, waves and currents, salinity and soil mineral content, particularly those in the forms of clay, silt and sand. Occurrence of four consociations in one locality is very rare, e.g. in Cilacap mangrove. One or two consociations in one locality can be found more often.

In some places especially at the coast of the deep sea, the mangrove community forms only a thin strip along the coast. Quite often species of *Bruguiera* are mixed with old formations of *Rhizophora*. A complete association of all species of mangrove seems unlikely to be found in Indonesian mangrove, usually not more than four genera. However, these associations are frequently not homogenous due to the fact that the stand is not a climax, but is a transitional formation. The sequence of consociation formation starting from the water edge toward the dryland is *Avicennia, Sonneratia, Rhizophora* and *Bruguiera*. Behind the *Bruguiera* consociation, a mixed community or association usually occurs. It is composed of species of Rhizophoraceae in association with various species of plants from other families, including some marginal dryland species. Plant species that may be found in Indonesian mangrove land are presented in Table 2.

The forested mangrove land in Indonesia is estimated to cover an area of approximately 1,537,000 ha or around 32 % of the total mangrove land (4.25 million ha). Surveys to determine the extent and density of mangrove forest have been done only in those regions allocated for leasing to enable formulation of wood production plan. Table 1 column 4 lists the forest areas that have been leased for wood production. Based on the results of the surveys, it is clear that the forest structure and stand density of Indonesian mangrove are influenced more by local ecological factors than by geographical ones. Table 3 shows the range of average number of stems and volume of trees per hectare.

Meanwhile , mangrove forests that exhibit high stand density were found at Aceh (Sumatra), Riau (Sumatra), Estuary of Kapuas River (West Kalimantan), Estuary of Sesayap (East Kalimantan), Segara Anakan (Central Java), Benoa (Bali), and Bintuni and Cendrawasih bay (Irian Jaya). These localities have stand volumes of more than 40 $m^3 ha^{-1}$.

The mixed mangrove community, which commonly includes some plant species that grow in swamps, wet lands and dray low lands, is actually a transition form between mangrove community and dry land community. The following are the characteristics of such a community:

Among the plant species composing the transition community there are old *Bruguiera* trees, distributed sparsely among other species occurring in the area. These old *Bruguiera* trees are the remnants of the once existing *Bruguiera* consociation.

- Among the plant species composing the transition community there are old Bruguiera trees, distributed sparsely among other species occurring in the area. These old Bruguiera trees are the remnants of the once existing Bruguiera consociation.
- Non-mangrove species usually are bushy trees with small diameter, except for some species of Moraceae which can attain large size, namely *Ficus, and Xylocarpus,* Meliaceae.
- The common dry land species occurring in the transition area are *Vitex cofasus, Hibiscus tiliaceus, Dillenia* spp., *Calophyllum* spp. and *Pandanus* spp.

Bushy mangrove communities may also be found in some places, particularly on the river banks. In term of areal extent, however, they are very limited. The stand is usually dominated by bushy plants, such as *Aegiceras* sp., *Scyphiphora* sp., *Lumnitzera* sp., *Hibiscus* sp., *Eugenia* sp., and *Pandanus* spp.

Nypa fruticans is a plant species that may form an extensive pure stand in many areas. Very often nipah stands occur behind true mangrove stand. They are most extensive in the northern part of South Sumatra, at the Kapuas estuary and in

South Kalimantan. Presently, a project has been initiated to exploit nipah forest for brown sugar production in South Kalimantan.

Fauna

As suggested earlier, exclusive mangrove fauna is most probably non-existent. In other words, no animal is truly an obligatory mangrove dweller. It is true, however, that some species are very closely associated with mangrove communities. These include mostly animals belonging to the marine elements, such as *Ellobium aurisjudae* (Gastropoda), *Thalassina anomala* (Crustacea) and *Periophthalmus* spp. (Pisces).

For the terrestrial elements, their attachment to mangrove ecosystem is very loose. They come and go following their living needs. Nonetheless, one species of primate, the proboscis monkey (*Nasalis larvatus*) shows a very close association with mangrove. This monkey, an endemic species to Kalimantan, is always found in the mangrove forest, feeding on the young leaves of *Avicennia* and *Sonneratia*.

The marine elements are the principal mangrove fauna (Soemodihardjo 1986). They are dominated by molluscs and crustaceans. The molluscs are composed mainly of the Gastropoda and are dominated by two families, namely the Potamididae and the Ellobiidae. As for the crustacean, it is composed mainly of the Brachyura. Some species live aggregatively in large numbers, e.g. *Terebralia palustris* and *Telescopium telescopium* (Gastropoda); *Sesarma* sp. and *Uca* spp. (Brachyura). Both the molluscs and crustacean constitute a principal element in the detritus-based wood-web nutrient cycling of the mangrove litter by fragmenting it into smaller pieces, providing easy access for the microorganism to work it further into dissolved material. Table 4 present the molluscan and crustacean species from Indonesian mangrove.

Soil

Research on mangrove soil has been done in some localities in Java, such as in Cilacap and in northern coast of Java. Outside Java, on the other hand, works on mangrove soil are very limited. Available records indicate that studies were done in Jambi (Sumatra) and in Berau estuary (East Kalimantan). Preliminary soil observations were done in some localities in Moluccas and Irian Jaya.

On the basis of this limited information, there is the indication that the extent, vegetation types, density of stand and species composition of Indonesian mangrove forest are determined mainly by edaphic and hydrological factors such as the composition and texture of soil, tidal regime, coastal topography, water depth, salinity, waves and currents, and the chemical properties of surrounding waters.

Generally speaking, mangrove soils, which may develop to a depth of 200 cm, have the following characteristics:

- high salinity as indicated by high electric conductivity (more than 20 m mhos cm^{-1}), sodium ion saturation and high sodium absorption ratio;
- high content of clay, usually more than 40%; together with silt, clay constitutes more than 80% of the volume of the soil mineral. The lower the clay and silt contents the lower the biodiversity and the stand density of the forest.
- no clear development of soil horizon is apparent; organic carbon content relatively high (3.5% to more than 17%).
- highly sulfidic as indicated by high content of pyrite (over 1.2 %), hence is classified into sulfaquent soil.
- mostly unripe, hence is classified into "entisol". Ripe soil has a Ripeness Index (n) of less than 0.5. The n values of Indonesian mangrove soil are mostly greater than 0.7.
- cat clay usually occurs; ionic status of sodium, magnesium and calcium mostly follows the following order: Na > Mg > Ca. Observations made at several mangrove sites suggested that the clay and silt contents of the soil strongly influence the composition and density of mangrove community. High clay and silt contents provide stronger support for the development of high plant density and rich species composition.

Below are the recorded properties of Indonesian mangrove soil from some localities.

Java

Segara Anakan (Central Java)

Physical composition: Clay, 53 - 86%; silt, 6 - 13 %; organic matter, 24 - 56 %.

Table 2. Plant species found in mangrove areas (Preliminary checklist compiled by Stephan Wulffraat)

Ground Ferns	
Pteridaceae	*Acrostichum aureum*
	Acrostichum speciosum
Blechnaceae	*Stenochlaena palustris*
Epiphytic ferns	
Adianthaceae	*Vittaria sp.*
Aspleniaceae	*Asplenium nidus*
Davalliaceae	*Davallia sp.*
	Humata parvula
Cycads	
Cycadaceae	*Cycas rumphii*
Polypodiaceae	*Cyclophorus cinnamoneus*
	Drymoglossum heterophyllum
	Drynaria sp.
	D. rigidula
	D. sparsisora
	Nephrolepis acutifolia
	Phymatodes scolopendria
	Ph. sinuosa
	Platycerium coronarium
Schizaeaceae	*Lygodium laxum*
Epiphytic herbs	
Asclepiadaceae	*Dischidia benghalensis*
	D. rafflesia
	D. nummularia
	Hoya sp.
Orchidaceae	*Aerides odorata*
	Anota violacea
	Bulbophyllum xylocarpi
	Cymbidium sp.
	Dendrobium aloifolium
	D. callibotrys
	D. pachyphyllum
	D. prostratum
	D. rhizophoreti
	D. subulatum
	D. teretifolium
	Oberonia laeta
	O. rhizophoreti
Melastomatceae	*Prachycentria constricta*
	Plethiandra sessilifolia
Rubiaceae	*Hydnophytum formicarum*
	Myrmecodia sp.
Parasites	
Loranthaceae	*Amyema gravis*
	A. mackayense
	Viscum ovalifolium
Ground herbs	
Acanthaceae	*Acanthus ebracteatus*
	A. ilicifolius
	A. volubilis
Aizoaceae	*Sesuvium portulacastrum*
Asteraceae	*Pluchea indica*
Chenopodiaceae	*Tecticornia australacia*
Araceae	*Colocasia esculenta*
	Cryptocoryne ciliata
Grass-shaped herbs	
Cyperaceae	*Cyperus compactus*
	C. compressus
	C. javanicus
	C. malaccensis
	Fimbristylis ferruginea
	Scirpus grossus
	Thoracostachyum sumatranum
Poaceae	*Chloris gayana*
(Gramineae)	*Cynodon dactylon*
	Diplachne fusca
	Paspalum scrobiculatum
	P. vaginatum
	Phragmites karka
	Sporobolus virginicus
Pandans	
Pandanaceae	*Pandanus tectorius*
Palms	
Palmae	*Calamus erinaceus*
(Araceae)	*Licuala sp.*
	Livistonia saribus
	Nypa fruticans
	Oncosperma tigillarium
	Phoenix paludosa
Vines or climbers, occasionally growing as shrubs	
Asclepiadaceae	*Cynanchum carnosum*
	Finlaysonia obovata
	Gymnanthera paludosa
	Sarcolobus banksii
Asteraceae	*Wedelia biflora*
Leguminosae	
- Caesalpinioideae	*Caesalpinia bonduc*
	C. crista
- Papilionoideae	*Aganope heptaphylla*
	Dalbergia candenatensis
	D. menoides
	Derris trifoliata
Rhamnaceae	*Smythea lanceata*
Verbenaceae	*Clerodendron inerme*

Table 2. Plant species found in mangrove areas (Preliminary checklist compiled by Stephan Wulffraat)

Woody shrubs, frequently growing out to small trees	
Anacardiaceae	*Gluta velutina*
Apocynaceae	*Voacanga grandiflora*
Bataceae	*Batis argillicola*
Chenopodiaceae	*Halosarcia indica*
Euphorbiaceae	*Glochidion littorale*
Goodeniaceae	*Scaevola sericea*
Leguminosae	
- Papilionoideae	*Desmodium umbellatum*
Lythraceae	*Pemphis acidula*
Melastomataceae	*Ochthocharis borneensis*
Myrsinaceae	*Aegiceras corniculatum*
	A. floridum
	Ardisia elliptica
Myrtaceae	*Osbornia octodonta*
Plumbaginaceae	*Aegialitis annulata*
Rubiaceae	*Ixora timoriensis*
	Scyphiphora hydrophyllaceae
Rutaceae	*Paramygna angulata*
Sapindaceae	*Allophyllus cobbe*
Tiliaceae	*Brownlowia argentata*
	B. tersa
Verbenaceae	*Premna obtusifolia*
Trees	
Apocynaceae	*Cerbera manghas*
	C. odollam
Avicenniaceae	*Avicennia alba*
	A. eucalyptifolia
	A. marina
	A.. officinalis
Bignoniaceae	*Dolichandrone spathacea*
Bombacaceae	*Camptostemon philippinense*
	C. schultzii
Celastraceae	*Cassine viburnifolia*
Combretaceae	*Lumnitzera littorea*
	L. racemosa
	Terminalia catappa
Ebenaceae	*Diospyros littorea*
Euphorbiaceae	*Excoecaria agallocha*
	E. indica
Flacourtiaceae	*Scolopia macrophylla*
Guttiferae	*Calophyllum inophyllum*
Lecythideceae	*Barringtonia asiatica*
	B. racemosa
Leguminoseae :	
- Caesalpinioideae	*Cynometra iripa*
	C. ramiflora
- Mimosoideae	*Pithecelobium umbellatum*
	Serianthes spp.
- Papilionoideae	*Inocarpus fagifer*
	Intsia bijuga
	Pongamia pinnata
Malvaceae	*Hibiscus tiliaceus*
	Thespesia populnea
Meliaceae	*Xylocarpus granatum*
	X. mekongensis
	X. moluccensis
Moraceae	*Ficus microcarpa*
Myristicaceae	*Myristica hollrungii*
Rhizophoraceae	*Bruguiera cylindrica*
	B. exaristata
	B. gymnorhiza
	B. hainessii
	B. parviflora
	B. sexangula
	Ceriops decandra
	C. tagal
	Kandelia candel
	Rhizophora apiculata
	R. mucronata
	R. stylosa
Sapotaceae	*Pouteria obovata*
Sonneratiaceae	*Sonneratia alba*
	S. caseolaris
	S. ovata
Sterculiaceae	*Heritiera littoralis*
	H. globosa

Elemental composition: Phosphorus content low; potassium and calcium contents high.

Ripeness Index: n value in the coastal area ranges from 1 to 1.4; further inland it is 0.7 - 1.0.

Organic carbon: Organic carbon content ranges from 3.5 to 17 %; decomposition rate is low.

Karawang (northern coast of West Java)

Physical composition: Clay, 40 - 70 %; silt, 20 - 41 %.

Cimanuk (northern coast of West Java)

Table 3. Species, number of stems and log volume of Indonesian mangroves.

Species	Stems ha^{-1}	m^3 ha^{-1}
Avicennia spp.	6 - 45	1 - 17
Sonneratia spp.	2 - 23	1 - 12
Rhizophora spp.	37 - 185	19 - 90
Bruguiera spp.	7 - 125	3 - 39

Notes: Other species also occur but in much smaller quantities. Volume estimates are derived from diameter measurements 130 cm above ground. Stem volume includes bark, but not branch or banir.

Physical composition: Clay, 16 - 45 %; silt, 20 - 41 %; sand, 25 - 48 %.

Rambut island (Jakarta Bay)

Physical composition: 10 centimeters of soil layer overlaying dead coral reef; consists of 90 % of sand. Further inland the soil is coloured brown; thickness: 30 to 50 cm; Clay : 44 %; silt 44.7 %.

Organic carbon: high organic carbon content; classified as "histosol".

Sumatra

Large stretches of mangrove areas occur in the east coast of Sumatra. Pedalogically, the coastal area is composed of four zones, namely the sub-tidal mud flat, the intertidal zone, the backswamp zone and the depression zone. Only the first two zones may be over grown by mangrove, hence only the soil of these two zones are discussed here.

Sub-tidal mud flat

This mud-flat is always inundated by sea water, even on low tide. The soil is classified as halic sulfic hydroquents. It is of finer texture, unripe (n > 07), high salinity and contains cat-clay at a depth of 50 to 100 cm. Generally this area is covered by *Sonneratia-Avicennia* association.

Intertidal zone

The land in this zone is uncovered by sea water during low tide. The soil is classified as halic sulfaquents. It is unripe, high salinity, contains cat-clay at a depth of less than 50 cm. At some parts, peat layer may be found over the surface. Halic sulfaquent soil with peat layer is called histic-halic-sulfaquent. Under the peat layer there is usually clay sediment with high pyrite content. Areas with lower organic matter are usually over grown by *Nypa fruticans*, whereas those with high organic matter content has *Rhizophora* and *Bruguiera*.

From soil research in South Sumatra mangrove forest, the following information was obtained:

- salinity of soil on levee area is higher than that of soil on hinter location;
- acidity of soil on levee area is lower (pH $\pm$ 7.4) compared with that of the hinter location (pH $\pm$ 4.8).
- clay content is 40 to 50 %; silt content 50 - 57 %.
- Ca, Na, Mg and K ions composition varied according to the vegetation cover of the area:

  Rhizophora forest : Na>Mg>Ca or K

  Nypa forest : Mg>Ca>Na or K

  Swamp and peat forest : Ca>Mg>Na or K.

Kalimantan

In this island, the mangrove soil contains higher concentration of quartz sand than it does clay and silt. Some experts believed that the high content of quartz sand is the limiting factor for the vegetation growth in the Southern coast of Kalimantan.

A somewhat different soil condition was found in the mangrove area of Berau and Tibi islands, East Kalimantan. Here the concentration of clay and silt was significantly higher than that in South Kalimantan. The clay concentration ranging between 43 to 77%; while the silt concentration varied from 19 to 55%. The principal mangrove species found were *Rhizophora apiculata*, *Avicennia* spp. and *Bruguiera* spp. Meanwhile, stands of *Nypa* occupy the hinter parts of the mangrove area.

Other Islands

Soil of mangrove areas in Moluccas is composed mostly of find sand and very limited solumn. More often mangrove vegetation develops on dead coral reef overlain by a thin layer of soil. Therefore, the mangrove vegetations here do not attain large sizes as do their counterparts in Sumatra and Kalimantan.

Some areas in Irian Jaya have fertile mangrove land, e.g. the mangrove area of Bintuni Bay, Sorong and Cendrawasih Bay. The clay concentration in this area is relatively high, ranging from 28% to 51%. So is the silt content; it ranges from 38% to 67%. The sand concentration, by contrast, is quite low, i.e. between 4% and 11%, while the organic matter is around 3.1%. Also high is the concentration of Ca, Mg, Na and K. In terms of vegetation cover, it includes the most dense and well develop mangrôve in Indonesia. Soil data from lesser Sunda Isles and Bali are not as yet available.

Losses of mangrove land

Mangrove land is a tidally influenced area stretching along a coastal line on a flat coastal plain. The front parts of mangrove land may be suitable for pond fishery, whereas the hinter parts, with certain treatment, may be sufficiently suitable for agriculture. For the above reasons, mangrove land is continuously under pressure of being converted for fishpond, agriculture or for other uses such as human settlements, industrial estates, etc.

The most extensive form of mangrove land conversion is the brackish water fish ponds. In 1980 covered an area of 155,081 ha, distributed mainly in Java, Sulawesi and Sumatra (Soewito 1982).

Experience has shown that mangrove lands are mostly not suited for agricultural purposes. Of all problems associated with reclaimed mangrove land, development of acid sulphate soil is the most frequent and damaging. Despite this, conversion of mangrove land for agriculture in Indonesia continues, e.g. in Cilacap, north coast of Java, Banjarmasin (Kalimantan) and South Sumatra (Soemodihardjo 1986). More than 5000 ha of mangrove land in Segara Anakan have been converted to rice fields, coconut plantations and human settlements. And the process is still continuing, particularly along the northern plain of Nusa Kambangan. In the Riau province thousands of hectares of mangrove land were transformed into coconut groves.

According to Simbolon (1991) mangrove lands that have been converted for other uses other than brackish water fishpond cover a total area of around 20,871 ha. They are utilized for agriculture, human settlements, real estate and salt ponds. In East Java the saltponds are reported to cover some thousands of hectares.

In practice, the government manages only the mangrove area under its jurisdiction. In Java only 20% of the total mangrove area is owned by the government. In the outer islands, by contrast, almost all mangrove area is under the authority of the government. Presently, the government maintains the policy that conversion of mangrove land in Java and South Sulawesi can be considered only for intensive utilization. In other words, to protect and conserve mangrove area, the government, in this case the Department of Agriculture and the Department of Forestry, prioritizes the development of intensive fishery and agriculture in the outer islands, while minimizing the activities in Java.

Socio-economic values

This section deals with the utilization of mangrove resources in Indonesia and its economic implications. Emphasis will be given on the various types of utilization such as forestry, fishery, agriculture, etc. However, it should be borne in mind right from the beginning that information on the socio-economic implications of mangrove utilization in Indonesia is to date very limited and fragmentary (Soemodihardjo 1986). This is especially the case with traditional utilization, for which no well compiled data are currently available. In other words, what is presented in this status report should not be taken as being final, nor comprehensive. A lot more information is needed to obtain a better understanding.

Resource utilization

Speaking of mangrove resource utilization, it should be remembered that in Indonesia the term mangrove land covers forested as well as non-forested tidally influenced coastal lands. Thus, the former includes all coastal areas covered by mangrove vegetations, while the latter consists of non-vegetated mud flat adjacent to mangrove formation and degraded mangrove land.

Forested mangrove land

Like the tropical dryland forests, mangrove forests in Indonesia are segregated into several categories according to their designated functions. The following are a brief descriptions of each forest category and its designated functional objectives (Simbolon 1991):

Production Forest - This forest is designated to provide harvestable products such as timber, poles, chipwood, fuelwood, charcoal, etc. The products can be for export, for home industry, and for local consumption. The production forest

Table 4. Marine elements of the fauna of Indonesian mangroves.

GASTROPODA		Amphibolidae	*S. fragilis* (Lamarck)
Potamididae	*Terebralia palustris* (Linnaeus)	Cerithidae	*Cerithium morum* Lamarck
	T. sulcata (Born)		*C. patulum*
	Telescopium telescopium Linnaeus		*Clypeomorus granosum*
	T. mauritsi Butot	Melangenidae	*Melangena galeodes* Lamarck
	Cerithidea djadjarensis (Martin)	Trochidae	*Monodonta labio* (Linnaeus)
	C. alata (Philippi)	Assimineidae	*Syncera breviculata* (Pfeiffer)
	C. obtusa (Lamarck)		*S. javana* (Thielf)
	C. quadrata Sowerby		*S. nitida* (Pease)
	C. weyersi Dautzenberg		*S. woodmasoniana* (Nevill)
	C. cingulata (Gmelin)	Stenothyridae	*Stenothyra glabrata* (A. Adams)
Ellobiidae	*Cassidula aurisfelis* Bruguire	Muricidae	*Chicoreus adustus*
	C. lutescens Butot		*Drupa margariticola*
	C. mustelina Deshayes	Nassariidae	*Nassa olivacea*
	C. triparietalis (Martens)		*Alectrion taenia*
	C. sulculosa (Musson)	**BIVALVIA**	
	Auriculastra subula (Quoy et Gaimard)	Corbiculidae	*Polymesoda coaxans* Gmelin
	A. elongata		*P. expansa* (Mousson)
	Ellobium aurisjudae Linnaeus	Veneridae	*Gafrarium tumidum* Roding
	E. aurismidae (Linnaeus)	Anomiidae	*Enigmonia aenigmatica* (Chemnitz)
	E. polita	Ostreidae	*Crassostrea cucullata* Born
	E. tornatelliforme (Petit)	Chamidae	*Chama fragum*
	Phytia plicata (Ferussac)	Mytilidae	*Brachyodontes bilocularis*
	P. trigona (Troschel)	Spondylidae	*Spondylus hystrix*
	P. pantherina	Arcidae	*Anadara antiquata* Linnaeus
	Melampus singaporensis (Pfeiffer)	**CRUSTACEA**	
	M. pulchellus Petit	Grapsidae	*Sarmatium indicum*
	M. semisulcatus Mousson		*S. crassum*
Littorinidae	*Littorina scabra* (Linnaeus)		*Metaplax elegans*
	L. carinifera (Menke)		*M. crassipes*
	L. intermedia Philippi		*Sesarma taeniolata* White
	L. melanostoma Gray		*S. meinerti* De Man
	L. undulata Gray		*S. edwarsii*
Neritidae	*Nerita planospira* Anto		*S. bataviana* De Man
	N. albicilla Linnaeus		*S. moeschi*
	N. chameleon		*S. eumolpe* De Man
	Neritina violacea (Gmelin)		*S. smithi* H. Milne-Edwards
	N. turrita (Gmelin)		*S. bocourti* A. Milne-Edwards
	N. bicanaliculata		*S. fasciata* Lancherter
	N. zigzag Lamarck		*S. palawensis*
	N. variegata Lesson		*S. bidens* De Haan
	N. auriculata Lamarck		*S. onychophora* De Man
	Clithon corona (Linnaeus)		*S. rousseauxi* H. Milne-Edwards
	C. ovalaensis		*S. erythrodactylum* Hess
Thiaridae	*Melanoides riqueti* (Grateloup)		*S. longipes* (Krauss)
	M. tuberculata (Muller)		*Metapograpsus latifrons* (White)
Amphibolidae	*Salinator burmana* (Blanford)	Ocypodidae	*Uca vocans* Linnaeus
			U. lactea (De Haan)

Table 4. Marine elements of the fauna of Indonesian mangroves.

Ocypodidae	*U. signatus* (Hess)	Ocypodidae	*O. arenaria* De Man
	U. consobrinus (De Man)		*O. cardimana*
	U. annulipes (H. Milne-Edwards)		*Ilyoplax delsmani* De Man
	U. dussumieri (H. Milne-Edwards)		*I. orientalis* De Man
	U. triangularis A. Milne-Edwards		*Tylodiplax indian*
	U. marionis	Portunidae	*Scylla serrata* (Forskal)
	U. coartatus	Gegarcinidae	*Cardisoma carnifex* (Herbst)
	U. rosea	Thalassinidae	*Thalassina anomala* Herbst
	Macrophthalmus convexus Stimpson	Alpheidae	*Alpheus crassimanus* Heller
	M. telescopicus Owen		*A. bisincisus* De Man
	M. tridentatum	Paguridae	*Coenobita cavipes* Stimpson
	M. definitus Adam et White	Balanidae	*Balanus* spp.
	Ocypoda ceratophthalmus (Pallas)		*Clibanarius* spp.

Sources: Soemodihardjo (1986), Kartiawinata *et al.* (1979), Sabar *et al.* (1979), Budiman and Darnaedi (1984), Mustafa *et al.* (1979).

is managed in such a way as to produce the maximum sustainable yield of forest products.

Protection Forest - Due to its natural property and the hydrological objective of the regional development a forest area could be maintained as protection forest. Its function includes among other things water regulation, flood prevention, maintenance of soil fertility and prevention of soil erosion. Mangrove greenbelt is an appropriate example of mangrove forest designated for protection purposes, particularly for coastal ecosystem. A number of regulations have been produced relating to mangrove protection forest. The most recent one stipulates that mangrove green belt shall be established along Indonesian coast.

Conservation Forest - The term conservation forest refers to forest area that is protected against human disturbance. It functions to preserve the forest and its content. In conformity with the final objectives, conservation areas are differentiated into Sanctuary Reserves and Nature Conservation Areas. The former is further divided into Strict Nature Reserve and Wildlife Sanctuaries, while the latter is divided into National Parks, Natural Recreation Park and Grand Forest Park.

The Strict Nature Reserve is completely protected from human interference, except for scientific purposes and education. An example of this category is the mangrove forest in Pulau Rambut, Jakarta. Mangrove as Wildlife Sanctuary is established for instance in Tanjung Puting, Kalimantan. In this area, mangrove is reserved as a habitat for the proboscis monkey, *Nasalis larvatus*, a species of primate endemic to Kalimantan. Mangrove Natural Recreation Park has been initiated by the State Forest Corporation in Segara Anakan, Cilacap. Meanwhile, planning to develop a Grand Forest Park on mangrove area has been started for the coastal area of Suwung, Bali. The Grand Forest Park is a conservation area but with additional function namely to accommodate collection of live plants and animals. The live plants collection consists of those plants occurring locally as well as exotic plant species. It has a variety of functions such as for research, scientific interest, education ,tourism and nature recreation.

Presently the mangrove resource of Bintuni bay (Irian Jaya), covering an area of approximately 260,000 ha, is being processed to be a conservation area. To support the process, research was carried out to get an idea on the present condition as well as on the socio-economic value of the resources.

Non-forested mangrove lands

As stated earlier, the non-forested mangrove land consists of bare or non-vegetated mud flats adjacent to mangrove formation, as well as degraded land previously covered by mangrove. More often than not the bare mud flat is newly formed land resulting from accretion processes. In the course of time it will be invaded by mangrove. Mud flats are commonly associated with river mouth, often taking the form of deltas. They result from sedimentation processes by which loads of suspended solids are deposited onto the sea bottom. Prevailing water current may carry the sediment load further to some distance before letting them to settle down. As such, mud flats may occur at some localities distantly separated from river mouth.

In the early stages of development mud flats are usually devoid of vegetation. Most likely it is due to the condition of the muddy substrate which is still unstable. Toward the land the mud flat becomes more and more compact making it possible for mangrove to grow.

Extensive mud flats are found in the north coast of Java, east coast of Sumatra, south and east coast of Kalimantan and south coast of Irian Jaya (Soemodihardjo 1986). They are usually rich with benthic fauna such as crustaceans, molluscs and other invertebrates. Cockles (*Anadara* spp) are amongst the bivalves of commercial importance that are harvested from mud flats (Soewito 1982).

Economic implications

In term of areal extent, the Indonesian mangrove resources is quite small compared with the upland tropical forest resource of this country. It constitutes no more than 3%, yet its contribution to the socio-economy of the country cannot be underestimated. Studies have been made to estimate the overall value of mangrove resources of Bintuni bay by Ruitenbeek (1991). He concluded that it supports 3000 households and an important shrimp industry. Traditional uses are estimated to generate a revenue of 20 billion rupiah or approximately US$10,000,000.

From the fishery sector the product is valued at 70 billion rupiah or US$35,000,000. In the meantime, if selective cutting were done, it would yield US$20,000,000. per year.

Some experts believe that the results of this observations was not convincing, considering that the annual income of the local population is much less than what is estimated in this work. It is suggested that the observation should be repeated with more accurate method. Estimation on the standing stock had been attempted, based on the result of an inventory involving 784,000 ha of mangrove forest from seven Indonesian provinces. The record shows that the average mangrove standing stock was 82.92 $m^3 ha^{-1}$. Of this standing stock, genus *Rhizophora* provided the biggest contribution (Table 3).

Various products of mangrove forest have been utilized by Indonesian coastal villagers for a long time. It takes the form of a direct products, such as firewood and nipah thatches, and also indirect products such as fishes and shellfishes, as well as amenities provided. Unfortunately, it is hardly possible to estimate the monetary value of these products due to the scarcity of data and information relating to this aspect. The following are the highlights of the utilization of mangrove resources in Indonesia, based on the available information.

Forestry

Direct products of mangrove forest include timber, poles, firewood, charcoal, tannin, nipa leaves and sugar. Traditional utilization, largely takes the form of fuelwood, housing materials and sugar. Housing materials include nipa leaves for thatches. They are collected from the forest in a traditional way, using simple hand tools such as machetes or hatchets. The products are primarily for home consumption, sometimes sold locally to get additional income.

In most rural coastal areas, fuelwood remains the source of energy for the household. Firewood is also the source of energy for some home industries. In this respect, Soemodihardjo (1986) reported the making of brown sugar from *Nypa* in the coastal villages of Cilacap and lime making industry in the Kangean island off the coast of Madura, East Java. Both activities required relatively high energy input; and mangrove wood was found to be handy to satisfy the need.

The use of mangrove products for housing materials is common in coastal villages near mangrove forest. In some cases, houses are built entirely of mangrove products (Soemodihardjo, 1986). The stilts are of nibong palm (*Oncosperma tigillaria*), the frames are of *Rhizophora* and/or *Bruguiera* stems, while the roofs and the wall are nipa thatches. Since the villages are usually located in the tidal area, the houses, by necessity, have to be erected on stilts. A network of boardwalks, also erected on stilts, connects one house to another. Boardwalks are mainly constructed from nibong stems.

Commercial exploitation of mangrove forest products, aiming primarily for export, has been going on for several decades. The end products include logs, charcoal, woodchips and scaffold poles. Until 1990 the mangrove forest that have been leased to concessionaires amounted to 877,000 ha (Simbolon 1991). In the meantime, a large scale experimentation to manufacture brown sugar from flower sap of *Nypa* has been underway for some years in West Kalimantan. It started with 1000 ha of *Nypa* forest and is scheduled to be extended to about 10,000 ha (Masuda 1990).

Currently logging activities are carried out in Sumatra, Kalimantan and Irian Jaya, the logs being exported to Taiwan and Japan. According to Burbridge & Koesoebiono (1980) export of mangrove logs in 1978 amounted to 382,737 m^3. From 1981 to 1983 Riau province exported 85,270 m^3 logs annually (P.T. Bina Lestari, unpublished report). In 1989 West Kalimantan produced 45,805 m^3 of mangrove round wood. Of this amount, 34,404 m^3 was for export, while the rest was for domestic consumption.

Charcoal is produced mainly in Sumatra, particularly Riau province. There were 836 kilns in this province in 1984 (Riau province Forestry Service, unpublished report). Around 22,207 tons of charcoal was produced in 1983 valued at US$1,094,300; and was exported to Singapore and Hong Kong. At the same time Masuda (1990) reported the existence of some charcoal kilns in West Kalimantan province, namely in Batu Ampar, Kubu and Teluk Batang. However, no data of charcoal production was available.

Production of mangrove woodchips and pulp in Indonesia was not started until 1979 when East Kalimantan exported 70,000 m^3 of chips. Since then several chip mills have been constructed, namely in Aceh, Riau and West Kalimantan. According to Simbolon (1991) export of chips and pulp in 1990 reached 257,497 m^3. Very recently another chip mill has been established in the mangrove area of Bintuni bay, Irian Jaya. It was built by the P.T. Bintuni Utama Murni Wood Industries (P.T. BUMWI) who have been granted permission to lease 137,000 ha of the worlds best mangrove that exist in the area (Zuwendra *et al*, unpublished report). The newly built chip mill has a full capacity of 184,400 m^3/yr. For 1988/1989 the production target was 50,000 m^3/ yr. This target was substantially lower than the full capacity, only 15,268 m^3 or 32,7% of the targeted production was attained.

Demand for scaffold poles seemed to be limited. So far, available statistical record regarding this commodity was only for year 1972 and 1977. Export of scaffold poles in both years was 17,000 and 11,736 m^3 poles respectively. The target country was Singapore.

Fishery

It is common knowledge that the water component of a mangrove ecosystem is not a separate entity but is an integral part of that of the open sea, interconnected through a network of canals and tidal creeks. Therefore species of fish that are strictly mangrove probably are non-existent (Soemodihardjo 1986). Nonetheless, positive correlation between mangrove areas and fish landings in the area has been quoted by many authors (Martosubroto & Naamin, 1977; Turner, 1987). Several species of shrimps have been reported to be dependent on mangrove communities at least during part of their life cycle (Macnae, 1974).

Benthic organisms are another important component of mangrove ecosystem, they are primarily molluscs and crustaceans. Some species have commercial value and they are harvested by local people for self consumption or sold at local markets. Among the most valued species of molluscs are the cockle (*Anadara granosa*), oysters and *Geloina coaxans*, while the most valued crustaceans are some shrimps and the mud crab (*Scylla serrata*).

On the basis of the methodology, mangrove fishery is differentiated into three categories, i.e. capture fishery, mariculture and pond culture. Of these three categories, mariculture is the least developed in Indonesia.

Capture Fishery

Within the mangrove ecosystem capture of fish and shrimps is done specifically in the tidal canals and creeks that criss-cross the mangrove area. In the mangrove of Segara Anakan (South of Central Java) and Grajagan (South of East Java), it is also done in the lagoon that form an integral component of the existing mangrove ecosystem in the area. Various fishing techniques are used, namely trammel net, gill net, cast net, fish weir/trap and hook and line.

The species composition of fish population of mangrove communities depends on the physical and chemical condition of the habitat. In the coral reef associated mangrove of Pari Island, north of Jakarta, the fish population was dominated by *Geres macrosoma* (Hutomo & Djamali, 1979; Adrim *et al*, 1984). At times, this species may account for 80% of the total catch. In the estuarine area of the Berau river (East Kalimantan), *Lates calcarifer* and the *Scomberomorus guttatus* were the most abundant (Djamali, 1984). Meanwhile, in the muddy habitat of the Segara Anakan mangrove, *Mugil cephalus* and *Cynoglossus lingua* were found to be the most common (Sujastani, 1989). These two species are known to be detritus feeders, hence the detritus-rich mangrove area is a perfect natural habitat for them.

Perhaps, Segara Anakan lagoon at Cilacap, may be taken as a good example of a fully mangrove influenced aquatic environment. Having a surface area of about 4000 ha with an average depth of 1.48 m, this body of water is literally surrounded by an extensive mangrove forest. Currently the mangrove forest in this locality is estimated to cover an area of no less than 14,000 ha. In other words the lagoon may be considered being fully under the influence of mangrove forest. In this lagoon artisanal fishery is still practiced today. During 1976 - 1982 the annual fish production ranged from 98.9 ton/yr to 939.6 ton/yr, with the average of 355.6 ton/yr. (FSC 1983, in Ecology Team & Sujastani 1989). The catch was composed of 60% migratory species, 35% resident species while the rest was occasional visitors.

Apart from exploiting the pelagic component, capture fishery activities in mangrove ecosystem include also capture of commercially valued benthic organisms. These involve several species of molluscs and one Crustacean. Among the molluscan species are *Anadara granosa, Ostrea cucullata, Geloina coaxans, Terebralia palustris* and *Telescopium telescopium*.

The first three species belong to class Bivalvia, while the last two species belong to Class Gastropoda. Of these molluscan species, *Anadara granosa* is the most widely consumed and marketed. Perhaps it should be mentioned here that *Anadara granosa* is not an inhabitant of mangrove forest in its strictest sense. Strictly speaking this species is an inhabitant of muds flats adjacent to mangrove formation. According to Sumarno (1984) some 37,000 ton of *Anadara granosa* was harvested from Indonesian coastal area in 1988.

The big mud crab, *Scylla serrata* is the only mangrove-associated benthic crustacean which is of commercial importance. It enjoys a good local market, in particular to supply the increasing sea food restaurants and fetches a favourably high price. To a limited extent it is exported to Singapore and Malaysia (Soemodihardjo 1986). The most common gear to catch this big crab is a baited trap. Capture of this crab is done mostly in the mangrove forest of Segara Anakan , along the north coast of Java, South Sumatra and Sulawesi.

Mariculture

The term mariculture in this context applies to all activities relating to rearing marine organisms in mangrove waters, except for the one that is done in man-made ponds. Blood cockles and oysters are among the bivalve molluscs that are commonly cultivated.

In the vicinity of mangrove forest of the western coast of Jakarta bay, farming of *Anadara granosa* has been practiced by the local villagers (Ismail 1971). However, the activity is done only when spats of this species are abundant. Heavy spat fall was recorded in 1967 and 1970. Farming sites are selected amongst the places where heavy spat fall occurs. Each farmer usually is allotted about one hectare of farming land. A bamboo fence is built around the allotted land to prevent disturbance.

Apart from the spats that already settled in the area prior to the fencing, a lot more, purchased from spat collectors, are introduced to the farming site. When collected, the spats measure between 3 to 5 mm. Most likely they come from May and June spawning season. After 5 to 6 months, they grow to an average size of 18.3 mm. Harvesting is done no later than January the next year, for the reason that the sea becomes too rough after that. At this time the fast growing specimens may attain a size of 35 mm. According to Ismail (1971) cockles production in this area may reach 4 ton ha^{-1} each season. Nothing special is done to promote the growth of the fenced cockles, except perhaps guarding them from theft and once in a while spreading the cockles evenly in the fenced area. This is necessary since there is the tendency of the cockles to aggregate at the seaward side of the farming area (Ismail 1971).

Other traditional bivalve farming is practiced in the eastern coast of Jakarta bay. Here, it is the oysters that are cultivated, instead of cockles. Empty shells of oysters are spread all over a sub-tidal mud flat adjacent to mangrove forest. These empty shells are to function simultaneously as spat collectors and substratum for the young oysters to grow.

Farming of the green mussels (*Perna viridis*) had also been attempted in Jakarta bay. Spat collectors of various types were hung down in the water column on plastic strings attached to a bamboo raft. After a few months the strings and the collectors are covered with juvenile green mussels. From the technical stand point, this rearing experiment was successful. However, demand of this mussels is very limited, hence for the moment the farming was discontinued.

Pond culture

Rearing of fish in brackish water fishponds has been known in Indonesia since the fifteenth century (Budiman and Kartawinata, 1984). Today it is widely practiced, especially in densely populated areas in Java and South Sulawesi. Nearly all mangrove lands in these areas have been converted to pond culture.

Naamin (1991) stated that in 1990 the brackish water fishponds in Indonesia covered an area of around 285,000 ha, distributed mainly in Java, Sumatra and Sulawesi. A small proportion existed in Bali, and in some islands in the Moluccas. Until a few decades back, milk fish (*Chanos chanos* Forsk) was the only species grown in the brackish water ponds. In 1970 the tiger prawn (*Penaeus monodon*) began to be cultured and currently 70% of the existing brackish water fish ponds are used to grow prawn. Meanwhile, rearing of other marine organisms in the brackish water ponds is beginning to receive attention.

Attempts have been made to grow *Lates calcarifer* and *Tilapia mossambica*, as well as species of marine algae such as *Gracilaria* sp. in the brackish water fishpond.

Regarding the shrimp fishery, three level of farming techniques are currently in operation in Indonesia. These three levels of farming techniques are extensive, semi-intensive and intensive farming techniques. In the first mentioned technique, the cultured shrimps depends solely on food produced naturally in the ponds. The initial stocking density is around 20,000 larvae ha^{-1} each season. The "seed" is obtained from a natural supply collected along the coast line. In the semi - intensive technique, supplementary feeding is provided to the juvenile shrimps after they have been in the pond for at least one month. Sometime the ponds are fertilized with green manure to enhance production of natural food organisms. Control of pest and predators may also be exercised during the preparation of the ponds. Density of initial stocking ranges from 20,000 to 80,000 "seed" ha^{-1} per season. The shrimp larvae for the initial stocking are obtained from shrimp hatcheries. In the intensive technique, the shrimps depend mainly on food supplied by the pond operator. The fry is obtained from hatcheries and the initial stocking is quite high, i.e. more than 80,000 larvae ha^{-1} per season. Most of the brackish water fishponds are still managed in a traditional way, hence the production is relatively low. Soewito (1982) reported that milkfish production from a traditionally managed brackish water fishpond was about 500 kg ha^{-1} $year^{-1}$. Introduction of fertilizer and control of predatory fishes may increase the yield up to 1000 kg ha^{-1} $year^{-1}$.

Agriculture

It has been widely publicized that mangrove land is not well-suited for agriculture. Development of sulfaquent soil is the primary constraint of using mangrove land for agriculture (Notohadiprawiro, 1979). In view of the fact that mangrove soil is nearly always excessively water-logged, it gives the false impression that it should be very appropriate to use the land for wet-rice cultivation. However, this impression is usually invalid. Most mangrove lands are made up of potentially sulfaquent soil. Undisturbed, this potential sulfaquent soil remains inert. Opening the land for exposing to air (O_2) agriculture will activate the potential danger to become a real one. Experience has shown that soil with pH equal to or below 4 will not support plant life. Other constraint associated with mangrove land is the high salinity. A number of plant species can tolerate relatively high salinity. The majority, however, can not do so. Notwithstanding the unfavourable characters for agricultural purposes, opening of mangrove land for agriculture continues in Indonesia. It happens in Cilacap, along the north coast of Java, Banjarmasin (Kalimantan), Riau (Sumatra) and Palembang (Sumatra) (Soemodihardjo, 1986). In Cilacap the mangrove land is opened to grow wet-rice and coconut. It has been happening for a few decades, particularly during the Japanese administration and during the war of independence. To date more than 5000 ha have been converted and officially handed over by the government to the tenants. The yield was reported to be relatively low, i.e. less than 1 ton ha^{-1} $year^{-1}$ (Hardjosuwarno, 1979).

Opening of mangrove land for coconut plantation have been occurring in Indragiri Hilir, Riau

Province (Sumatra). Thousand of hectares of mangrove land is now coconut grove. It was reported that the rate of conversion reached 300 to 400 ha a year. As a matter of fact there are constraints in developing coconut plantation on ex-mangrove land. According to the report, no less than 50% of the coconut trees here are leaning. And the life span is 15 to 20 years, instead of 30 to 40 years of the normal trees. The back portion of mangrove land is also utilised for palm oil plantations.

Mining

Soemodihardjo (1986) reported the occurrence of a number of mining activities in the coastal areas. These included mining of tin, bauxite, iron sand, oil, gravel, and shells. Of these activities only oil mining in East Kalimantan has been done directly within mangrove area. Others were done outside mangrove ecosystem; nonetheless these activities may impact significantly on surrounding areas, including adjacent mangrove communities.

Tin and bauxite mining takes place in the west coast of Sumatra. Tin deposits are mined sub-litorally, while bauxite is mined supra-littorally. Therefore, strictly speaking the impact of mining activities to gather these two minerals on mangrove ecosystem is primarily caused by the tailing process rather than by the mining itself. Unfortunately no works has been done to assess the impacts.

Exploitation of iron-sand deposit occurs on the beach sand east of Cilacap, southern coast of central Jawa. Riyanto (1982) reported that the mining activities, which follow open-pit mining system, rapidly devastated the original beach. Within 6 years, no less than 15 km of the beach have been exploited, destroying the biotic components in the process.

Other uses

This category of non-forested mangrove land uses include utilization for salt pands, tourism, settlement and sewerage. Not much information on these aspects is currently available. The following are a brief description of these different uses.

Production of cooking salt (NaCl) in Indonesia is done only in limited localities. Soemodihardjo (1986) stated that salt making industries occurred in Gresik and Madura (East Java), Rembang (Central Java) and Jeneponto (Sulawesi). Detailed information on the extent of the saltpan and the overall production were lacking, except for Rembang where it covered an area of approximately 1000 ha, yielding around 60 ton in two to three months (Kompas Daily News 14 August, 1984).

The interest of developing mangrove forest as recreation area is currently growing. Some countries, like Trinidad, Philippines and Australia, provide tourism facilities in the mangrove area. In Indonesia utilization of mangrove forest as recreation area has been initiated in Cilacap. Here several hectares of a successfully reafforested mangrove land were provided with recreation facilities, such as concrete foot path, boardwalk and fishing pond. The place is crowded with visitors on Sundays and other holidays. In this way, it is expected that appreciation on mangrove forest by the people at large will be augmented. For the people living in the surrounding area, mangrove recreation area will awaken their awareness that mangrove resource has other uses apart from producing timber for housing and fuelwood. Human settlement in the mangrove is believed to have occurred since long time in the past. Consequently mangrove resources have undergone increasing pressure with increasing human population. For example, in the Cilacap region about 5000 ha of mangrove land have been converted to human settlement and rice fields. Although at the beginning the conversion was done illegally, at the end the government could do nothing but officially grant ownership of the land. Similar illegal encroachment of mangrove forest occurs in other parts of Java. Nearly all mangrove land along the north coast of Java have been transformed into brackish water fishponds, and the remainder suffers from human encroachment.

The use of mangrove land as sewerage is currently found in Bali. Here some 15 ha of mangrove land have been converted into a sewerage pond to collect waste water from the Nusa Dua Hotel. The sewage is just left in the pond to undergo natural processes without special treatment.

Environmental significance

Coastal protection

The role of mangrove ecosystem in preventing coastal erosion is widely recognized. The mangrove root system is suitable to act as sediment trap and to stabilize the sedimented particles. Coastal protection decreases with the decreasing size of the tidal forest.

Destruction of mangroves due to the increasing needs of fire-wood, housing and agricultural land area, in the river mouth of Duri and Pemangkat river (West Kalimantan Province) cause a serious problem of erosion (Syukur, 1984). In Dumai (Riau Province), landslide and coastal erosion happened because of the conversion of mangrove forest into agricultural land (Notohadipoero and S.A. Siradz, 1978). The same situation was also found in Pamanukan forest area. In this area, mangrove forest along the coast deteriorated due to human actions, such as harvesting for firewood and construction of fish-ponds, rice-fields, human settlements, etc.

Mangrove disturbance resulted in problems such as erosion of the soil in the coastal area. Based on data of Ciasem-Pamanukan Forestry Agency it was revealed the erosion rate of coastal land from 1981 to 1984 was 33 ha $year^{-1}$.

Destruction of large mangrove forest, in the long run will have adverse effects on adjacent ecosystem. These include, beside erosion, increased siltation, alteration of water level, lowering of water quality in lagoons and estuaries, salinity and loss of wind breakers. With respect to siltation, accrued land is frequently formed naturally along the shore mainly around river mouths. This happens in many places such as in Delta Brantas, Segara Anakan (Cilacap), Krap Island (Maluku), etc. (Bratamihardja and Z.R. Pohan, 1986). In Mondal Island to the north of West Java, there are ± 600 ha (± 21 ha/year) accrued land overgrown by *Avicennia* spp.

It has recently been appreciated that mangrove forests are among the world's most important natural resources, but most of mangrove areas have received practically no attention in term of rational management. They have already been degraded to the critical point, various parts of the mangrove forests have been destroyed, over-exploited or felled. The main issues related to mangrove management are :

a) the degradation or complete destruction of tidal forests for non sustainable uses as urban and industrial developments;

b) the removal of parts of tidal forests for the development of coastal pond aquaculture;

c) the effect of other non-sustainable uses of mangroves on fisheries and aquaculture, such as mangrove exploitation products.

Because of the important role of mangrove forests, it has been proposed to allocate the forests for coastal protection, such as in Lampung (± 200 meters from the seashore) (Irawan, 1990), Tanjung Karawang - Jakarta (with the length and width of 5 km and 100 meters, respectively) (Djaja, *et. al*, 1982), Angke Kapuk - Jakarta (Al Rasyid, 1982), etc. For the sustainability of mangrove ecosystem until the year of 2000 mangrove land needs to be allocated for forest protection estimated to reach approximately± 1,275,303 ha (30% of the total Indonesian mangrove forest) (Simbolon, 1991).

Mangrove greenbelt is mangrove area borders on seashore and riverbank in which due to its specific natural characteristics have biological, physical and chemical functions. Besides, it is an ecosystem which is very important in producing organic material, controlling erosion, protecting the land from sea water intrusion and wind (Soewito, 1982).

The conclusion of technical meeting on the evaluation of the result of mangrove forest survey held in Jakarta, June 1982 stated that the functions of mangrove greenbelt are (Soerianegara, 1986):

a) Aquatic Biological Function
   - source of food / aquatic fertility
   - shelter place
   - breeding place
   - nursery

b) Aquatic Chemical and Physical Function
   - protection against wave
   - shelter belt
   - keeping the land from sea water intrusion
   - conservation of soil erosion
   - flood control
   - protection from pollutants.

The width of mangrove greenbelt should be adjusted to the local shore condition and have to take into consideration the sustainability and economic principles.

Wartaputra (1991) stated that through a decree jointly signed by the Minister of Forestry and Minister of Agriculture, the Indonesian

Government decided to maintain mangrove greenbelt of 200 m width along the coast. It is expected this regulation will later be lifted up to higher level to become a Presidential Decree in which the width of mangrove greenbelt is determined by certain formula (see Chapter 1 c; Presidential Decree No. 32, 1990).

Coastal fishery

The role of mangrove ecosystem in supporting coastal fishery has been widely publicized. However, the assertion is largely based on indirect evaluation rather than on direct measurement or experimentation. Understandably, such a deduction must rely on some assumptions, a process that inherently contains certain shortcomings or weaknesses. Consequently, the resulting conclusion will likewise inherit that undesirable characteristic.

Basically the value of mangrove ecosystem to coastal fisheries is concomitant with its ability to :

a) provide organic matters in the form of litterfall;

b) serve as a nursery ground for the larval and juvenile forms of many marine organisms;

Perhaps it should be pointed out here that only a very small proportion of mangrove litter is directly consumed by primary consumers. Presently, only *Terebralia palustris* (Gastropoda), and *Sesarma* spp. (Brachyura) are known to devour freshly fallen mangrove leaves (Nishihira 1983; Macintosh 1984; Robertson 1988). The majority of the litter undergoes certain steps of degradation process to end up as a stinking, black mangrove detritus on the forest floor. Despite its undesirable smell and its dirty looking appearance, this deposit of plant matter signifies the role of mangrove community in its fullest sense. It serves as the base of a complex detrital food-web in the coastal ecosystem.

Apart from providing food materials for the biotic component of the ecosystem, mangrove community has other things to offer, namely protection from hazardous natural forces and disturbances. The ability of mangrove vegetation to grow on a tidally influenced land and the unique physical character of mangrove root system are the key factors that enable mangrove communities to serve as shelter for the larvae and juveniles of fishes, shrimps and other mangrove dwellers.

Rich or productive coastal fisheries in Indonesia are commonly associated with mangrove forests. To name a few examples are the offshore fisheries at Cilacap, Bagan Siapi-api (Sumatra) and Bintuni Bay (Irian Jaya). These three localities are fringed with extensive mangrove forests and are recorded as productive fishing grounds.

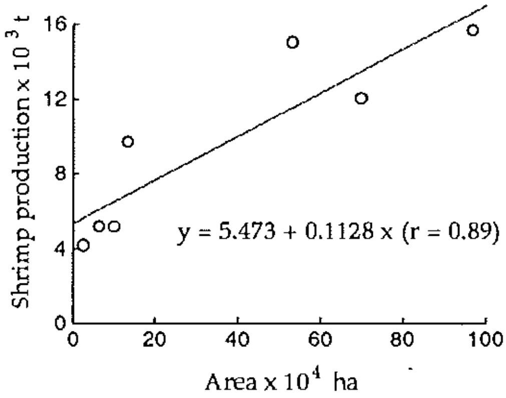

Fig. 2. Relationship between mangrove area and shrimp production (After Martosubroto and Naamin, 1977).

The big mud crab, *Scylla serrata*, that lives in close association with mangrove forest is commercially important. A significant quantity of this crab is caught in the mangrove forest of Cilacap and Musi Banyuasin (South Sumatra) using baited traps.

Some species of penaeid shrimps are reported to be mangrove dependent (Macnae, 1974), at least during part of their early life cycle. The importance of mangrove to shrimps was further emphasized by Martosubroto and Naamin (1977), who empirically demonstrated that there was a positive correlation between shrimp landings and mangrove area in Indonesia (Fig. 2).

Wildlife habitat

Protection of the habitat is the principal means in wildlife management. The protected habitat should be sufficiently large to sustain the life of the dependent animals. Mangrove ecosystem is an important habitat for many species of fish, invertebrates, reptiles, birds and even some large mammals. It may function as feeding ground, breeding and nesting areas, resting place and foraging areas.

Species of non-aquatic animals that are found naturally in the mangrove area include :

Mammals

- proboscis monkey (*Nasalis larvatus)*
- crab eating monkey (*Macaca fascicularis*)
- leaf monkey (*Presbytis* spp.)
- mangrove cat (*Felis vivrrina*)
- barking deer (*Muntiacus muncak*)
- mouse deer (*Tragulus javanicus*)
- otter (*Herpestes javanicus*)
- javan civet (*Paradoxurus hermaphroditus*)

Aves

- milky stork (*Ibis cinereus*)
- lesser adjuvant stork (*Leptoptilus javanicus*)
- night heron (*Mycticorax caledonicus*)
- egrets (*Egretta* spp.)
- glossy ibis (*Plegadis falcinellus*)
- white necked stork (*Ciconia episcopus*)
- oriental darter (*Anhinga melanogaster*)
- cattle egret (*Bubulcus ibis*)
- king fisher (*Halcyon* spp.)

The existing mangrove wildlife protection areas in Indonesia to date is presented in Table 5.

Management and conservation

Laws and regulations

The principal laws and regulation relating to conservation of mangrove ecosystems in Indonesia are :

a) Act of the Republic of Indonesia No. 5, 1990, concerning conservation of living resources and their ecosystems.

This act, which consists of 45 articles, serves as a guiding principle for the management, utilization, protection and conservation of all living resources.

b) Act of the Republic of Indonesia No. 5, 1967, concerning Forestry Principles.

This law provides guiding principle for the management, utilization protection and conservation of forest and forest land, including mangrove forest.

On the basis of this act, implementation guidance relating to various forestry activities

Table 5. Wildlife protection areas in Indonesia that contain a mangrove component

No.	Location	Region	Area (ha)	Principal Animal Species Protected
1	Berbak, Jambi	Sumatra	8,500	*Crocodilus* spp.
2	Kuala Langka	Sumatra	1,000	*Crocodilus* spp.
3	Kuala Jambuaye	Sumatra	3,000	*Crocodilus* spp.
4	Muara Angke	Jakarta	15	*Egretta* spp.; *Halcyon* spp.; *Anhinga* spp.
5	Muara Cimanuk	North Coast of Java	7,100	*Ibis* spp.
6	Muara Mauk	North Coast of Java	1,000	*Bubulcus ibis*
7	Pulau Sepanjang	Madura	2,430	*Ibis cinereus*; *Halcyon* spp.; *Ciconia episcopus*
8	Teluk Kelumpang	South Kalimantan	13,750	*Nasalis larvatus*
9	Pamuka	South Kalimantan	10,000	*Nasalis larvatus*
10	Muara Kendawangan	South Kalimantan	150,000	*Nasalis larvatus*
11	Tanjung Puting	Central Kalimantan	11,000	*Nasalis larvatus*; *Anhinga* spp.; *Ibis cinereus*
12	Muara Kahayan	Central Kalimantan	150,000	*Nasalis larvatus*
13	Teluk Adang dan Teluk Apar	East Kalimantan	128,000	*Crocodilus* spp.
14	Gunung Lorentz	Irian Jaya	*	*Crocodilus* spp.; *Halcyon* spp.; *Ciconia episcopus*
15	Pulau Dolok	Irian Jaya	105,000	*Crocodilus* spp.; *Threskiornis aethiopicus*

Besides those areas on the list there are some mangrove areas in process of being allocated for wildlife conservation area

* Mangrove area as a part of the total conservation area

were established, including those for utilization, conservation and rehabilitation of mangrove forests and mangrove forest land.

c) Presidential Decree No. 32, 1990, pertaining to the establishment of protection areas.

This Decree contains several articles, one of which relates to the establishment of mangrove greenbelt using the formula,

Mangrove greenbelt (m) = 130 x maximum tidal range (m).

On the basis of this equation, the width of mangrove greenbelt at various important sites is calculated (Table 6).

d) Director General of Forestry Decree No. 60, 1978, pertaining to Mangrove Sylvicultural System.

This Decree consists of several articles, concerned with harvesting, rehabilitation and reforestation of mangrove forest and mangrove forest land.

Organization

The Department of Forestry is responsible for the management of mangrove forest land. The management include all activities relating to utilization, protection and conservation of mangrove ecosystem and mangrove forest land. While the management of mangrove forest outside the forest land is under the responsibility of the local government.

In carrying out the responsibility, the Forestry Department delegates its authority to various agencies, namely Directorate General of Forestry, Directorate General of Forest Protection and Nature Conservation, Directorate General of Forest Inventory and Forest Land Use.

Other central government agencies that indirectly responsible for mangrove ecosystem are the Ministry of State for Population and Environment and the Directorate General of Fisheries. The last mentioned agency is under the supervision of the Minister of Agriculture.

Strategy on conservation management

The strategy and policy on conservation management of mangrove ecosystem in Indonesia are based on the principles:

a) To maintain essential ecological processes and life support systems. This principle includes soil rehabilitation and protection, recycling of nutrients, and maintaining hydrological condition.

b) To preserve genetic diversity. Genetic diversity include protection of samples of different habitats, communities and species which provides the opportunity for harvesting or cultivating new resources.

c) To ensure the sustained utilization of species and ecosystem. It covers utilization of wildlife, fishery resources, forest, grazing lands, which support both rural communities and major industries, so that these are not depleted by the industries they sustain.

This strategy ensures the preservation of all form of ecosystems and natural life for the benefit of future generations. The Directorate General of Forest Protection and Nature Conservation has the mandate to implement this policy.

Silvicultural systems

The silvicultural system that has been practiced in Indonesian mangrove is the "Seed Trees Method". This system provide guidelines for harvesting, rehabilitation and reaforestation techniques. Briefly, the guidelines run as the follows.

a) Mangrove vegetations at the sea front and the river's bank, with a width of respectively 50 m and 10 m, are to be preserved for hydrological protection.

b) Mangrove forest land utilization must be based on approved work plan;

c) Forestry planning is to be based on forest inventory. The latter is carried out in the following way:

   i) Systematic strip sampling for observation and recording of all trees having diameter of 10 cm and over;

   ii) Line plot sampling for observation and monitoring of all saplings, ranging from those having a total height of 150 cm to those having a DBH (diameter at breast height) of less than 10 cm. The plot size is 5 x5 m and the distance between two successive plots is 100 m.

   iii) Line plot sampling for observation and monitoring of all seedlings that have a total height of less than 150 cm. The plot size for the seedlings is 2 m x 2 m and the distance between two successive plots is 100 m.

d) Cutting rotation is 30 years; while log extraction technique is the canal system.

e) Forest stand maintenance include thinning and clearing, horizontally as well as vertically.

f) Stand regeneration follows natural as well as artificial process, supplemented by enrichment planting.

It appears that there is the need to further improve the above silvicultural guidelines so as to allow for incorporation of research findings in the system, while at the same time taking environmental issues into consideration.

Reforestation

To protect forest land and mitigate damaged lands, programmes of reforestation has been put into operation. The result was that quite extensive bare and damaged mangrove forest lands are being restored. These programmes were done for instance in Segara Anakan and Pamanukan mangrove land.

There are several objectives that are expected to be achieved through this programmes. First, to increase the income of rural people through what is popularly called "the prosperity approach".

Table 6. Minimum width of mangrove greenbelt at various sites in Indonesia following the formula stipulated in the Presidential Decree No. 32, 1990

No.	Location	Avg.range of highest spring tides (m) (RHSR)	130 x RHSR	Minimum width of mangrove greenbelt (m)
1	Aceh, East Coast	2	234	230
	Aceh, West Coast	1	182	200
2	North Sumatera, East Coast	3	325	325
	North Sumatera, West Coast	1	182	200
3	Riau, Jambi and South Sumatera	4	546	540
4	Lampung	1	182	200
5	Bengkulu, West Sumatera	1	182	200
6	Java, West Coast	1	143	200
	Java, North Coast	1	143	200
	Java, East Coast	3	351	350
	Java, South Coast	2	273	270
7	West Kalimantan, Central Kalimantan & South Kalimantan	3	442	440
8	East Kalimantan	2	304	365
9	South Sulawesi, Central Sulawesi & South East Sulawesi	2	195	200
10	North Sulawesi	3	325	325
11	Bali, NTB, NTT & Timtim	2	260	250
12	Maluku	2	299	300
13	Irian Jaya, North Coast	2	260	260
	Irian Jaya, South Coast	9	1,118	1,100
	Irian Jaya, West Coast	2	273	275

Source: Dinas Hidro Oseanografi TNI-AL (1987)

Through this approach, the rural population inhabiting the mangrove land and those living in the surrounding areas are benefited by the production of food crops and firewood. Second, the programme aims to improve the existing condition of the mangrove, Third, habitat improvement to protect species of wildlife which are dependent on the existing mangrove ecosystem.

For the first objective, efforts are concentrated on the development of employment opportunities and on the provision of alternative source of energy and housing materials, through reforestation of open mangrove land.

Conclusions and recommendations

Conclusions

1. Mangrove forest ecosystem is an important part of the Indonesian wetland and has invaluable roles from both economic and ecological points of view.
2. Extensive mangrove areas are found in Sumatera, Kalimantan and Irian Jaya. The smaller parts are found in Maluku, Java, Sulawesi and Nusa Tenggara.
3. The main human activities in mangrove areas are aquaculture, fishery, recreation and collection of forest products.
4. Researches on various aspects have been carried out in mangrove areas; nevertheless enhancement of research institutes and agencies is necessary to accelerate research activities in remote areas.
5. The Government Policy in term of laws and regulations guiding the management of mangrove areas is presently adequate and covering all aspects, environmentally as well as economic.
6. Well compiled data are presently scarce. This situation becomes the constraint of improving the management policy and its implementation.

Recommendations

Activities relating to mangrove area management needs to be emphasized to support the achievement of greater socio-economic and environmental benefits of the resource for the national sustainable development. To that end, the following programme of activities are recommended.

a). Resource inventory

b) Basic and applied research

c) Inventory and evaluation of current activities on and relating to mangrove area

d) National planning of mangrove area management

e) Long term and annual planning of the activities above (a - d)

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The socio-economic, ecological and environmental values of mangrove ecosystems in Malaysia and their present state of conservation.

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General description

Distribution and extent of mangroves

Mangrove forests in Malaysia develop well in sheltered estuaries where waters are brackish, and wave and tidal conditions are conducive to mud accumulation. Along more exposed coastlines, they are confined to the protected landward side at the lee of sand bars. In total, there are about 641,000 ha of mangrove forests in Malaysia of which 57% are found in Sabah, 26% in Sarawak and the remaining 17% in Peninsular Malaysia (Table 1). Of the total, about 446,000 ha or 70% have been gazetted as forest reserves. Currently, there are a total of 112 mangrove forest reserves in the country (Table 2). These reserves form part of the country's Permanent Forest Estate which is managed for sustainable forestry production. With the exception of Sabah and Sarawak, there are no reliable statistics on the extent of stateland mangroves in the country. The figures for the various states are only rough estimations. Stateland mangroves are forests outside the reserves and they come under the jurisdiction of the respective State Governments.

In Peninsular Malaysia, mangroves are found mainly on the sheltered west coast that borders the Straits of Malacca in the states of Kedah, Perak, Selangor and Johor (Fig. 1). Major nearshore islands which are predominantly colonised by mangroves include the Klang islands in Selangor and Pulau Kukup in Johor. These islands often have fairly extensive mudflats. Small patches of mangroves do occur along rocky shores and they includes those found in Pulau Langkawi, Kedah, in Pulau Pangkor, Perak and in Port Dickson, Negeri Sembilan. In the south, mangroves are found in the estuaries of the Pulai and Johor rivers which drain into the Straits of Johor. On the east coast, patches of mangroves are confined to sheltered estuaries of the Kemaman river in Terengganu; Pahang, Bebar and Rompin rivers in Pahang; and Sedili Besar and Sedili Kecil rivers in Johor.

In Peninsular Malaysia, the total extent of mangrove forests is about 107,700 ha. Of the total, about 92,300 ha (85.7%) are gazetted as forest reserves while the remaining 15,400 ha (14.3%) are stateland mangroves (Table 1). There are 74 mangrove forest reserves of which 54 reserves occur on the west coast, 13 reserves occur on the east coast and the remaining 7 reserves occur along the Straits of Johor in the south. Of the 11 states in Peninsular Malaysia, Perak has the greatest number of mangrove reserves of which 19 reserves form the Matang mangroves.

Table 1. Current extent (ha) of mangrove forest reserves and stateland mangroves in Malaysia .

State	Mangrove Forest Reserves	Stateland Mangroves	Total
Johor	16,697	8,000	24,697
Kedah	8,034	100	8,134
Kelantan	-	20	20
Malacca	314	-	314
Negeri Sembilan	1,061	-	1,061
Pahang	2,032	450	2,482
Penang	406	100	506
Perak	40,869	2,600	43,469
Perlis	-	100	100
Sabah	316,460	49,000	365,460
Sarawak	36,992	131,000	167,992
Selangor	21,983	4,000	25,983
Terengganu	954	-	954
Total	445,802	195,370	641,172

In Sabah, mangrove forests are found mainly on the east coast at Labuk, Sandakan, Trusan Kinabatangan, Darvel, Cowie, Lahat Datu and Tawau (Fig. 2). On the west coast, they occur along the shores of the Kudat and Bengkoka peninsulas and along the estuaries of the Klias and Padas rivers. Mangroves in Sabah cover a greater area than in any other state in Malaysia. The total extent is about 365,500 ha (Anon., 1989) or 57% of the country's total (Table 1). About 87% have been

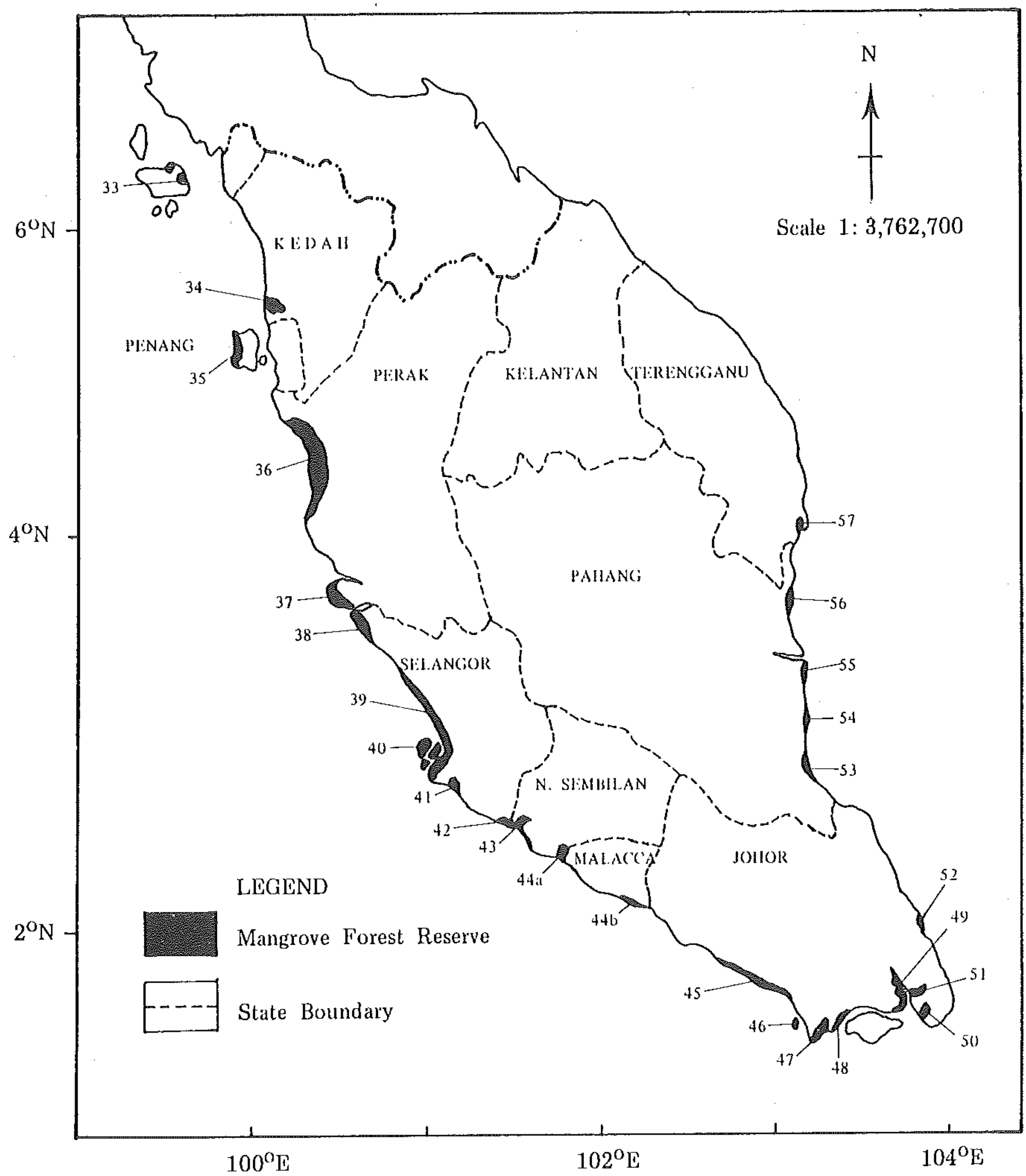

Figure 1. Location of mangrove forest reserves in Peninsular Malaysia

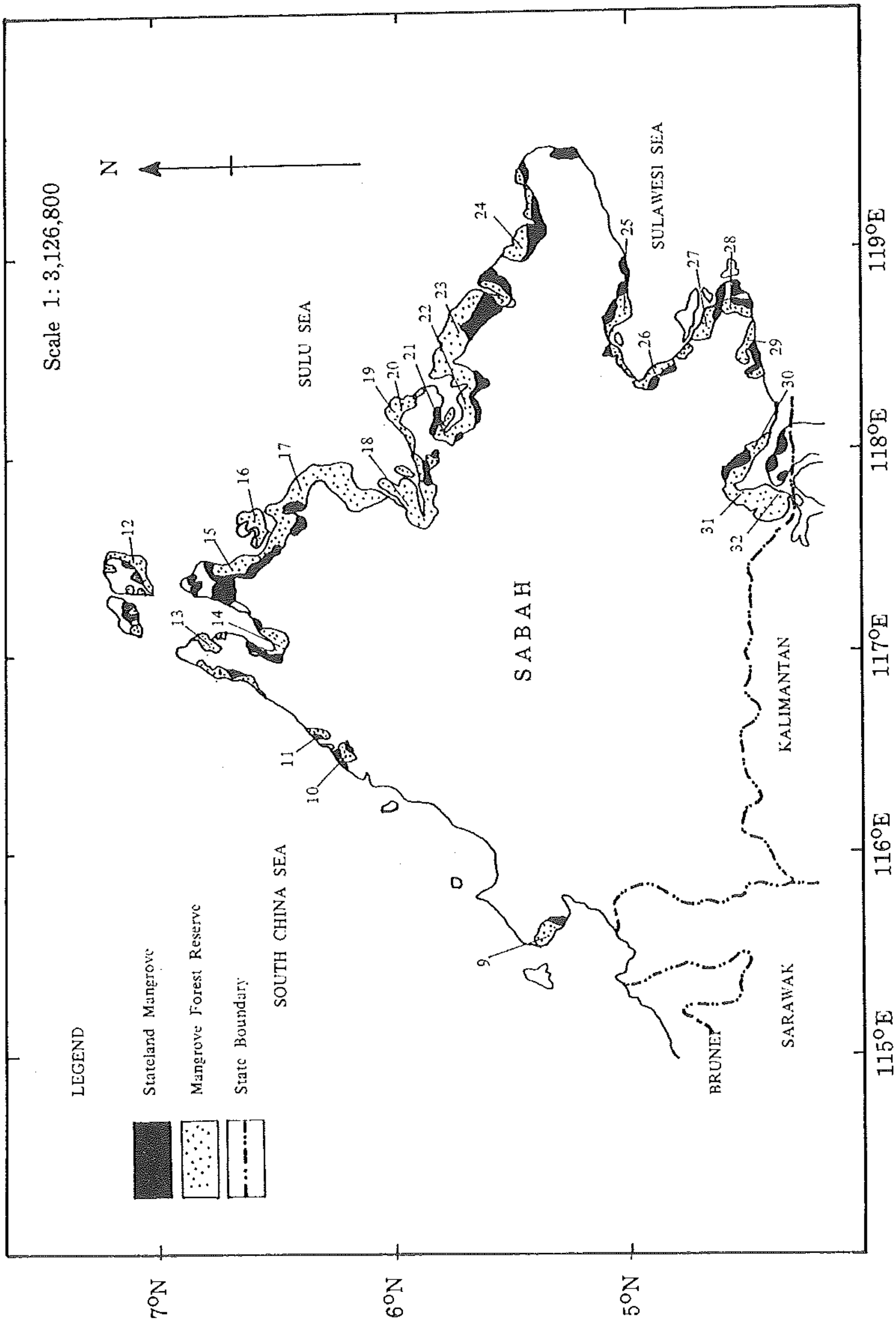

Figure 2. Location of stateland mangroves and mangrove forest reserves in Sabah

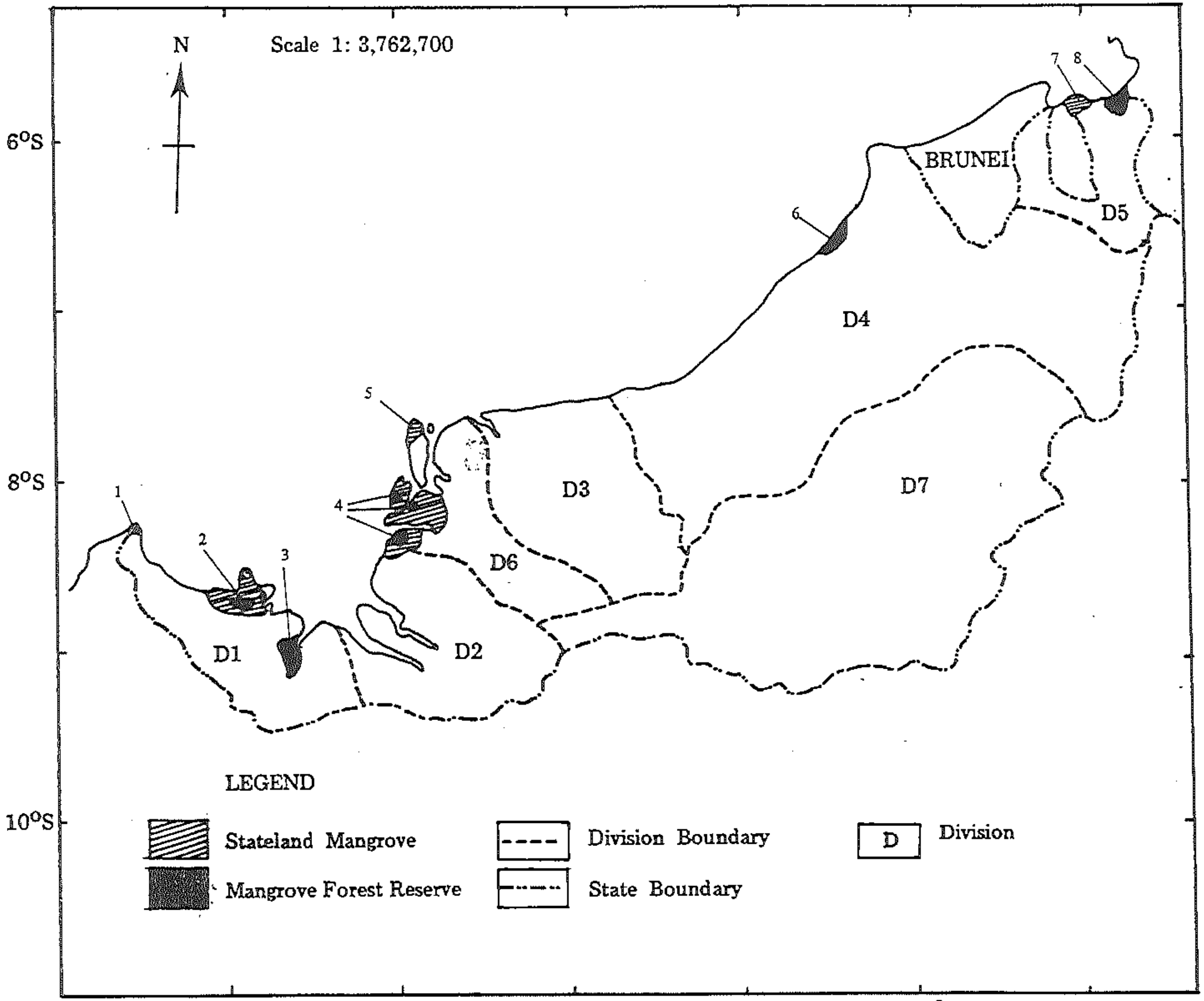

Figure 3. Location of stateland mangroves and mangrove foret reserves in Sarawak

designated as forest reserves with only 13% remain as stateland forests. There are currently 26 mangrove forest reserves in Sabah out of the country's total of 112 reserves (Table 2).

In Sarawak, mangroves are confined to the deltas of the Sarawak, Rajang and Trusan-Lawas rivers in the First, Sixth and Fifth Divisions, respectively (Fig. 3). The total extent of mangroves in Sarawak is about 168,000 ha (Anon., 1991) of which only 22% have been gazetted as forest reserves (Table 1). Concomitantly, there are only 11 mangrove forest reserves in the state (Table 2). The remaining 131,000 ha account for more than 67% of the country's total stateland mangroves. There is therefore a need for Sarawak to designate more mangrove areas as forest reserves.

Analysis of loss of mangroves

Between 1980 and 1990, mangrove forest reserves in Malaysia had dwindled from about 505,000 ha to 446,000 ha (Table 3). This accounted for a reduction of about 12%. Greatest loss was experienced in Terengganu, Johor, Selangor and Negeri Sembilan. In Malacca, the extent was increased from 77 ha to 314 ha. This was due to the establishment of the Sebatu Mangrove Forest Reserve addition to the existing Linggi Mangrove Forest Reserve (Table 2). Figures in Table 3 are compiled from various publications and reports. The reliability of these figures is questionable and should therefore be used with caution. In this context, the following case studies are used to provide a better analysis of the loss of mangrove forests due to various landuses. They include the South Johor mangroves, the Pulau Lumut and Kapar Mangrove Forest Reserves and the Benut mangrove forest.

The South Johor mangroves

There are ten mangrove forest reserves in the coastal districts of Pontian, Johor Bahru and Kota Tinggi in South Johor. In 1960, the total extent of these reserves was reported to be about 23,000 ha (Edington, 1963). Analysis of the 1986 aerial photographs by Chan (1991) showed that the total extent had dwindled to about 18,000 ha. A total of about 4,900 ha have therefore been alienated, involving the loss of 84 forest compartments (Table 4).

The loss of mangrove reserves was due mainly to conversion to agriculture, shrimp culture and reversion to stateland mangroves. They resulted in a loss of 2,240, 1,169 and 1,167 ha, respectively (Table 5). Other conversional activities include human encroachment (Sg. Johor and Lebam Forest Reserves), impoundment for freshwater supply (Sg. Johor Forest Reserve) and mining for tin (Sg. Santi Forest Reserve). Of these reserves, the Benut Forest Reserve suffered the greatest loss. It was reduced from 2,661 ha in 1960 to a meagre 300 ha in 1986 due to conversion of its landward forests to agriculture (1,194 ha) and the reversion of its existing belt of seafront mangroves to protective stateland forests (1,167 ha).

Stateland mangroves which occur outside forest reserves are not managed for sustained timber production. Hence, they are often subject to pressures of alienation. In South Johor, their extent has dwindled from 8,752 ha in 1970 to 7,789 ha in 1986 (Table 6). Recent development showed that this resource has been further reduced. For example, another 48 ha (37 %) of the Sg. Lunchu stateland mangroves near Johor Bahru were cleared for shrimp culture between 1986 and 1988.

The Pulau Lumut and Kapar Mangrove Forest Reserves

The Pulau Lumut Mangrove Forest Reserve (4,349 ha) is one of the Klang mangrove islands, forming a deltaic complex of the Klang and Langat rivers in Selangor. In the late 1950s, an area of 1,249 ha in the central portion of the island was bunded for agricultural purposes and subsequently designated a Malay Reservation Land. The area was reclaimed primarily for coconut plantations and supports a population of about 5,000. An inspection of the 1990 Landsat imagery showed that the reservation had expanded to 1,724 ha and another 32 ha of the forest reserve along the west coast have been cleared for port development. The resultant extent of the forest reserve has been reduced to 2,593 ha. Currently, an expressway and a bridge are being constructed linking the port to the mainland. Capitalising on the development of the port, its ancillary infrastructures, the expressway and bridge, the development of an industrial estate on Pulau Lumut has been proposed. Should the proposed industrial estate (2,277 ha) be approved, the Pulau Lumut Mangrove Forest Reserve will be diminished to a meagre 316 ha in the southern part of the island.

The Kapar Mangrove Forest Reserve represents the largest block of mangrove forest in Selangor. It stretches from the Sembilang river in the north to

Table 2. Gazetted mangrove forest reserves in various states of Malaysia

Mangrove Forest Reserve	Location No.	No. of Reserves
Sarawak		11
Samunsam	1	
Sarawak	2	
Sampadi	2	
Kampung Tian	3	
Rajang	4	
Loba Pulau	4	
Paloh	4	
Pulau Bruit	5	
Kuala Sibuti	6	
Kedalian	7	
Terentang	8	
Sabah		26
Menumbok	9	
Sulaman Lake	10	
Abai	11	
Pulau Banggi & Pulau Belembangan	12	
Limau-Limauan	13	
Kudat & Marudu Bay	14	
Bengkoka Peninsula	15	
Pulau Jabongan	16	
Sungei Sugut & Sg. Paitan	17	
K. Bonggaya & K. Labuk	18	
Gum-Gum & Sg. Loboh	19	
Sibyte	20	
Sepilok	21	
Elopura	22	
Trusan Kinabatangan	23	
K. Segama - K. Maruap	24	
Lahat Datu	25	
Kuala Yingkayu	26	
Segarong	27	
Semporna	28	
Tanjung Nagas	29	
Kukusan	30	
Umas-Umas	30	
Tawau	31	
Batumapun	32	
Kedah		11
Ayer Hangat	33	
Bukit Malut	33	
Pulau Dayang Bunting	33	
Gua Cherita	33	
Kisap	33	
Kubang Badak	33	
Pulau Langgun	33	
Pulau Timun	33	
Selat Panchor	33	
Tanjung Dagu	33	
Merbok	34	
Penang		1
Balik Pulau	35	
Perak		21
Cabai Malai	36	
Palau Gula	36.	
Pulau Kecil	36	
Pulau Kelumpang	36	
Pulau Pasir Hitam	36	
Pulau SanggaBesar	36	
Pulau Sangga Kecil	36	
Pulau Selinsing	36	
Pulau Sg. Nibong	36	
Pulau Trong Selatan	36	
Pulau Trong Utara	36	
Sg. Limau	36	
Sg. Temerlok	36	
Sg. Tinggi	36	
Sg. Baharu	36	
Teluk Kertang	36	
Trong	36	
Jebong	36	
Sg. Sepetang	36	
Tanjung Burong	36	
Rungkup	37	
Selangor		15
Kuala Bernam	38	
Banjar Utara	39	
Banjar Selatan	39	
Pulau Tengah	40	
Pulau Kelang	40	
Pulau Tonggok	40	
Pulau Gedong	40	
Pulau Pintu Gedong	40	
Pulau Selat Kering	40	
Pulau Che Mat Zin	40	
Pulau Lumut	40	
Kapar	40	
Sepang Kecil	40	
Jugra	41	
Kuala Sepang	42	

Table 2. Gazetted mangrove forest reserves in various states of Malaysia (Continued)

Mangrove Forest Reserve	Location No.	No. of Reserves
Negeri Sembilan		3
Sepang	42	
Lukut	43	
Linggi	44	
Malacca		2
Linggi	44a	
Sebatu	44b	
Johor		10
Benut	45	
Pulau Kukup	46	
Sg. Pulai	47	
Sg. Kemudi & Bahan	48	
Pendas	48	
Sg. Johor	49	
St. Santi	50	
Lebam	51	
Belungkor	51	
Kuala Sedili	52	
Pahang		11
Kelebor	53	
Palau Jawa	53	
Nibong Empat Puloh	53	
Pulau Lang	53	
Buah Keras	53	
Sampah	53	
Pontian	53	
Bebar	54	
Sg. Miang	55	
Kuantan	56	
Sg. Cherating	56	
Terengganu		1
Kuala Kemaman	57	
TOTAL		112

Port Klang in the south. Between 1970 and 1990, the reserve has been reduced from 4,865 ha to 2,481 ha. A total area of 1,183 ha have been converted to agriculture while port extension, power station construction and housing development accounted for a further loss of 255, 215 and 731 ha, respectively. For the above period, a total of 2,384 ha or 49 % of the reserve have therefore been converted.

The Benut mangrove forest

The Benut Mangrove Forest (1,557 ha) is located in the district of Pontian, Johor. It stretches from Pontian Kecil in the south to Rengit in the north and has a coastline of about 40 km that borders the Straits of Malacca. It consists of the Benut Forest Reserve (300 ha) and the Benut Stateland Mangrove (1,257 ha) which is mainly accreting seaward mangroves varying from 0.25 to 1.0 km in width.

The Benut river that drains the forest has a wide estuary with high sand and shingle ridges extending about 2 km offshore (Hawkins and Howes, 1986). The mangroves at the estuary are accreting rapidly seawards. From 1970 to 1986, the mangrove shore at the mouth of Sg. Benut had advanced about 600 m, suggesting an accretion rate of about 40 m per year.

The whole of the Benut Mangrove Forest was designated a Mangrove Forest Reserve between 1931 and 1935 (Burgess, 1950). The reserve had six forest compartments and covered an area of about 2,800 ha during the time of reservation. In 1960, the reserve has been reduced to about 2,661 ha (Edington, 1963).

By 1986, the reserve has dwindled to only about 300 ha (Chan, 1991). Timber extraction for poles and firewood is currently on-going in the reserve. The remaining forest seaward of the coastal bunds (1,167 ha) has been degazetted and reverted to a Stateland Forest. The total area of mangrove forest excised for agriculture under the West Johor Agriculture Development Project has been estimated to be about 1,194 ha. Since the inception of the project, about 66 km of coastal bunds have been constructed. From 1970 to 1986, the stateland forest has gained about 389 ha through accretion.

Table 3. Area (ha) of mangrove forest reserves in Malaysia in 1980 and 1990.

State	1980	1990	± ha	± %
Johor	25,619	16,697	-8,922	-34.8
Kedah	9,037	8,034	-1,003	-11.1
Malacca	77	314	237	+75.5
Negeri Sembilan	1,352	1,061	-291	-21.5
Pahang	2,496	2,032	-464	-18.6
Penang	406	406	-	-
Perak	40,869	40,869	-	-
Sabah	349,773	316,460	-33,313	-9.5
Sarawak	44,491	36,992	-7,499	-16.9
Selangor	28,243	21,983	-6,260	-22.2
Terengganu	2,982	954	-2,028	-68.0
Total	505,345	445,802	-59,543	-11.8

Major forest types and associated flora

Avicennia-Sonneratia forests

In Malaysia, these forests are typically located at the seafront where the muddy substrate is soft and deep. Two subtypes are distinguishable, namely, the shoal subtype which is formed offshore by deposition of sand and silt, and the accretion type which is formed by silt brought down by rivers. Examples of the former can be seen on the islands off Port Klang in Selangor while those of the latter occurs extensively along the banks of the Kelumpang and Selinsing estuaries in Perak, and the Paloh and Rajang estuaries in Sarawak.

The deep and soft mud is usually occupied by *Avicennia alba* while the firmer soil further inland supports *Avicennia marina*. Along estuaries and rivers, *Sonneratia alba* and *Avicennia officinalis* grow gregariously but never extensively. Along accreting shores, these pioneer species regenerate profusely and rapidly colonise newly formed mudflats.

Rhizophora-Bruguiera forests

These forests represent the major forest type of the tidal mangroves. The dominant species is *Rhizophora apiculata* with scattered occurrence of *Bruguiera cylindrica* and *Bruguiera parviflora*. Along the banks of rivers and creeks, *Rhizophora mucronata* grows gregariously.

In more inland sites where the soil is firmer, an array of other species is found. They include *Xylocarpus granatum*, *Xylocarpus moluccensis*, *Bruguiera gymnorrhiza*, *Bruguiera sexangula*, *Ceriops tagal*, *Ceriops decandra*, *Excoecaria agallocha*, *Heritiera littoralis*, *Lumnitzera racemosa*, *Lumnitzera littoralis* and *Scyphiphora hydrophyllacea*. In open sites, the mangrove ferns *Acrostichum aureum* and *Acrostichum speciosum* grow in dense thickets.

Dryland mangroves

Dryland mangroves denote the final stage of forest succession and represent the transition into inland forests. They are often found towards the landward side of mainland mangroves or in the interior of island mangroves and are inundated by occasional spring tides. Unlike the tidal mangroves, species are more diverse. Common

Table 4. Loss of area (ha) and forest compartments in various mangrove forest reserves in South Johor from 1960 to 1980

Forest Reserves	1960		1986		Loss	
	Extent	Compartments	Extent	Compartments	Extent	Compartments
Pulai	9,148.6	500	7,633.2	443	1,515.4	57
Sg. Johor	3,800.3	173	3,215.8	155	585	18
Sg. Kemudi and Bahan	156	22	156	22	0	0
Pulau kukup	650	17	650	17	0	0
Sg. Lebam	1,473.0	19	1,354.0	18	119	1
Belungkor	1,261.8	38	1,261.8	38	0	0
Sg. Santi	2,502.1	43	2,453.5	42	49	1
Pendas	816	56	546	49	270	7
Benut	2,661.0	0	300	0	2,361.0	0
Kuala Sedili	433	0	433	0	0	0
Total	22,901.0	868	18,002.7	784	4,898.3	84

tree species identified by Watson (1928) in this forest type include *Bruguiera gymnorrhiza, Rhizophora apiculata, Xylocarpus moluccensis, Intsia bijuga* and *Oncosperma tigillarium*. Dixon (1959) reported the abundance of *Acrostichum* ferns and that *Rhizophora apiculata* trees found in these forests are gnarled, heavily branched and stunted with natural regeneration sparse or absent.

In Matang, dryland mangroves occur in patches throughout the forest reserves and cover a total area of about 2,200 ha or about 5.3% of the reserves (Haron, 1981). Based on a floristic survey carried out in an undisturbed dryland mangrove forest, a total of 2,012 trees of 5 cm dbh and above was recorded in nine 0.25 ha random plots (Chan, 1989). They belonged to 30 species and 23 genera. The species are ranked in terms of their abundance (density per hectare) in Table 7. Commercial species are *Rhizophora apiculata, Oncosperma tigillarium, Bruguiera gymnorrhiza* and *Instia bijuga*. Species having diameters greater than 50 cm dbh include those of *Bruguiera gymnorrhiza, Intsia bijuga, Euodia roxburghii, Rhizophora apiculata* and *Ficus microcarpa*.

Nypa forests

Forests of *Nypa fruticans* commonly occur along the banks of tidal rivers where there is greater freshwater influence. These forests may extend several kilometres inland. The palm generally grows gregariously, interspersed with *Avicennia* and *Sonneratia* near estuaries, with *Rhizophora* and *Bruguiera* on soft mud further inland and with *Heritiera* and *Excoecaria* on stiffer ground (Chai, 1975; Fong, 1984). The undergrowth comprise mainly of *Acrostichum* ferns growing on lobster mounds.

In Peninsular Malaysia, the past extent of *Nypa* forests was estimated to be about 13,500 ha by Heath (1949). An estimation based on aerial photographs taken between 1968 and 1970 revealed an extent of only about 4,900 ha (Table 8). The largest blocks of forests, covering more than 1,000 ha, are found at the estuary of the Perak river. Chan (1991) reported the presence of 165 ha of *Nypa* forests in the districts of Pontian and Kota Tinggi in South Johor (Table 9). With the rapid conversion of landward mangroves, the current extent remains unknown. The extent of *Nypa* forests has been reported to be about 147,000 ha and 31,000 ha in Sabah and Sarawak, respectively (Anon., 1989; Anon., 1991).

Table 5. Alienation of mangrove forest reserves in South Johor from 1960 to 1986.

Forest Reserve	Shrimp culture	Agriculture	Human Encroachment	Impoundment	Mining	Stateland	Total
Pulai	740	776	-	-	-	-	1,515
Sg. Johor	318	-	214	52	-	-	585
Sg. Kemudi and Bahan	-	-	-	-	-	-	-
Pulau Kukup	-	-	-	-	-	-	-
Sg. Lebam	111	-	8	-	-	-	119
Belungkor	-	-	-	-	-	-	-
Sg. Santi	-	-	-	-	49	-	49
Pendas	270	-	-	-	-	-	270
Benut	-	1,194	-	-	-	1,167	2,361
Kuala Sedili	-	-	-	-	-	-	-
Total	1,169	2,239	222	52	49	1,167	4,898

Relative extent of different forest types

The relative extent of different mangrove forests types in Malaysia is not known with the exceptions of several areas. The Matang mangrove which has been sustainably managed for wood production since the early 1900s represent one of such areas. It comprises of three ranges, namely, Kuala Sepetang, Kuala Trong and Sungei Kerang, 19 forest reserves, and 108 forest compartments. Of the major forest types found, *Rhizophora* forests cover 34,769 ha or 85% of the total area of 40,711 ha (Table 10). *Avicennia* forests which cover 3,067 ha are found at the estuaries of the Kelumpang, Selinsing, Sangga Besar and Larut rivers in the Kuala Sepetang Range and at the estuary of the

Jarum Mas river in the Sungei Kerang Range. Dryland forests, which occur on more elevated sites, have a patchy distribution throughout Matang. About 70 such patches make up the total of 2,205 ha of dryland forests. Pulau Kecil, a 42 ha island of old growth *Rhizophora* forest located opposite the fishing village of Kuala Sepetang, has been gazetted a virgin jungle reserve. Other forest types include research forests retained for thinning trials and seed collection, and bagan forests which are specially allocated to meet the needs of fishing villagers for firewood and fishing stakes. Degraded areas mainly include sites cleared for housing and charcoal kilns.

Table 6. Area (ha) of stateland mangroves in South Johor in 1970 and 1986.

	1970	1986
Johor Bahru	1,228	1,214
Kukup	833	801
Pontian Kecil	1,556	1,556
Kota Tinggi	3,626	2,871
Kuala Sedili	592	570
Tanjung Surat	917	777
Total	8,752	7,789

Fauna found within forest habitats

The fauna of mangrove forests in Malaysia may be considered under three categories, namely, (a) terrestrial fauna which live largely in the forest canopy, (b) those residing in the intertidal zone and (c) those living in estuaries, creeks and inlets.

Terrestrial fauna

Many species of mammals, birds and insects live in the canopy of mangrove forests (Berry, 1972). The leaf monkey, proboscis monkey and the long-tailed macaque live permanently in the mangrove forest and feed on leaves and fruits. Many species of birds including migrant birds that feed on mudflats, roost in the mangrove canopy (Nisbet, 1968). Reptiles such as monitor lizards, several species of snakes and small lizards are common. Many species of insects and other arthropods also dwell in the canopy of trees (Murphy, 1990).

Table 7. Ranked frequency distribution of species based on density per hectare of trees 5 cm dbh and above in an undisturbed dryland mangrove in Matang (after Chan, 1989).

No.	Species	No of Trees/ha
1	Rhizophora apiculata	140.9
2	Heritiera littoralis	130.2
3	Ficus microcarpa	123.1
4	Flacourtia jangomas	76.9
5	Oncosperma tigillarium	70.7
6	Bruguiera gymnorhiza	66.7
7	Teijsmanniodendron hollrungii	53.3
8	Barringtonia asiatica	48.9
9	Ilex cymosa	31.1
10	Planchonella obovata	28.4
11	Petunga roxburghii	23.6
12	Intsia bijuga	18.7
13	Euodia roxburghii	18.2
14	Canthium didymus	15.9
15	Polyalthia sclerophylla	9.8
16	Cynometra ramiflora	8.0
17	Terenna fragrans	7.6
18	Ardisia elliptica	4.9
19	Pittosporus ferrugineum	3.6
20	Ficus sundaica	2.2
21	Glochidion perakensis	1.8
22	Vitex pinnata	1.8
23	Eugenia kunstleri	1.8
24	Eugenia leucoxylon	1.3
25	Ficus annulata	0.9
26	Polyalthia glauca	0.9
27	Ficus obscura v. borneensis	0.9
28	Ficus bracteata	0.4
29	Xylocarpus granatum	0.4
30	Ficus crassiramea	0

Intertidal fauna

The mudflats that occur at the foreshore of mangrove forests is the habitat of many invertebrates, migrant birds, fish and prawns (Broom, 1982; Duncan *et al.*, 1984; Sagathevan, 1990). Mudflats along the coast of Selangor and Perak are extensively used for the culture of the blood cockle *Anadara granosa*. The annual

Table 8. Extent of *Nypa* forests in the various states of Peninsular Malaysia (1968-1970).

Location	*Nypa* Forests (ha)
Johor	212
Kedah	204
Kelantan	325
Malacca	125
Negeri Sembilan	30
Pahang	603
Penang	548
Perak	1,542
Perlis	38
Selangor	409
Terengganu	836
Total	4,872

production of the cockles in the two above states is estimated at 40,000 tonnes (Sagathevan, 1990).

The intertidal fauna of mangrove forests in Malaysia has been well documented with regard to species composition, abundance and distribution.

The lower portion of trunks of trees growing at the seafront supports dense populations of barnacles *Balanus amphitrite* and *Chthamalus withersii* and several species of bivalves and gastropods (Berry, 1972; Tee, 1982). Found in abundance are dense populations of the small mytilid bivalve *Xenostrobus variabilis* which are predated on by the neogastropod *Thais tissoti*. The abundance of the encrusting fauna decreases with distance towards the upper shore. *Littorina* spp. and *Nerita articulata* are common on tree trunks throughout the mangrove shore (Sasekumar, 1974).

Mangrove meiobenthos (small invertebrates ranging from 50 and 1000 microns in size) consist predominantly of free-living nematodes, harpacticoid copepods and kinorhynchs (Sasekumar, 1984). Densities of total meiofauna range from 1,129 per 10 cm^{-2} in seafront *Avicennia* forests to 140 cm per 10 cm^{-2} in more inland *Bruguiera* forests.

The community of macrobenthos varies considerably in species composition depending on forest types. In seafront *Avicennia* forests, the sediment surface is dominated by *Assiminea brevicula*, *Telescopium* spp. and *Salinator burmana* and a number of other gastropods. The infauna is dominated by fiddler crabs *Uca dussumieri*, *U. mani*, *Metaplax elegans*, *Ilyoplax* spp. and alpheid prawns (Sasekumar, 1974). A few polychaete species are also common in the substrate.

As one moves inland where tidal inundation is less frequent, grapsid crabs belonging to the family Sesarmidae are found in abundance. These crabs consume leaf detritus and play a dominant role in mangrove litter breakdown (Malley, 1978; Leh and Sasekumar, 1985). Other macrobenthos include fiddler crabs *Uca rosea*, *U. triangularis*, sipunculid *Phascolosoma arcuatum* and polychaete *Leiochrides australis*. The common gastropods are ellobiids *Telescopium* spp., *Cerithidea obtusa* and *Littorina conica*.

In Malaysia, densities of crabs of up to 80-90 individuals per m^2 have been recorded (Macintosh, 1988). Densities of macrobenthos vary along the shore gradient, for example, the snail *Assiminea brevicula* varies in densities from 188 per m^2 in the lower shore to 5 per m^2 in the upper shore. Densities of macrobenthos have been estimated by Sasekumar (1974), Macintosh (1984) and Leh (1982).

Table 9. Extent of *Nypa* forests in South Johor in 1986 (after Chan, 1991).

Location	*Nypa* Forests (ha)
Benut	89
Kuala Sedili Besar	28
Pontian Kecil	24
Pontian Besar	24
Total	165

Macintosh (1984) and Leh (1982) studied the productivity of several common species of crabs. Annual production of fiddler crabs was estimated at 4.6 to 28.9 kcal m^{-2} yr^{-1} while that of two grapsid crabs *Chiromantes eumolpe* and *C. onychophorum* was estimated at 109.6 kcal m^{-2} yr^{-1}. Secondary production is higher in undisturbed forests than in disturbed or cleared sites (Leh, 1982 ; Sasekumar 1984).

Aquatic fauna

Estuaries, creeks and inlets which form an integral part of the mangrove environment are important habitats for commercially important marine animals such as fish and prawns. The use of mangrove waterways as nursery grounds by fish

Table 10. Forest types of the Matang mangroves (after Haron, 1981).

Range	*Rhizophora* forest	*Avicennia* forest	Dryland forest	Research forest	Virgin Jungle Reserve	Bagan forest	Degraded area	Total
Kuala Sepetang	17,053	2,061	1,465	44	42	191	99	20,955
Kuala Trong	10,390	8	519	62	0	0	98	11,077
Sungei Kerang	7,326	998	221	32	0	58	44	8,679
Total	34,769	3,067	2,205	138	42	249	241	40,711

and prawns has been well established, and a positive correlation between commercial yields of fish and prawns and the area of mangrove forests has been found in Malaysia as in other parts of the tropical World (Turner, 1977; Jothy, 1984; Sasekumar & Chong, 1987). In a recent study, Chong *et al.* (1990) compared various habitats in the coastal waters of Selangor and came to the conclusion that mangrove waterways function importantly as feeding grounds for juveniles of commercially important prawn species. Studies in two large mangrove estuaries, Matang and Merbok, both on the west coast of Peninsular Malaysia, provide further evidence that mangrove waterways provide a habitat for juveniles of commercially important fish (Khoo, 1990).

Tables 11 and 12 show the fish and prawn species sampled in several habitats of the mangrove environment including the inshore waters of Selangor. The mangrove inlets/creeks had the highest density and biomass of fish and prawns compared to other coastal habitats (Table 13). They are the habitats of immature stages of some species of fish and prawns (Chong, 1979). The abundance of fish and prawns in the mangrove waterways is attributed to the availability of space and food (Chong and Sasekumar, 1981; Sasekumar *et al.*,1984; D'Cruz and Sasekumar,1990). Many mangrove benthic invertebrates as well as commercially important fish and prawns consume carbon derived from mangrove vegetation. This has been clearly demonstrated in the study of the stable carbon isotope ratios of consumer organisms (Rodelli *et al.*, 1984).

Shoreline changes

Formation, zonation and succession

In sheltered estuaries where river currents come into contact with the tide, flow is checked, favouring the deposition of sediments. Progressively, the estuary bed is banked up. When the bank has developed adequately, it becomes gradually colonised by pioneer mangrove tree species such as those of *Avicennia* and *Sonneratia*. With the colonisation of these species, the level of the bank is rapidly raised by further silt deposition aided by their expansive cable root systems. In time, propagules of other mangrove tree species such as *Rhizophora* and *Bruguiera* establish themselves and eventually succeed the pioneer species. The most ideal situation for the formation of extensive mangrove shores occurs in sheltered estuaries where numerous meandering creeks and rivers form a network of waterways. Examples of such areas include the estuaries of the Klang and Langat rivers in Selangor (Klang Mangroves), the Sepetang and Gula rivers in Perak (Matang Mangrove) and the Rajang and Paloh rivers in Sarawak (Rajang Mangrove).

Along the more exposed coasts, the wave action of the South China Sea is more severe, particularly during the North East monsoon when sediments brought down by rivers are readily dispersed. However, in some protected estuaries, the seaward flow of the river is sluggish and a sand bar may form across the mouth (Watson, 1928). As a result of the combined actions of currents and the North East monsoon, the bar extends southwards. *Casuarina equisetifolia* trees often grow on the bar while mangroves colonise the protected landward side at the lee of the bar. Under the prevalence of occasional storms, the bar may be broached and when this happens, a new river mouth is formed while the channel of the old mouth silts up and becomes colonised by mangroves. Later, a new bar is formed in front and the whole process is repeated. Consequently, one can observe successive relict sand bars with *Casuarina* trees and old decadent mangroves persisting in the hollows. Several east coast rivers show this tendency and this is particularly

Table 11. Mean percentage abundance by numbers of the 10 most important species of fish caught in creeks by bagnet (CR), inlets by gill nets (IG), inlets by beam trawl (IB), intertidal mudflats by enclosure traps (IM), subtidal edge of mudflats by trawl (SM), near inshore (NI) and far inshore (FI) waters by trawl in Selangor, Peninsular Malaysia.

	Sites						
Species	CR	IG	IB	IM	SM	NI	FI
Ambassis gymnocephalus	11.87	53.36	34.94	4.64	19.40	-	-
Apogon quadrifasciatus	-	-	-	-	3.03	4.70	-
Arius caelatus	-	-	-	5.92	-	-	-
Arius sagor	-	-	-	3.70	-	-	-
Arius tonggol	-	-	-	9.75	-	-	-
Arius venosus	-	-	-	-	6.28	-	-
Chelonodon fluviatilis	7.56	-	2.73	-	-	-	-
Cynoglossus macrolepidotus	-	-	-	13.65	-	-	5.90
Glossogobius giuris	-	-	1.28	-	-	-	-
Harpodon nehereus	-	-	-	-	-	-	10.08
Ilisha megaloptera	3.24	-	2.48	-	3.79	26.42	12.63
Johnius belangerii	-	-	-	-	-	-	4.04
Johnius coitor	-	-	-	6.72	4.63	2.85	12.43
Johnius soldado	-	-	-	-	3.79	5.41	-
Johnius sp.	-	-	1.90	-	-	8.09	-
Leiognathus brevirostris	4.09	1.62	-	-	-	-	2.99
Leiognathus daura	-	-	10.08	-	-	-	-
Liza malinoptera	-	0.59	-	-	-	-	-
Liza subviridis	5.93	1.58	-	6.99	-	-	-
Macrones gulio	-	-	-	26.50	-	-	-
Osteogeneiosus militaris	-	-	-	-	2.76	-	-
Otolithes ruber	-	-	-	-	4.49	12.02	-
Platycephalus scaber	-	-	-	-	-	1.78	-
Pomadasys hasta	-	-	1.01	6.72	-	-	-
Sardinella melanura	-	24.28	-	-	-	-	-
Scatophagus argus	-	-	1.98	-	-	-	-
Scomberoides commersonianus	3.29	-	-	-	-	-	-
Secutor insidiator	9.83	0.59				1.72	6.72
Stolephorus indicus	-	1.58	-	-	-	-	
Stolephorus tri	-	0.55	-	-	8.84	8.75	13.60
Tenulosa sinensis	-	-	-	-	-	-	1.72
Thryssa hamiltoni	11.35	2.70	14.53	-	-	-	-
Thryssa kamalensis	-	5.99	23.01	2.62	7.94	-	-
Upeneus sulphureus	-	-	-	-	-	5.40	3.57
Zenarchopterus buffoni	6.32	-	-	-	-	-	-
Zenarchopterus candovittatus	15.50	-	-	-	-	-	-
Others	21.02	7.16	6.06	12.79	35.05	22.86	26.32
Total number of species	43.00	69.00	49.00	37.00	55.00	58.00	92.00

Source: Chong *et al.* (1990)

Table 12. Mean percentage abundance by numbers of all prawn species caught in creeks by bag net (CR), inlets by beam trawl (IB), intertidal mud flats by enclosure trap (IM), subtidal edge of mud flats by trawl (SM), near inshore (NI) and far inshore (FI) waters by trawl in Selangor, Peninsular Malaysia

	Sites					
Species	CR	IB	IM	SM	NI	FI
Macrobrachium sp.	2.92	1.68	2.87	-	-	-
Metapenaeopsis stridulans	-	-	-	-	-	0.15
Metapenaeus affinis	0.30	3.88	13.23	56.74	0.38	3.43
Metapenaeus brevicornis	-	30.01	4.36	4.57	2.13	2.98
Metapenaeus lysianassa	-	-	0.22	-	-	-
Palaemon stylifera	-	-	70.34	-	-	-
Parapenaeopsis coromandelica	-	-	3.03	12.39	-	2.98
Parapenaeopsis gracillima	-	-	0.06	-	-	0.54
Parapenaeopsis hardwicki	-	-	0.17	0.22	65.00	13.02
Parapenaeopsis hungerfordii	-	-	-	17.39	5.38	10.04
Parapenaeopsis maxillipedo	-	-	-	0.87	3.46	11.68
Parapenaeopsis sculptilis	-	0.10	-	1.74	16.15	61.28
Penaeus indicus	2.92	13.53	1.43	-	-	0.24
Penaeus merguiensis	11.40	21.93	3.86	2.39	0.77	1.19
Penaeus monodon	-	0.21	-	-	-	-
Penaeus penicillatus	82.46	28.65	0.44	-	-	0.12
Solenocera subnuda	-	-	-	3.48	6.58	5.69
Trachypenaeus fulvus	-	-	-	0.22	-	0.03
Total number of species	5	8	11	10	8	14

Data from Chong *et al.* (1990)

marked in the estuaries of the Rompin, Merchang and Bebar rivers.

Accretion

An accreting mangrove shore is a result of gradual sedimentation of silt brought down by rivers and progressive colonisation of mangroves. It is characterised by a raised mud flat and a dense low crop of *Avicennia* trees advancing seawards. Kuala Sanglang, a fishing village at the boundary of Kedah and Perlis, was located at the seafront about a decade ago. It is now about 300 m inland, suggesting an accretion rate of about 30 m per year (Salleh and Chan, 1988). Between Benut and Pontian Kecil in Johor, the mangroves have gained about 400 ha in area from 1970 to 1986. At the estuary of the Benut river, the mangrove shoreline has extended 600 m seawards, implying an accretion rate of about 40 m per year.

Erosion

Contrary to the natural phenomenon of accretion in certain mangrove areas, erosion may occur in other areas and it is often associated with alienation for various landuse purposes (Carter, 1959; Macnae, 1968). An eroding mangrove shore is characterised by the general lowering of the nearshore profile, formation of a retreating scarp, collapsing of mangrove trees, and the presence of a beach of shell fragments (Salleh and Chan, 1988). Chan (1985) has reported several cases of severe coastal erosion of mangrove outside agriculture bunds. A survey carried out in 1985 (Anon., 1985) indicated that about 87 km of the mangrove coastline fringing agriculture areas are subjected to severe erosion. Selangor, where agriculture schemes are most extensive, has 42 km of the coastline severely affected. This is reflected in eroding mangrove fringing shorelines at Sungei Besar and Jeram. In Sungei Besar, due to rupture of the coastal bund and ingression of seawater which destroyed agriculture crops, a retreat bund

Table 13. Biomass and density of the major catch components as sampled in the four habitats on the Selangor coast, Peninsular Malaysia

Habitat	Parameter	Fish	Prawn	Others	Total
Creeks/inlets	kg ha^{-1}	17.70	3.18	0.52	21.40
	number ha^{-1}	12,860	1,238	83	14,181
	mean wt of individuals (g)	1.38	2.57	6.26	
Mudflats	kg ha^{-1}	5.96	0.77	1.79	8.52
	number ha^{-1}	866	239	306	1,411
	mean wt of individuals (g)	6.88	3.22	5.85	
Near inshore	kg ha^{-1}	6.06	0.23	1.32	7.61
	number ha^{-1}	642	45	119	806
	mean wt of individuals (g)	9.44	5.11	11.09	
Far inshore	kg ha^{-1}	3.74	1.14	1.79	6.67
	number ha^{-1}	492	328	278	1,098
	mean wt of individuals (g)	7.60	3.48	6.44	

Data from Chong *et al.* (1990)

was constructed. In Jeram, a beach has covered the mangrove substrate. There is severe dieback of mangrove trees due to the movement of shell fragments which abraded the barks away. Chan (1985) has attributed the causes to the scouring effects of strong waves and to the bunding or barraging of rivers for irrigation. The diversion of river water for irrigation restricts the inflow of freshwater and sediments which are vital to the sustenance of the mangrove ecosystem.

Socio-economic values and patterns of use

We would like to point out that socio-economic values are extremely hard to quantify. Returns can be at different levels (e.g. as sold by the harvester or by the middle man at wholesale prices or as sold by the final retailer) and in many reports this is often not made clear. There can also be many hidden costs: e.g. in the mangrove pond prawn industry, infrastructural cost like pond construction costs and interest on land costs are not included in budgets. This means that direct comparisons are often not valid. Detailed studies have to be made in order to get valid comparisons of costs.

Forestry

Traditionally mangroves are harvested for fuel (as firewood or first converted to charcoal) and for poles (now mainly used as piling). Much of this tradition persists. In the Matang mangroves in the State of Perak we see what is considered to be the best managed mangrove forest in the world. The mangroves here have been managed (see Ong, 1982 for a description) since the early part of this century [see Watson, 1928 for a detailed description of the forest and the early management plan as well as subsequent managements plans by Noakes (1952), Dixon (1959), Mohd. Darus (1969), Haron (1981). This is one of the very few examples of a proven highly successful sustained management of a tropical rainforest ecosystem. Ong (1978) touched on the economic returns from the Matang system but a more detailed and systematic study would be very useful since without such a study it is not possible to compare the socio-economic values of different activities.

Ong (1978) estimated that in Matang, the extraction and processing of timber provided employment for a direct workforce of about 1,400 and an indirect workforce of another 1,000. Total annual revenue from timber was estimated at US$6,000,000 with about US$450,000 going to the State as royalty and other taxes. The fishing industry on the other hand provided employment for an estimated direct workforce of 2,600 and an indirect workforce of about 7,500. Annual revenue was estimated to be US$12-30 million (see Tang *et al.*, 1981). Thus this 40,000 ha mangrove provided employment (directly and indirectly) for an estimated 12,500 persons and an annual revenue of up to US$46 million. On an area basis this converts to an approximate monetary return of just over US$1,000 ha^{-1} yr^{-1}. Although this refers to a sustainable return it is low. On the workforce side, each worker is supported by approximately 3 ha of mangrove.

More recently, in Sabah (1970) and Sarawak (1968), vast tracts of mangroves have been degraded as a result of harvesting of mangroves for the woodchip industry (for conversion into rayon in Japan). A single chipping plant can consume a vast amount of mangrove logs so such operations require hugh areas of mangroves. Large areas need to be felled resulting in problems of regeneration (inadequate supply of propagules to seed the clear felled areas. Nair (1977) has looked at the economics of this industry. The industry may be very lucrative for the Japanese importers of the woodchips (who have a virtual monopoly of the market and so dictate the price) but economic benefits derived by the local population is minimal especially compared to the scale of degradation. The industry also has a limited lifespan. The plant in Sarawak (after less than 25 years) has now virtually run out of mangrove wood (non-sustainable harvesting is the problem) and has been working below capacity even though it has resorted to chipping wood from non-mangrove forests.

The Sarawak plant was allocated an annual coupe of 607 hectares which would have consumed some 15,000 hectares in 25 years (as a comparison, the annual coupe in Matang is 1,000 hectares). Since they have already run out of wood it would imply that more than the originally allocated annual coupe may have been removed. We do not have the exact figure but estimate that the actual area harvested would be much closer to at least double the 15,000 hectares based on the originally allocated annual coupe. The industry in Sarawak provided employment for about 200 mill workers (the number now is closer to 10% of that) and an estimated 500 persons involved in felling and transport. Annual revenue is estimated at US$3 million (this value may be different from what the Japanese woodchip industry actually gets).

Each of the two Sabah plants was allocated 2,025 hectares as the annual coupe. The plants in Sabah were closed down a few years ago. In the 15 years or so of operations an estimated 70,000 hectares of mangroves in Sabah were severely degraded. The industry provided employment for approximately 1,500 and annual revenue derived was estimated at about US$5 million (Liew, 1980). Thus on the workforce side, each worker is supported by approximately 45 ha of mangrove - a figure that is 15 times that in Matang.

On an area basis the mangroves used for woodchips production in Sabah yield over US$1,200 per ha^{-1} yr^{-1}. This is about the same as that derived from timber and fish in Matang. However, the Matang figure was derived by dividing annual revenue by the total mangrove area and not just the annual coupe. Based on division by annual coupe the Matang figure is about 40 times higher than the woodchips figure.

Based on economic returns as well as the provision of employment, the Sabah mangrove woodchips operation gives a mere 2.5% of the returns of the Matang charcoal and poles operation (based on a unit area basis). On top of this Matang has a proven sustainable record whereas the woodchips operation has proved to be not sustainable. The closing down of the mangrove woodchips industry in Sabah is thus an economically and ecologically rational move.

Capture fisheries

Many species of commercial fish are found within mangrove estuaries (e.g. Jothy, 1984) and many of these fish and prawns use mangroves as nursery and feeding grounds (Sasekumar *et al.*, 1990; Leh and Sasekumar, 1984; Thong and Sasekumar, 1984; Chong *et al.*, 1990). Many fishing activities go on within the mangrove waterways although at least some of these are not legal. The mudcrab (*Scylla serrata*) fisheries alone must contribute to significant economic returns but this has hardly been quantified. Wong *et al.* (1984), reported a landings of 152 tonnes, worth an estimated US$125,000 (to the fishermen so the market value was much higher), in the east coast of Peninsular Malaysia (where the mangrove area is very small) in 1978. They quoted a (1972) figure of 500 tonnes for Sabah. Even more lucrative is bagnet fishing in mangrove estuaries with its high grade commercial catches of prawn (*Penaeus monodon*) and pomfrets (*Pampus chinensis*). Table 14 (from Khoo, 1989) gives a good idea of the species composition of bagnet catch in the Sungai Merbok mangroves in the state of Kedah. Again, no quantification of its economic returns is available. Jothy (1984) estimated that in 1981 about a third of the commercial species of fish and shellfish landed in Peninsular Malaysia were mangrove or mangrove associated species (Table 15). This represents a catch of some 209,000 tonnes of fish and shellfish with a value estimated at around

Table 14. Species composition of bagnet fishery (from Khoo, 1989).

Species	Count	Weight	Species	Count	Weight
Ambussis spp.	334	972.5	*Setipinna taty*	15	311.9
Arius venosus	20	528.3	*Stolephorus andhraensis*		
Caranx malabaricus	1	2.1	*S. heterolobus*		1,200.0
Chorinemus lysan	1	7.7	*S. indicus* ?		
Gobiidae	8	42.8	*Thrissocles dussumieri*	5	55.6
Johnius sina	225	240.3	*T. hamiltoni*	3	109.0
J. soldado	1	77.7	*T. mystax*	1	19.4
Kowala spp.	1	6.8	*Triancanthus* spp.	13	1.4
Lagocephalidae	13	613.7	*Trichiurus glossodon*	20	78.7
Leiognathus brevivostris	6	13.2	Trypauchenidae	1	11.0
Liza spp.	38	435.3	Other species		547.0
Lobotes surinamensis	1	23.2	*Alepheids*	24	70.0
Mugil spp.	6	125.2	*Penaeus merguiensis*	358	3,073.1
Opistroptherus tardoore	12	400.0	*P. monodon*	8	136.8
Osteogeniosis miltaris	5	387.7	*Parapeneopsis sculptilis*	7	10.0
Pampus chinensis	4	3,238.0	*Metapenaeus lysianassa*	194	139.0
Pellona elongata	401	567.6	*M. brevicornis*	24	94.0
P. pelagicus	?	730.0	*M. ensis*	178	303.3
Platycephalus spp.	1	4.0	*N. dobsoni*	104	82.4
Pomadasy hasta	2	96.8	*P. masterisi*	8	4.0
Rastrelliger spp.	4	6.5	Other prawns (juveniles)	164	14.7
Sardinella fimbriata	3	17.1	*Squilla* spp.	1	10.0
Scatphagus argus	4	88.2	Spider crab	4	8.0
Sciaena russeli	1	24.9	*Loligo* spp.	468	1,039.3
Secutor ruconis	2,116	2,627.1	*Sepia* spp.	91	1,166.2
Selar kalla	27	97.7	Others (mixed species)		460.0

US$250 million per annum. Khoo (1989) gives details of annual landings for 1986 of marine fishes associated with mangroves in Peninsular Malaysia (Table 16).

Tang *et al.* (1981) compared the economic returns from fisheries as well as forestry activities and returns from fisheries far outweigh those from forestry products. They estimated the returns from fisheries in Matang in 1979 to be US$32.7 million.

Choy (1991) recently reported that: "In Matang, a total of 2,543 fishermen operate the 1,357 boats licensed in the district. This excludes a large population which is indirectly employed in such activities as fish/prawn processing, servicing, repairs, boat-building, transportation and marketing. This figure excludes also those operating unlicensed boats." Of the 2,543 fishermen, about 50% work on board the 585 trawlers licensed in the district. The rest are mainly traditional fishermen and operate mainly the traditional and passive gears such as gill nets, hooks and lines and fishing traps. These fishermen are also usually involved in the cockle industry.

The critical question is will the destruction of mangroves affect the coastal capture fisheries? It probably would but at the moment there appears to be no quantitative answer. Some nutrients from the mangroves are probably exported to the adjacent coastal waters by a process of "outwelling", but the extent of this is not easily quantified (e.g. Gong and Ong, 1990). If this outwelling is significant then the calculations of the economic returns from capture mangrove fisheries must extend to the adjacent coastal waters.

Table 15. Capture fishery production in Peninsular Malaysia in 1981 in relation to mangroves.

	Mangrove cover (ha)[1]	Capture fishery production (t)[2]					
		Overall	Non mangrove species[3]	Mangrove species[4]			
				Total	Molluscs	Custacea	Fish
Peninsular Malaysia (overall)	113,000	649,000 (100%)	440,000 (68%)	209,000 (32%)	71,000	74,000	64,000
Peninsular Malaysia (West Coast)	96,000	433,000 (100%)	249,000 (58%)	184,000 (42%)	71,000	61,800	51,400
Peninsular Malaysia (East Coast)	17,000 (100%)	216,000 (88%)	191,000 (12%)	25,000	-	12,600	12,200

Source: Jothy (1984)
Notes: [1] National Mangrove Committee, Malaysia (1983), personal communication;
[2] Anon. 1982;
[3] Species having hardly any association with the mangrove ecosystem;
[4] Species that may be classified as casual or seasonal migrant or resident of the mangrove ecosystem.

Aquaculture

Different types of aquaculture occur in mangrove areas. This can be classified into two types: one using the waterways of the mangroves and the other by construction of ponds in the mangroves.

The former is very much more ecologically compatible and includes floating cage culture of grouper (*Epinephelus* spp.) and sea bass (*Lates calcarifer*), growing of cockles (*Anadara granosa*) on mud banks as well as mussel and oyster culture on poles or floating cages. Floating cage culture of fish and shellfish is now almost ubiquitous in Malaysian mangroves. The ecological implications of this activity has been described by Gong *et al.* (1985).

As an indication of the intensity of sea bass (*Lates calcarifer*) cage culture activity in mangrove estuaries, Choy (1991) reported that in Matang a total of 72 fishermen operate about 2,528 cages. A total of 26 tonnes was harvested in 1990, valued at about US$96,000.

Matang is a major cockle producer as the richest cockle beds in the state of Perak and some of the richest natural cockle spat fall areas are found here. Of the 3,002 ha of land approved for cockle culture in the state of Perak, 1,373 ha are in the district of Larut Matang (Choy, 1991). These are farmed by 48 operators and yielded 11,385 tonnes of cockles in 1990 valued at about US$2 million. This is a promising industry that has minimal adverse ecological impact. Indeed the shells of these molluscs are extremely good sinks for atmospheric carbon dioxide (see Ong, 1991).

Construction of ponds for the intensive culture of fish (mainly the tiger prawn, Penaeus monodon) is a relatively new activity in the mangroves of Malaysia. In a relatively short span of time this activity has become very widespread and most of the mangroves in Malaysia have areas converted into ponds. This activity is particularly widespread in the mangroves of Johore [extremely visible from the air from flights into Singapore (Changi) Airport from the north] but even remove mangroves like those in Sabah and Sarawak are not spared. Department of Fisheries statistics showed that in 1987 aquaculture ponds occupied about 600 hectares of mangroves in Johore. These ponds produced 245.3 tonnes which represents more than 80% of the total brackish pond production of Peninsular Malaysia (ASEAN/US CRIMP, 1991). The biggest single aquaculture pond development (apparently not very successful) in this region can be found in the Tawau mangroves of Sabah.

Prawn (*Penaeus monodon*) aquaculture in mangrove ponds has attracted much attention because of its potential high economic returns as well as the availability of cheap mangrove land. The economic risks involved is however extremely high for intensive culture systems. Feed (for the prawns) cost is extremely high since specially formulated pelletised food is used (trash fish which was used when the industry first started is unreliable mainly because supply has become limited). With a conversion rate of 2 (dry pellet weight) to 1 (wet prawn weight), up to about US$4 could be spent on feed alone for the production of each kilogram of fresh prawn and with the ex-farm price of the prawn at about US$7 the profit margin is not high especially when seed,

Table 16. Annual landings for 1986 of marine fishes which are associated with the mangrove ecosystem in Peninsula Malaysia (from Khoo, 1989)

Local Name	Species	Catch (t)
Kebasi/selangat	*Andontostoma* spp.	3,541
Siakap	*Lates calcarifer*	139
Duri	*Arius* spp.	4,794
Dengkis	*Siganus* spp.	1,086
Gelama	*Johnius* spp./*Scienena* spp.	12,031
Gerut gerut	*Pomadasys* spp.	918
Jenahak	*Lutianus* spp.	1,223
Kerapu	*Epinephalus* spp.	2,427
Kikek	*Secutor* spp.	945
Malong	*Muraenesox* spp.	1,521
Alu alu	*Sphyraena* spp.	1,517
Bawal	*Pampus chinensis*	5,068
Belanak/kedera	*Liza* spp./*Valamugil* spp.	4,550
Kurau/senangin	*Eleutheronema* spp.	861
Bilis	*Stolephorus* spp.	17,758
Tamban	*Sardinella fimbriata*	9,133
Bulan	*Megalops cyprinoides*	16
Kembong	*Rastrelliger* spp.	41,701
Udang putih	*Penaeus merguiensis*	7,449
Udang minyak	*Parapenaeopsis* spp.	15,228
Udang merah ros	*Metapenaeus ensis*	5,997
Udang kulit keras	*Parapenaeopsis sculptilis*	2,100
Udang harimau	*Penaeus monodon*	598
Udang baring	*Acetes* spp.	9661
Ketam	*Scylla serrata*	4,126
Sotong biasa	*Loligo* spp.	13,073

maintenance and infrastructural costs are added. This can still be profitable if there are no "accidents" e.g. sudden algal blooms that can kill all the prawns overnight, or disease epidemic), especially those that wipe out the crop just before the prawns reach marketable size. Economically, the potential is there (although it may be more apparent that real, especially for large ventures) but the risks are extremely high. Mangroves are also not the most suitable land for aquaculture mainly because most mangrove areas are potentially susceptible to acid sulphate conditions. To a certain extent this can be overcome by the application of agriculture lime but this drastically reduces the profit margin. In some areas lack of freshwater during certain times of the years means that growth rates are drastically reduced as a result of high salinity. There are many problems to be solved yet.

Ong (1982) and Ong et al. (1980) have provided detailed studies of the ecological implications of prawn pond development in mangrove areas (Sungai Merbok mangroves in the State of Kedah).

Agriculture

Law (1984) has discussed the use of mangrove for agriculture in some detail. We reproduce the summary of his paper as follows:

"Under natural conditions soil in the mangrove swamps contain high contents of dissolved salts. Most if not all of these soils, also contain high amounts of pyrites. These two properties combined together present special problems in the development of such soils for agricultural crops.

Apart from the coconut no other crops can tolerate the high salt content. The mangrove soils must first of all be drained and the salts removed by leaching. As the soil is structureless clays the leaching process may take 3 to 5 years before crops can be planted.

The pyrites in the mangrove soils present a second problem. In an anaerobic state, such pyritic soils have near neutral pH and are called potential acid sulphate soils. With the creation of aerobic conditions by drainage prior to cultivation, the pyrites oxidize rapidly to form sulphuric acid resulting in a rapid fall in soil pH, making these soils unsuitable for the cultivation of crops.

Studies have indicated the need for controlled drainage to keep the pyritic layers in a reduced condition to prevent/limit oxidation of the pyrites, and hence the production of sulphuric acid. With even such techniques however, only very limited number of crops can be grown: crops which can tolerate a high watertable and acid sulphate conditions.

Large areas of existing acid sulphate soils have been reclaimed from mangrove swamps. With proper management techniques, oil palm and coconuts on these acid sulphate soils have yields approaching that of non-acid sulphate soils.

The water required for controlled drainage in the drains must be non-saline. Unless this can be ensured, mangroves should not be considered for agricultural development."

Based on the very considerable experience of the Agriculture Department of Malaysia in the use of mangroves for aquaculture, Law (1984) cautioned that "The large scale conversion of mangrove swamps into agricultural land should be cautioned. Alternative areas which do not posses the inherent adverse properties of the mangrove muds should be considered first."

A classic case of very unsuccessful conversion of mangroves for agricultural crops is seen in the Merbok mangroves in the state of Kedah. Here, hundreds of hectares of mangroves were cleared, bunded (to prevent seawater intrusion) and tilled for growing rice but this has proved to be a dismal failure due to the development of acid sulphate conditions. Although rice will grow, the yield is extremely low and most of the reclaimed land now lies idle in a badly degraded condition.

Residential and industrial development

"Good" examples of the use of mangroves for residential and industrial development can be seen in some of the bigger cities in Malaysia.

In Kuching, Sarawak more and more mangrove areas are being cleared for residential and other developments. The mangroves are filled in and houses are built on top. This is a recent phenomenon.

In Penang, the international airport sits on reclaimed mangroves. The rest of the mangroves on the south-eastern part of the island is being "reclaimed" for industrial estates. The remarkable diversity of mangrove species here (extremely useful for teaching purposes since the area is very close to a University) are being filled by sand pumped in from the surrounding sea bottom. No attempt has been made to preserve even a small part of the mangroves (with a bit of foresight on the part of the planners, this could easily have been a viable eco-tourism project).

Resort Development

There are probably some areas of mangroves that have been reclaimed for resort development. There are plans in the State of Johore for the mangroves around Gelang Patah for such a purpose. On Pulau Redang (the marine area of this island is a Marine National Park), in the State of Terengganu, a golf resort is being established and some of the fairways cut through mangroves. Much of the mangroves on the landward side will perish unless the developers take proper measures to ensure that tidal inundation is not disrupted. With proper advice and planning, it is possible to reduce damage to the mangroves.

Ecological and environmental values

Coastal protection

Mangroves typically establish and occur on sheltered accreting coasts so it is a bit of a contradiction to say that mangroves afford coastal protection. However, even sheltered coasts are subjected to episodic storms and such events can periodically (e.g. cyclic hurricane destruction of mangroves in Florida) destroy areas that have taken tens of years to establish. If mangroves in areas of episodic storm events are removed then the severity of damage by storms will be greater; so in this sense mangroves afford coastal protection.

In Peninsular Malaysia, mangroves on the Straits of Malacca are highly sheltered and there are not truly huge storms (even episodic ones). Still, the normal geomorphic processes occur and even on sheltered coasts like that in the Straits of Malacca, there are areas of accretion and areas of erosion (e.g. See Chan, 1985 and Section 1.6 in this report). Removal of mangroves from areas susceptible to erosion will aggravate the erosion problem. Where mangroves occur in small areas of highly sheltered coasts which are subjected to severe seasonal monsoons (as is often the case on the east coast of the Peninsula), it is debatable if the mangroves here provide coastal protection.

The mangroves in East Malaysia are more variable than those on the Peninsula so their role in affording coastal protection varies.

It is difficult to put a dollar figure to the protection accorded by mangroves but if one considers that the building of hard protective structures costs in the region of US$3,000 per metre of coastline and we take a figure of 1,000 kilometres of mangrove lined coasts in Peninsular Malaysia, we are dealing with a figure of US$3,000 billion. Even 1% of this figure is a staggering sum.

Feeding and nursery grounds for fisheries

The mangrove ecosystem is important to fish living in the mangrove waterways as it is a source of food and it also serves as a nursery ground for various species. It is often not easy to isolate the role of the mangrove ecosystem as a feeding or nursery ground; and indeed, a lot of the time, the mangroves serve both purposes (in which case, the mangroves can be said to provide a complete habitat).

Feeding grounds

Various gut content studies have shown that detritus derived from mangroves in Malaysia constitutes an important source of food for mangrove and nearby coastal fisheries. For example, Leh and Sasekumar (1984) studied the gut content of various prawn species in the mangrove waterways of Selangor and found that 12-36% (by volume) of the food of penaeid prawns consisted of plant matter, and of this, 11-62% consisted of recognisable intact vascular plant tissue. Thong & Sasekumar (1984) studied the gut contents of 55 species of fish of the Angsa Bank (an extensive fishing area about 10 km away from the mangrove fringed Kuala Selangor coast) and found that plant detritus (presumably largely from mangroves) constituted 9% of the diet and was found in 89% of the fishes sampled. Using stable carbon isotopes, Rodelli *et al.* (1984) also confirmed that many commercially important fish and prawns consume carbon derived from mangrove vegetation.

Mangrove invertebrates can also constitute an important source of food to coastal fisheries. For example, Sasekumar *et al.* (1984) found that many fish of the adjacent coastal waters invaded the mangrove shores of the South Banjar Mangrove Forest Reserve, Selangor, at high tide to consume resident mangrove invertebrates including grapsid crabs, sipunculids and the encrusting fauna of tree stems. In addition, mangrove invertebrates can also release their larval stages into the adjacent waters where they constitute a source of food for planktophagous fish. For example, Macintosh (1979) estimated that 200,000 *Uca* (fiddler crab) larvae m^{-2} $year^{-1}$ are released into the adjacent waters.

Mangroves can also contribute indirectly to the productivity of the adjacent coastal waters through the export of nutrients. Gong and Ong (1990) estimated for the Matang Mangrove Forest Reserve that the amounts of macro-nutrients (N, P, K, Ca, Mg and Na) released annually through litter, dead trees and slash are 12210, 11870 and 2690 tonnes respectively, Nixon *et al.* (1984) attempted to establish if mangroves constitute sinks or sources of organic carbon and nutrients through the use of mixing diagrams in two estuaries in the Matang mangroves, Perak and the Kuala Selangor mangroves, Selangor. They concluded that for the time of year the study was conducted (July), both estuaries functioned as sinks for suspended solids, particulate organic carbon, nitrogen and phosphorus and (to a lesser degree) silica. However, as Nixon *et al.* (1984) themselves pointed out, additional sampling throughout an annual cycle is required before generalisations as to whether these mangroves act as sinks or sources of nutrients and organic matter can be made.

Nursery grounds

Mangroves in Malaysia serve as a spawning ground for various commercial fisheries, examples of which include *Lates calcarifer* (sea bass) and the freshwater giant prawn *Macrobrachium rosenbergii* (Khoo, 1989) which only breeds in salinities of 12 to 17% and whose larvae can only survive within this range of salinity (Ling, 1969).

Some mangroves also constitute the natural spat fall areas of the blood cockle (*Anadara granosa*) e.g. the Matang mangrove area where some 800 ha are natural cockle beds (Choy, 1991). The seed from these beds are transplanted to culture beds in Matang and in other parts of the country.

Habitat

Mangroves provide a habitat for several important commercial fishes. For example, Khoo (1989) found that about two thirds of the species of important coastal fisheries were found within the Matang and Merbok mangrove estuaries (Tables 17 and 18). Species which complete the whole of their life history within the mangroves include *Ambassis kopsii*, various *Arius* spp. (catfish), *Liza subviridis* (mullet) and *Dorosoma nasus*; but the majority including *Rastrelliger* sp. (mackerel), *Epinephelus* spp. (grouper), *Chorinemus lysan* (queenfish) and *Lutianus argentimaculatus* (mangrove snapper) use the mangrove habitat only during the juvenile phase (Khoo, 1989).

Table 17. Check list of fishes from Matang and Merbok mangroves. From Khoo (1989)

Ambassis gymnocephalus	*Muraenesox cinereus*
Ambassis kopsii	*Mystus gulio*
Anodontostoma chacunda	*Opistoptherus tardoore*
Apogon thermalis	*Osteogeniosus militaris*
Arius caelatus	*Oxyurichthys microlipis*
Arius maculatus	*Pampus chinensis*
Arius microcephalys	*Paraplotosus anguillaris*
Arius sagor	*Pellona elongata*
Arius spp.	*Pellona pelagicus*
Arius venosus	*Periophthalmodon schlosseri*
Boleophthalmus boddash	*Periophthalmus koelreuteri*
Butis butis	*Platycephalus crocodilus*
Caranx sexfasciatus	*Pomadasys hasta*
Caranx speciosus	*Pseudorhombus arsius*
Chorinemus lysan	*Pseudorhombus* sp.
Dorosoma nasus	*Rastrelliger* sp.
Eleutheronema tetradactylus	*Sardinella fimbriata*
Epinephalus sp.	*Scatophagus argus*
Epinephalus tauvina	*Sciaena russeli*
Eugnathogobius microps	*Sciaena* sp.
Eupleurogrammus intermedius	*Secutor ruconius*
Gerres punctatus	*Selar kalla*
Gymnura sp.	*Setipinna taty*
Halophryne sp. A	*Siganus javus*
Halophryne sp. B	*Sillago sihama*
Hamirhampus xanthropterus	*Sphyraena jello*
Johnius carutta	*Stolephorus andhraensis*
Johnius goldmani	*Stolephorus heterolobus*
Johnius sina	*Stolephorus indicus*
Johnius solado	*Terapon jerbua*
Ketengas typus	*Tetraodan fluviatilis*
Kowala sp.	*Thrissocles dussumieri*
Lagocephalidae	*Thrissocles hamiltonii*
Lates calcarifer	*Thrissocles mystax*
Leiognathus brevivostris	*Toxotes chatareus*
Leiognathus equulus	*Toxotes jaculator*
Liza subviridis	*Triacanthidae*
Liza vaigensis	*Trichiurus glossodon*
Lobotes surinamensis	*Trypauchenidae*
Lutianus argentimaculatus	*Tylosurus strongylura*
Lutianus monostigma	*Upeneus sulphureus*
Megalops cyprinoides	*Valamugil cunnesius*
Monodactylus argenteus	*Valamugil seheli*
Mugil spp.	

Chong *et al.* (1990) studied the fish and prawn communities of 4 coastal habitats in Selangor and suggested that the mangroves in Selangor function more as feeding grounds than as nursery grounds for juveniles of commercially important fish species but are important nursery areas for commercial prawn species.

Foraging and stop-over sites for migratory shorebirds

Several mangrove areas and adjacent mudflats are important as foraging sites for various species of resident birds as well as stop-over sites for migratory species. For example, a recent evaluation of the importance of wetlands to bird fauna in the West coast of Peninsular Malaysia (Silvius *et al.*, 1987)· estimated a peak bird population of some 55,000 to 60,000 individuals from at least 32 species. The most abundant species were the Common Redshank (*Tringa totanus*), the Curlew Sandpiper (*Calidris ferruginea*), the Black-tailed Godwit (*Limosa limosa*), the Terek Sandpiper (*Xenus cinereus*), the Large Sandplover (*Charadrius leschenaultii*) and the Mongolian Plover (*Charadrius peronii*) which together accounted for nearly 70% of the migrant wader populations. Using a turnover rate of 3 to 6 times, Silvius et al. (1987) estimated that a total of 200,000 to 400,000 waders visit the west coast of Peninsular Malaysia annually and a large proportion of these remain in Malaysia during the northern winter.

Resident populations of large waterbirds include the Milky Stork (*Mycteria cinerea*) and the Lesser Adjutant Stork (*Leptoptilos javanicus*). Silvius *et al.* (1987) estimated that only about 100 Milky Storks are left and these are confined almost entirely to the Matang Mangrove, Perak. In November 1989, a Department of Wildlife and National Parks survey team found twenty-one nests in Matang (Bakewell and Jaensch, 1989) so the endangered Milky Stork can once more be classified as a breeding bird in Malaysia after a lapse of more than 50 years! There are about 150 to 200 Lesser Adjutant Storks on the West Coast of Peninsular Malaysia and most of these are found in Matang. These birds build their nests in tall trees and therein lies the problem. As the Matang Mangrove is a forest managed on a 30-year rotation, there are few tall trees available to birds as nesting sites.

Silvius *et al.* (1987) state that the commonest heron species along the west coast of Peninsular

Table 18. Check list of prawns in Matang and Merbok mangroves (from Khoo, 1989).

Acetes spp.
Alpheidae (members)
Macrobrachium rosenbergii
Metapenaeus brevicornis
Metapenaeus dobsoni
Metapenaeus ensis
Metapenaeus lysianassa
Parapeneopsis sculptilis
Penaeus merguiensis
Penaeus monodon

Malaysia are the Black-crowned Night Heron (*Nycticorax nycticorax*), the Great Egret (*Egretta alba*), the Little Green Heron (*Butorides striatus*) and the Little Egret (*Egretta garzetta*). They observed that the Black-crowned Night Heron nests in low *Avicennia marina* forest of 4 to 5m height and there is a very large colony at Sungai Burung, Perak. The presence of the herons appears to kill the mangrove forest in the colony area thus decreasing the number of suitable nesting sites. This results in an increase in size of the nesting area or in the actual shifting to another nesting site. The Little Green Heron has a population in Matang of 600 to 1000 individuals. Two sites in Matang are also regularly used by small numbers of the endangered Chinese Egret (*Egretta eulophotes*).

Other common species of mangrove birds which are largely associated with mangrove creeks include the Brahminy Kite (*Haliastur indus*) which have nests in *Rhizophora* and *Bruguiera* trees in Matang and the Kelang Islands (Selangor) of Pulau Tengah and Pulau Ketam (Silvius *et al.*, 1987). The White-bellied Sea Eagle (*Heliaeetur leucogaster*) is common in Matang but not in Selangor or the Kelang islands. The most common kingfishers are the Black-capped Kingfisher (*Halcyon pileata*) and the Common Kingfisher (*Alcedo atthis*) which are both migrant and wintering species. The Collared Kingfisher (*Halcyon chloris*) is the most common resident species.

Thus, there are several species of birds (including some rare and endangered species) in the mangrove and associated mudflat areas. This rich birdlife is of value largely as a recreational and scientific resource. However, this birdlife is threatened largely because of reclamation of mangrove areas, hunting and human disturbance of the habitat (e.g. by crab fishermen). Hunting has led to the disappearance of a heronry at Pulau Ketam and collection of eggs and young may have contributed to the decline of the Milky Stork population (Silvius *et al.*, 1987). Large flocks of migratory waders were regularly disturbed by hunting in several sites in Selangor which may have a considerable impact on their condition. The Black-headed Ibis (*Threskiornis melanocephalus*) which used to be resident along the west coast of Peninsular Malaysia no longer occurs. Two heronries of the Grey Heron (*Ardea cinerea*) have ceased to exist and no signs of breeding of the Great Egret was observed. There are also no recent observations of the Sumatran Heron which used to be common on the Coasts of Peninsular Malaysia (Silvius *et al.*, 1987).

Primary and secondary productivity

Primary productivity

Mangroves are often considered to be amongst the most productive of natural ecosystems in terms of primary productivity. This primary productivity essentially consists of mangrove tree productivity, productivity of epiphytic and benthic macro- and micro-algae, and productivity of phytoplankton.

Primary productivity can be discussed in terms of gross or net productivity. Gross primary production is all the carbon fixed by the plant while net primary production is the carbon left after metabolic processes have been taken care of (i.e. Net primary production = Gross primary production - respiration). Net primary production of trees consists of biomass increment, including roots, litter production and losses through herbivory.

Table 19. Standing biomass, mean annual incrementb (MAI), litter and net productivity in stands of different ages of *Rhizophora apiculata*. (From Ong *et al.*, 1984).

Age (yr)	Biomass ($t\ ha^{-1}$)	MAI ($t\ ha^{-1}$)	Litter ($t\ ha^{-1}\ yr^{-1}$)	Net productivity ($t\ ha^{-1}\ yr^{-1}$)
5	16	3	7	10
10	180	18	10	28
15	200	13	10	23
25	300	12	11	23

Ong *et al.* (1984) estimated the above-ground tree productivity in terms of biomass increment (allometric regressions) and littler productivity (litter traps) in the managed Matang mangrove forest of Malaysia to be 10 tonnes dry matter ha^{-1} yr^{-1} in the young stands (5 year old), peaking at 28 tonnes ha^{-1} yr^{-1} in the 10 year old stand and levelling off to 23 tonnes ha^{-1} yr^{-1} in the 15 and 25 year old stands (Table 19). They found that litter productivity was lowest at 7 tonnes ha^{-1} yr^{-1} in the 5 year old stand but this levelled off at 10-11 tonnes ha^{-1} yr^{-1} in the older stands. [As a comparison, Sasekumar and Loi (1983), obtained litterfall values of 15.4, 14.0 and 15.8 tonnes ha^{-1} yr^{-1} respectively for *Avicennia, Sonneratia* and *Rhizophora* stands in Kuala Selangor, Selangor whilst Chai (1982) estimated litterfall in a mature *Rhizophora* stand in a Sarawak mangrove to be 8.6 tonnes ha^{-1} yr^{-1}].

What happens to this productivity? Since Matang is managed for timber production (for charcoal, firewood and poles mainly) on a 30 year rotation with two thinnings at around 15 years and 20 years, around 5 to 10% of the standing biomass is removed annually for commercial purposes. Another sizeable proportion (around 10%) of the biomass is "released" to the mangrove ecosystem through dead trees, slash after final felling and thinning and through litter-fall (Gong and Ong, 1990). This component is very important to the mangrove ecosystem as it returns nutrients and carbon to the ecosystem and to the nearby coastal waters. Using the figure of 50% export, Gong and Ong (1990) estimated that the export of biomass and nutrients from the Matang mangroves through leaf litter alone is 3.9 and 0.9 tonnes ha^{-1} yr^{-1} respectively.

For the Matang waterways, Ong *et al.* (1984) estimated the gross aquatic (plankton) productivity (using the dissolved oxygen light and dark bottle method) to range from 0.9 tonnes C ha^{-1} yr^{-1} in small (partially shaded by mangrove trees) streams to 3.5 tonnes C ha^{-1} yr^{-1} in completely exposed streams. In both situations, the net primary productivity was found to be zero. As suggested by Ong *et al.* (1984), although phytoplankton may not contribute a significant amount to net primary productivity in the mangrove ecosystem, they are important in maintaining a reasonable level of dissolved oxygen in the waterways and in reducing the biochemical oxygen demand of the system.

Epiphytic and benthic algal productivity has not been studied in Matang. This productivity varies depending on the area of the intertidal zone, the light conditions, the prevailing temperature and the organisms themselves (Gong, 1984). Heald (1971) estimated the primary productivity of benthic organisms in the mangroves of Florida to be 1.2 g C m^{-2} day^{-1} or 27% of the litter productivity. Thus benthic productivity can be significant.

As estimations of net primary productivity using biomass increment and litter production take a lot of time and effort, Bunt *et al.* (1979) suggested the light attenuation method as a quick method to estimate potential productivity. Using this method, Gong *et al.* (1991) estimated the potential productivity of various mangroves (six localities) in Malaysia to range from 3.9 tonnes dry matter ha^{-1} yr^{-1} in a pristine strip of mangroves on a sandy foreshore in Bako, Sarawak to 20.39 tonnes ha^{-1} yr^{-1} in a well developed estuarine mangrove in Tawau, Sabah (Table 20). Using the same method, Soepadmo and Zain (1984) estimated the potential productivity in the Sementa Mangroves (Kelang) to be 11.49, 18.96 and 21.27 kg C ha^{-1} day^{-1} in the *Avicennia, Rhizophora* and *Bruguiera* zones respectively. Using a conversion of x2 to convert carbon to organic matter, the estimates above are equivalent to 8.38, 13.84 and 15.53 tonnes dry matter ha^{-1} yr^{-1}.

Gong *et al.* (1991) also measured various soil parameters (Table 20) as well as the stand structure (Table 21) in the localities where they measured potential productivity. They calculated the correlations between potential productivity and these parameters (Table 22) in an attempt to establish the factors important for potential productivity and found that soil temperature and stand density were the only two factors significantly correlated with potential productivity which decreased when the soil temperature went above 29°C and increased with increasing stand density.

In a preliminary study of primary productivity of mangrove trees in Matang using the gas exchange method, Gong *et al.* (1992) estimated the net photosynthesis measured as CO_2 assimilation in a 20 year old of *Rhizophora* to range from 11.0 to 5.6 µmol CO_2 m^{-2} s^{-1} from the top to the bottom of the canopy. The assimilation rate reached a maximum at light (photon flux density) values of around 800 µmol m^{-2} s^{-1} and was also highly correlated with stomatal conductance.

Table 20. Summary of the potential productivity, light characteristics and stand structure of various mangrove sites in Malaysia (From Ong *et al.*, 1991).

Location	Site	Dominant species	Mean GBH (cm)	Stems ha^{-1}	Basal area ($m^2 ha^{-1}$)	I_o (PAR) ($\mu mol\ m^{-2} s^{-1}$)	Light penetration	Canopy cover (%)	Potential productivity ($t\ ha^{-1} yr^{-1}$)
Matang	1	Ra	35.1	2,567	29.5	769	300	88	8.31
Matang	2	Ra	13.0	10,825	16.6	1,550	55	72	12.72
Matang	3	Ra	15.2	1,927	12.0	1,075	77	94	12.23
Matang	4	Ra	42.7	1,975	22.1	510	53	97	11.68
Matang	5	Ra	39.8	1,500	35.2	1,807	150	96	12.71
Matang	6	Ra/B	15.5	2,501	27.9	1,117	64	97	14.78
Merbok	1	Ra	42.4	1,850	30.8	1,525	84	69	10.68
Merbok	2	Ra	57.9	800	24.8	1,223	77	89	13.08
Merbok	3	Ra	37.3	2,150	30.2	500	49	95	11.69
Merbok	4	Ra/B	34.6	2,025	20.0	1,575	63	85	14.58
Merbok	5	Ra	36.1	2,450	28.1	1,613	94	80	12.18
Merbok	6	Ra	10.2	11,400	28.7	1,450	36	76	14.98
Sandakan	1	C/Ra	35.7	3,210	30.0	471	43	100	12.17
Sandakan	2	Rm	77.4	1,650	79.0	675	125	98	8.78
Sandakan	3	Ra/C	37.8	1,063	22.5	1,841	302	85	8.19
Sandakan	4	Ra	45.3	1,950	17.9	2,112	386	82	7.42
Tawau	1	C/Rm	30.2	7,075	38.7	2,332	39	80	17.42
Tawau	2	Ra	29.0	4,325	33.3	1,204	92	96	13.16
Tawau	3	Ra	19.6	7,375	33.8	1,209	34	92	17.47
Tawau	4	Bp	22.9	7,300	31.3	1,522	17	85	20.39
Tawau	5	C	21.3	8,600	41.9	1,778	75	90	15.22
Rajang	1	Rm	17.9	5,900	23.1	606	46	100	13.80
Rajang	2	Bp	24.4	2,550	22.0	1,143	62	100	15.57
Rajang	3	Bp	16.3	4,550	25.4	120	60	100	3.96
Rajang	4	Sa	33.8	1,242	11.6	928	274	100	6.49
Rajang	5	Ra	12.2	6,550	26.8	577	35	94	16.01
Rajang	6	Bp	13.1	3,625	21.8	1,227	173	96	7.99
Rajang	7	Ra	12.8	9,400	17.7	1,397	65	85	13.87
Rajang	8	Am	15.4	2,251	14.3	1,142	595	100	3.51
Bako	1	Sa	9.0	5,175	13.8	2,340	1,127	100	3.90

Notes: 999 indicates missing values.

Am = *Avicennia marina* Ra = *Rhizophora apiculata*

B = *Bruguiera* spp. Rm = *Rhizophora mucronata*

Bp = *Bruguiera parviflora* Sa = *Sonneratia alba*

C = *Ceriops* spp.

Table 21. Summary of the soil parameters in various mangrove sites in Malaysia (from Gong *et al.*, 1991).

Location	Site	Date	Time (hr)	Soil type[†]	Salinity (ppt)	Temp. (C)	pH	Eh (mv)	OM (%)	Clay (%)
Matang	1	21-04-87	1300	Clay	999	999	999	999	999	999
Matang	2	22-04-87	1130	Clay	17.1	999	999	999	19.6	42.5
Matang	3	04-02-88	1600	Cl-Lm	15.0	27.6	6.7	344.7	24.6	31.5
Matang	4	05-02-88	1030	S-C-L	12.0	26.9	6.4	106.7	37.1	23.3
Matang	5	04-02-88	1030	S-C-L	16.0	28.3	6.5	67.1	30.2	27.8
Matang	6	05-02-88	1430	S-C-L	14.0	26.9	6.6	-60.0	50.9	21.5
Merbok	1	14-05-87	1245	Cl-Lm	28.0	999	6.0	999	23.6	31.2
Merbok	2	14-05-87	1200	Cl-Lm	27.0	999	5.3	999	29.0	33.0
Merbok	3	14-05-87	1400	Cl-Lm	28.0	999	6.0	999	11.3	34.4
Merbok	4	20-05-87	1430	Cl-Lm	31.3	999	6.0	999	19.6	37.4
Merbok	5	21-05-87	1200	Cl-Lm	31.0	999	6.0	999	22.9	33.7
Merbok	6	21-05-87	1330	Cl-Lm	999	999	999	999	21.5	35.7
Sandakan	1	21-08-87	1115	S-Lm	28.0	29.0	7.0	79.0	27.0	21.0
Sandakan	2	21-08-87	1315	S-C-L	30.0	29.5	6.7	-58.7	35.1	22.7
Sandakan	3	21-08-87	1045	S-Lm	28.0	999	7.0	999	29.9	14.7
Sandakan	4	22-08-87	1250	Loam	28.0	29.6	6.5	364.0	15.0	20.9
Tawau	1	24-08-87	1220	Cl-Lm	30.0	28.3	5.3	273.5	26.0	31.4
Tawau	2	25-08-87	1230	Cl-Lm	28.0	28.1	5.7	-36.2	28.1	30.2
Tawau	3	25-08-87	1430	Loam	999	27.7	5.8	12.3	32.7	22.4
Tawau	4	27-08-87	1130	Cl-Lm	31.0	27.2	6.7	31.0	23.5	33.1
Tawau	5	27-08-87	1435	Cl-Lm	19.0	27.8	6.7	104.0	21.4	26.0
Rajang	1	12-11-87	1000	Cl-Lm	20.5	26.5	3.8	495.9	13.7	35.3
Rajang	2	12-11-87	1010	Cl-Lm	16.0	26.8	4.3	258.6	10.6	35.1
Rajang	3	12-11-87	1225	Clay	25.0	27.5	5.6	202.7	15.2	41.5
Rajang	4	12-11-87	1345	Cl-Lm	27.3	30.4	6.4	-76.9	11.4	31.3
Rajang	5	13-11-87	1200	Clay	12.0	26.8	6.1	7.9	12.5	41.1
Rajang	6	14-11-87	0900	Cl-Lm	25.0	27.1	6.2	84.3	15.4	32.3
Rajang	7	14-11-87	1110	Loam	20.5	27.5	6.4	114.9	20.6	32.5
Rajang	8	14-11-87	1240	S-C-L	29.5	31.7	6.9	-91.2	12.1	22.1
Bako	1	18-11-87	1330	S-Lm	18.0	39.0	7.1	125.0	4.3	10.5

[†] Cl-Lm = Clayey loam; S-C-L = Sandy clay loam; S-Lm = Sandy loam
999 indicates missing values

Secondary Productivity

Secondary productivity in the mangroves consists of productivity of the terrestrial organisms including herbivores (e.g. crabs, monkeys), the carnivores (e.g. wild boars), and the bacteria and other detritivores; as well as the productivity of the waters in terms of zooplankton productivity, nekton productivity (important commercially especially in terms of fish and prawns) as well as benthic productivity.

Most of the studies on secondary productivity in Malaysian mangroves have been on crab populations. Loke (1984) developed an energy budget for a leaf eating sesarmid crab (*Chiromanthes eumolpe*) in the Merbok Mangroves, in which she estimated that the standing biomass of 35.47 kJ m^{-2} had a production of 168 kJ m^{-2} yr^{-1} (or 14% of the consumption which in turn was 9% of the annual *Rhizophora* leaf litter production). This detritus energy assimilated by the crab population into their bodies becomes available to higher trophic level consumers. Mangrove crabs are eaten by various animals including birds,

Table 22. Correlations (Pearson's r) between potential productivity and various para meters in various mangrove sites in Malaysia

Parameter	n	Range	r
Soil			
% clay	29	11 - 43	+0.29
Temperature (°C)	21	26.5 - 39.0	-0.60*
Salinity (ppt)	27	12.0 - 31.3	-0.16
pH	27	3.8 - 7.1	-0.32
Eh (mV)	21	-91 - +364	+0.08
Organic Matter (%)	29	4 - 51	+0.36
Stand Structure			
Stems ha^{-1}	30	800 - 11400	+0.44*
Basal Area ($m^2 ha^{-1}$)	30	11.6 - 79.0	+0.23
Mean GBH (cm)	30	9.0 - 77.4	-0.10
Stand height (m)	12	10 - 25	+0.06

* Significant at p = 0.05

snakes and carnivorous fish such as *Arius sagor* (catfish) and *Pomadasys hasta* (grunter) that invade the mangrove shore at high tide (Sasekumar *et al.*, 1984). Thus crabs form an important link in the transfer of energy from detritus to predator food webs in the mangrove community.

Macintosh (1984) studied the *Metaplax, Uca* and *Sesarma* crab populations in the Selangor mangroves and estimated that the total annual production of these crabs is 0.9 to 17g m^{-2} (equivalent to 2.5 to 30 kcal m^{-2}). Leh (1982) estimated the production of two species of *Chiromanthes* in a cleared area to be 61.6 kcal m^{-2} yr^{-1} while that in a *Rhizophora* forest (mangrove in Selangor) was 109.6 kcal m^{-2} yr^{-1}.

Sasekumar (1984) obtained indirect estimates of the productivity of meiofauna (largely free-living nematodes, harpacticoid copepods and oligochaetes; size 53-1000 µm) from annual turnover rates and average biomass values (Table 23). He found that the estimates for the *Bruguiera* zone (landward edge forest) was the lowest but even the estimates for the *Rhizophora* and the *Avicennia* zones were much lower (only a third) of that of an estuarine mudflat in southern England. More work is needed to establish the ultimate fate of the meiofauna.

Management and conservation

Forest policy and legislation

In Malaysia, forestry is a state matter under the Constitution. This means that the legislative and executive authority rest with the state governments concerned. Thus all forests including the mangroves would come under the jurisdiction of the respective State Forestry Departments. In terms of overall forestry development and management, the Federal Government is responsible mainly in research and development, education and training, forest industries development, and provision of advice and technical assistance.

There is no particular policy for the mangrove forests per se. In the context of management and conservation of mangroves, the National Forestry Policy (1978) applies. The objectives of the policy are as follows:

1. To dedicate as Permanent Forest Estate (PFE) sufficient areas of land strategically located throughout the country in accordance with the concept of rational land use in order to ensure:
   i) sound climatic and physical conditions of the country, the safeguarding of water supplies, soil fertility and environmental quality and the minimisation of damage by floods and erosion to rivers and agricultural lands, such forest land being known as PROTECTIVE FORESTS;
   ii) the supply in perpetuity of all forms of forest produce which can be economically produced within the country and are required for agricultural, domestic and industrial purposes, such lands being known as PRODUCTIVE FORESTS;
   iii) the conservation of adequate forest areas for recreation, education, research and the protection of the country's unique flora and fauna, such forest lands being known as AMENITY FORESTS.
2. To manage the PFE with the objective of maximising social, economic and environmental benefits for the Nation and its people in accordance with the principles of sound forest management.
3. To pursue a sound programme of forest development through regeneration and

Table 23. Average biomass and annual productivity of meiofauna in three mangrove forest zones on the Selangor coast (from Sasekumar, 1984).

Parameter	*Bruguiera* spp.	*Rhizophora* spp.	*Avicennia* spp.
Total wet weight biomass (mg $10cm^{-2}$)	0.96	7.54	6.16
Total dry weight biomass (mg $10cm^{-2}$) converted on wet:dry ratio of 4:1 (Gerlach, 1971)	0.24	1.89	1.54
Productivity based on average turnover ratio of 10 (P/B = 10) (mg dry weight $10cm^{-2}$)	2.40	18.85	15.40
Productivity (mg C $10cm^{-2}$) based on the assumption that carbon comprises 40% of the animals' dry weight (Steele, 1974)	0.96	7.54	6.16
Productivity (g C m^{-2})	0.96	7.54	6.16

rehabilitation operations in accordance with approved silvicultural practices in order to achieve maximum productivity from the PFE.

4. To ensure thorough and efficient utilisation of forest resources on land not included in the PFE, prior to the alienation of such land by means of proper co-ordinated planning by land development agencies in order to obtain maximum benefits for the people through complete harvesting and processing of such resources, adhering strictly to the optimum need of local processing industries.

In Peninsular Malaysia, in order to streamline procedures and practices of forest management, the National Forestry Act (1984) was instituted to bring about uniformity to the hitherto diverse and varied State Forest Enactments and Rules. Under the Act, it is mandatory for every State Forestry Department to prepare and implement proper forest management plans in respect to mangroves and other forests of the PFE.

Apart from the National Forestry Act, respective state laws have also been enacted to safeguard the forest resources in the state. In Sabah, forestry activities are regulated by the Forest Enactment 1968, Forest Rules 1969 and Forest Enactment (Amendment) 1984. In Sarawak, forestry activities involve not only the regulation and management of forest resources but also the protection and management of National Parks and Wildlife Sanctuaries. They are regulated by the Forest Ordinance, National Parks Ordinance and Wildlife Protection Ordinance.

The role of forestry agencies

In Peninsular Malaysia, three major agencies are responsible for matters pertaining to forestry activities. The roles of these agencies are

Table 24. Gazetted mangrove conservation areas in Malaysia

State	Locality	Classification	Area of Mangroves (ha)
Johor	Pulau Kukup F.R., Compt. 6	Virgin Jungle Reserve	26
Pahang	Sg. Miang F.R., Compt. 1	Virgin Jungle Reserve	56
Perak	Pulau Kecil	Virgin Jungle Reserve	42
Sabah	Batumapun	Virgin Jungle Reserve	164
	Umas-Umas	Virgin Jungle Reserve	830
	Elopura	Virgin Jungle Reserve	1,093
	Kota Belud	Bird Sanctuary	1,518
	Sepilok	Virgin Jungle Reserve	1,235
Sarawak	Samunsam	Wildlife Sanctuary	220
	Bako	National Park	166
Selangor	Kuala Selangor	Nature Park	320
Total		11	5,670

Table 25. Mangrove conservation areas proposed for gazettement in Malaysia

State	Locality	Classification	Area of Mangroves (ha)
Johor	Pulau Kukup F.R. & Tanjung Piai	Proposed State Park	800
Sarawak	Sibuti	Proposed Wildlife Sanctuary	402
	Pulau Bruit	Proposed Wildlife Sanctuary	620
Total		3	1,822

coordinated by the Ministry of Primary Industries which oversees all matters related to forestry.

The Forest Department of Peninsular Malaysia which was established in 1901 is responsible for forest administration, management and development, and the orderly implementation of the National Forest Policy in all states. A major function of the department is to advise and co-ordinate forestry development activities with the State Forestry Departments.
The Forest Research Institute Malaysia (FRIM) was established in 1985. It is governed by the Malaysian Forestry Research and Development Board which is entrusted with the responsibility of conducting research and development activities on forestry and forest-based industries and providing technical support to other agencies.

The Malaysian Timber Industry Board (MTIB) was established to undertake the market promotion of timber products and to assist in the establishment of timber-based industries. Services provided include the promotion of local and foreign investments in downstream, export-oriented wood-based industries. In addition, it regulates and oversees business conduct to ensure orderly transactions and sound trade relations.

In Sarawak, the Forestry Department is entrusted with all aspects of forestry management, research and development, conservation, utilisation, extension, training and trade. Likewise in Sabah, the Forestry Department attends to all matters relating to forestry management, research and development, trade and marketing, extension and education, and law and enforcement.

Forest management

Historical development

In Peninsular Malaysia, the history of mangrove management has been one of continual change where several harvesting systems were proposed, adopted, amended and discarded, and sometimes reintroduced and again discarded (Noakes, 1952). The reason for this is that logging permittees are traditionally conservative and that only existing methods of exploitation are considered practical.

The Minimum Girth System of 30 cm was the first system tried out in 1904. Although it was simple in operation, it was discredited in that the undergirth trees retained were unable to effectively seed up felling areas. They were often damaged during exploitation, suppressed trees produced practically no propagules, were susceptible to windthrow and unevenly distributed. It was tried again in 1924-1925 where a minimum girth of 38 cm was prescribed.

The Retention of Seed Trees System was introduced in 1913 with retention of 25 seed trees per hectare prescribed. It was revived in 1925 with the introduction of thinning to induce advance regeneration and the number of seed trees was increased to 50 trees per hectare only where regeneration was found to be insufficient. The system had the advantage of great flexibility with each area being treated on its merits. It was however discarded because the seed trees usually die or were windthrown before they were able to seed up the felling areas. In any case, the cost of planting was less than their royalty value. The system remained in operation till about 1940.

The Bicyclic Felling System was tried out experimentally, aimed at retaining seed trees temporarily. Half the crop was to be removed using a 6 m stick while the remaining half was to be clear felled after a fruiting season. The experiment could not be completed owing to the Japanese Occupation (1942-1945).

In Sabah, selective felling of trees was confined to a small scale whereby the annual coupe in any one locality never exceeded 300 hectares. The imposed diameter limits varied with the management and utilisation objectives. For forests designated for charcoal production, the limit was 20 cm and above while those designated for production of firewood and fishing stakes, the limit was 10 cm.

In 1970, with the advent of forest harvesting for production of wood chips which required annual coupes of between 2,000 and 4,000 hectares, a more refine Minimum Diameter System was formulated. It involved systematic felling of forest compartments, retention of seed trees in even-sized stands, felling of non-commercial trees and retention of buffers.

In Sarawak, three large tracts of mangrove forests were gazetted as forest reserves in the early 1920s and 1930s. They were the Sarawak Mangrove Forest Reserve in the 1st Division, the Rajang, Paloh and Loba Pulau Mangrove Forest Reserves in the 6th Division and the Kenalian, Kayangaran and Terentang Mangrove Forest Reserves in the 5th Division.

Early exploitation was confined to mangrove forests near Kuching in the 1st Division and near Sarikei and Sibu in the 6th Division. In the 1950s, all the reserves were managed based on working plans. The plans covered a period of 10 years each with the management objectives to meet domestic demands for firewood and charcoal, and to export the surplus. In the 1960s, the objectives of the plans were broadened to cover aspects of regeneration, conservation and greater utilisation of resources.

Harvesting systems

In Peninsular Malaysia, the harvesting system being practised is clear felling, where the whole crop is removed by a single operation. It was introduced since the 1930s. It is usually not recommended since it is destructive and large tracts are often covered with logging slash and almost completely devoid of natural regeneration. In addition, the sudden exposure encourages the growth of fast growing weeds such as *Acrostichum*, *Acanthus* and *Derris* species. This will mean that extensive plantings and site preparations (incurring enormous expenses) have to be carried out to restock blank areas (Watson, 1928). To reduce the need for extensive planting, the clear felling system as practised in Matang is accompanied by the retention of seed trees and intermediate felling (thinning) to induce advance regeneration.

The prescribed rotation age varies with states. In Matang, Noakes (1952) reported that growth figures of trees within sample plots indicated that the mean annual increment culminates at about 23 years and hence the rotation was reduced from 40 years (from 1930-1949) to the present 30 years (since 1950). It is now generally accepted that a 30 year rotation is suitable for maximum production of trees ranging from 12-22 cm dbh. In Selangor, the rotation has been fixed at 25 years since 1957 (Soo, 1979). Johor advocates a rotation of only 20 years since poles and fuelwood in most demand are about 12 cm in diameter and these can be produced at about 18 years (Edington, 1964).

In Sabah, all trees greater than 10 cm dbh are to be systematically felled within alloted compartments (Liew, 1980; Phillipps, 1984). In areas where the stands are even-sized, at least 40 trees per hectare are to be retained as seed trees. The felling of trees greater than 10 cm dbh includes those of non-commercial species such as *Avicennia* spp. and *Xylocarpus granatum* though their removal from the site is optional. Along the coast and estuaries, a vegetation belt of 10 m width is to be retained to safeguard against erosion and to serve as a seed source for regeneration.

Sarawak adopts the Minimum Diameter System of forest harvesting (Chai, 1980; Chai and Lai, 1984). The diameter limit is fixed at 6.5 cm with rotation cycles of 15 years in charcoal production forests and 20 years in firewood production forests.

Silvicultural systems

Natural regeneration

Propagule production in mangrove forests is generally abundant since *Rhizophora* trees display copious and annual flowering and fruiting. Hence there is often adequate natural regeneration prior to forest harvesting. However, natural regeneration may be almost completely annulled when the forest is clear felled. This results in the need for retention of seed trees to ensure adequate regeneration. There is little doubt that seed bearers will regenerate the forest floor in their immediate neighbourhood.

In Peninsular Malaysia, the 1980-1989 Matang Mangrove Working Plan (Haron, 1981) advocated the retention of seven mother trees per hectare of logged forest and a three metre buffer strip of vegetation along the coast and riverbank. The current plan (1990-1999) which relies primarily on artificial regeneration has done away with the retention of mother trees but expanded the width of buffer strips to five metres.

In Sabah, the harvesting system being practised requires the need to retain 40 trees greater than 10 cm dbh in forest stands with even-sized trees and 10 m wide buffers along the coast and waterways.

Artificial regeneration

Planting programs are introduced as natural regeneration was found to be inadequate in some logged mangrove areas. In Malaysia, planting is routinely undertaken in Perak and Selangor. In other states such as Johor, planting is claimed not to be necessary because of the greater tidal amplitude which enables efficient dispersal of water-borne propagules and gradual seeding up of logged sites. In Sabah and Sarawak, planting was carried out only in experimental plots.

The two species commonly planted are *Rhizophora apiculata* and *R. mucronata*. The planting operation is simple and can be done by untrained workers. It essentially involves inserting the propagules bottom down into the mud along predetermined lines and at fixed spacing. Spacing varies from 1.2 X 1.2 m for *R. apiculata* (6,727 per hectare) to 1.8 X 1.8 m for *R. mucronata* (2,989 per hectare). Under normal conditions, two or three workers can plant up a hectare in a day. Planting programmes are scheduled to coincide with the fruiting season.

In Matang, planting is carried out by the field staff of the District Forest Office at about US$34 per hectare (Ismail Awang and Gan, 1989). Propagules are purchased from contractors at US$3.50 and US$4.80 per thousand for *R. apiculata* and *R. mucronata*, respectively (Ismail Awang and Gan, 1989). From 1980-1986, a total of about 5,500 ha have been planted. In Selangor, planting is done by contract with supervision by the District Forest Office. The cost varies from US$35 to $40 per hectare (Soo, 1979).

Normally, site preparation prior to planting is not necessary as planting is done two years after felling when most of the logging slash has already decomposed. However, in areas infested by dense thickets of *Acrostichum* ferns, site preparation through eradication is inevitable. In Malaysia, this is routinely carried out in Matang. During the 1970s, the ferns were removed manually by uprooting clumps using a wedged iron bar. This method was found to be ineffective and laborious. Subsequently, in the early 1980s, eradication trials using a herbicide (Velpar 90) was found to be effective. Since then, the chemical method has replaced the manual method. The cost per hectare varies from US$200 to $400, depending upon the denseness of the fern thickets (Ismail Awang and Nazir Khan, 1986). From 1980-1986, a total of about 2,300 ha have been chemically treated.

Thinning

In Malaysia, thinning or intermediate felling is carried out only in Matang. Practised since the 1930s, a stick of prescribed length is used to regulate the intended interval between trees. The prescription requires that only trees occurring within the radius drawn by the stick using a commercial tree of good form as the centre. The effect of the stick will depend largely on the initial distribution of trees in the stand.

Thinnings I and II are carried out in 15- and 20-year old forest stands, using a 1.2 m stick and a 1.8 m stick, respectively. On the average, about 190 to 250 and 60 to 125 pieces of poles are removed from the two thinnings, leaving behind about 3,360 and 1,680 trees per hectare (Haron, 1981). A third thinning (regeneration felling) which was carried out in 25-year old forests, using a 2.1 m stick has now been omitted since it was found that the stand at final felling is inadequately stocked.

Undoubtedly, thinning operations will have beneficial effects on the thinned stands in terms of diameter growth and natural regeneration. However, the timing and intensity will need investigations in order to obtain maximum yield and at the same time leaving behind a productive stand for final felling. Based on observations that there is high mortality of pole-sized trees after 10 years due to natural stand thinning, Gong et al. (1984) proposed that Thinnings I and II be performed at 12 years and 17 or 18 years, respectively.

Forest conservation

In Peninsular Malaysia, protected mangrove forests account for only 0.3% of the total area of about 108,000 ha. The Kuala Selangor Nature Park (about 320 ha), which has yet to gain legal recognition, represents the largest protected mangrove area (Table 24). The other protected areas take the form of Virgin Jungle Reserves (VJRs) which are generally small and are not representative of all mangrove forests in Peninsular Malaysia. They include the Pulau Kukup VJR (Compartment 6; 26 ha) in Johor, Sungei Miang VJR (Compartment 1; 56 ha) in

Pahang and Pulau Kecil VJR (42 ha) in Perak. Mangroves are not included in the present network of protected national parks and wildlife sanctuaries. The whole of Pulau Kukup and Tanjung Piai in South Johor (800 ha), which represent the southernmost tip of the Asian Continent, have been proposed by the Johor State Government to be set aside as a State Park (Table 25). The State Forestry Department is currently drawing up a conservation plan for the area.

In Sarawak, protected mangrove forests account for 0.2% of the total area of about 168,000 ha. About 220 ha of mangroves occur within the Samunsam Wildlife Sanctuary which covers a total area of 6,100 ha and about 166 ha occur within the Bako National Park which covers a total area of 2,700 ha (Table 24). It is envisaged that with the gazettement of the Sibuti and Pulau Bruit Wildlife Sanctuaries, another 1,022 ha of mangroves will be conserved (Table 25).

In Sabah, protected mangrove forests account for 1.3% of the total area of about 366,000 ha. Some 3,747 ha are protected as VJRs at Batumapun, Umas-Umas, Elopura and Sepilok while another 1,518 ha occur within the Kota Belud Wildlife Sanctuary (Table 24).

The following areas have been proposed as potential sites for conservation by Ong and Gong (1991) and Anon. (1987):

Sungei Merbok mangrove, Kedah

Kuala Gula mangrove, Perak

Kuala Selangor mangrove, Selangor

Pulau Tengah, Selangor

Southern part of Pulau Ketam, Selangor

South Johor mangroves, Johor

Sungei Sedili Kecil mangrove, Johor

Tanjung Agas mangrove, Pahang

Tawau mangroves, Sabah

Maruap mangroves, Sabah

Sandakan mangroves, Sabah

Klias mangroves, Sabah

Sarawak mangroves, Sarawak

Rajang mangroves, Sarawak

Lawas-Limbang mangroves, Sarawak

Due to extensive exploitation of mangroves and conversion to various landuses in Malaysia, opportunities to conserve and protect pristine mangroves are rapidly diminishing. The national conservation strategy which is currently being developed for the Malaysian Government by WWF Malaysia should identify more representative mangrove areas for conservation. Ong and Gong (1991) proposed that about 5% of the total mangrove area (or some 30,000 ha) should be conserved.

Case studies of sustainable management practices

Matang mangrove

Covering a total area of about 41,000 ha, the Matang mangrove (5° 8'N; 100° 35'E) in Perak has been managed sustainably for wood production since its reservation which began in 1902. The first working plan was drawn up by D.S.P. Noakes in 1952 for the period 1950-1959. Subsequent revisions were made by R.G. Dixon, Mohd. Darus and Haron Abu Hassan for the periods 1960-1969, 1970-1979 and 1980-1989, respectively. The current plan for 1990-1999 is being finalised by the Perak Forestry Department. These 10-year plans are primarily aimed at supplying quality wood for production of charcoal, firewood and poles on a sustained yield basis. Other objectives include conservation of forest habitats, protection of forests against erosion, rehabilitation of degraded sites, maintaining the ecological functions of mangroves as feeding and breeding grounds of coastal fauna, and setting aside adequate forest for forestry research and training. The plans provide detailed descriptions of the resource, and schedules for regulation of yield, harvesting, silvicultural operations, and conservation and protection.

In Matang, management plans have been faithfully revised and implemented. Thinning as a silvicultural operation is routinely carried out in 10- and 15-year old stands while planting of *Rhizophora* in logged forests has become a standard practice. The success of management is reflected in the extent of quality forest stands which accounts for over 85% of the total area. The coastal waters, estuaries and waterways of Matang support a flourishing fishing industry and its extensive mudflats serve as feeding and stopover sites for both resident and migratory shorebirds. Recently, efforts have been made to promote ecotourism. Facilities include boat cruising, a mangrove museum and boardwalks. The success story of Matang has attracted the attention of mass media, naturalists and researchers locally and abroad. It is not surprising that the Matang mangrove has been often reported to be one of the best managed mangroves in the world.

The Kuala Selangor Nature Park

Established in 1987, the Kuala Selangor Nature Park (3° 20' N; 101° 15'E) in Selangor is the first of its kind in Malaysia. Managed primarily for nature conservation, the park is situated at the southern part of the Selangor river estuary and southeast of the Kuala Selangor town. It is overlooked by Bukit Melawati, a historic site which is also a nature reserve.

The area was originally earmarked for development of a new township for Kuala Selangor. In 1986, the Malayan Nature Society (MNS) and the Asian Wetland Bureau (AWB) wrote to the Selangor State Government proposing that the area was suitable for development into a nature park. In 1987, the park was declared open and since then the State Government has annually provided MNS with a small grant to manage the park. The nature park has now been gazetted as a town park under the Local Government Act 1976.

The park covers a total area of about 320 ha. The major habitat types found include intertidal mudflats (141 ha), mangrove forests (50 ha), secondary coastal forests (121 ha) and a saline lake system (10 ha). The mangroves and intertidal mudflats which are located outside a coastal bund, form part of the Banjar South Mangrove Forest Reserve.

Zonation of the mangrove forest is distinct with accreting natural *Avicennia* forest at the seafront. Further inland, previously logged *Rhizophora* forest transits into *Rhizophora-Bruguiera* forest at the bund. This has resulted in an unnatural forest structure with the largest trees at the seafront and the smallest trees at the landward side. Similarly, the coastal forest behind the bund is degraded since it has been earmarked for development into a new township.

Despite human disturbances, the Kuala Selangor Nature Park still sustains diverse wildlife. The mudflats and saline lake are feeding and roosting sites for migrant and resident birds. Over 150 species of shorebirds have been recorded. The park is home to the increasingly threatened silvered-leaf monkeys *Presbytis cristata* and is the only known breeding site for the grey herons in Malaysia. A variety of invertebrates such as crabs, mudskippers, gastropods and bivalves are found in the mangroves.

Management of the park is coordinated by the MNS Kuala Selangor Nature Park Management Committee. The primary objectives of the park are to maintain the existing mudflat and mangrove communities, to provide suitable habitats and breeding sites for wildlife, to promote environmental research and to enhance nature education and wildlife-related tourism. A management plan has been drawn up for the park.

Over the years, the management has sought to establish several measures in order to achieve its objectives. In collaboration with the National Zoo which has successfully bred milky storks in captivity, the park is the chosen site for a release programme of this internationally important species of shorebird. Should a breeding population be established in the wild, the Kuala Selangor Mangrove Nature Park would gain international recognition. Presently, the Matang Mangroves are the only known breeding site for milky storks which are considered endangered. Nature trials and board walks have been developed and hides have been constructed at several sites for wildlife observation. Other facilities of the park include chalets which can accomodate about 50 persons and an information centre. The watching of fireflies in a nearby mangrove and the annual bird race organised by MNS are additional attractions of the park.

The Kuala Selangor Nature Park has proven to be a success story where a coastal area, originally earmarked for development, was conserved for nature education. The overwhelming support of the public is reflected by the thousands of visitors annually. Undoubtedly, the park serves as a model for replication elsewhere in the country.

Guidelines for sustainable management

The NATMANCOM Guidelines for Brackishwater Aquaculture in Malaysia

Brackishwater aquaculture in Malaysia is developing rapidly. With the improvement and advancement of techniques in breeding and rearing species such as the tiger prawns (*Penaeus* *monodon*), banana prawns (*Penaeus merguiensis*) and sea bass (*Lates calcarifer*), there is a great potential in culturing these species. Consequently there is now a demand for coastal areas such as mangroves for such activities.

The pressure on the Government to release mangrove areas for aquaculture is mounting especially when these cultured species fetch a high price and have good food value and great export potential. However, extensive conversion of mangroves for pond culture will result in removal of the invaluable forests (traditionally, a source of timber for firewood, poles and charcoal production) which in turn may have adverse effects on the coastal capture fishery resources.

Consequently, the Director General of the Fisheries Department in Peninsular Malaysia has requested the assistance of the Malaysian National Mangrove Committee (NATMANCOM) to study this issue and to formulate guidelines on the use of the mangrove ecosystems for brackishwater aquaculture for consideration of the Government.

In July 1986, the Malaysian NATMANCOM prepared a report entitled, "Guidelines on the Use of the Mangrove Ecosystem for Brackishwater Aquaculture in Malaysia".

The report considered the following rationale on the use of mangroves for brackishwater aquaculture:

1. Mangrove utilisation can be broadly classified into two basic groups. Forestry, coastal capture fisheries and aquaculture techniques such as on-bottom culture (e.g. cockle), cage culture (e.g. fish) and raft culture (e.g. mussel) which requires the sustenance of the forest ecosystem to function belong to the first group. Agricultural, industrial and residential development which results in permanent excision and removal of the forest ecosystem belong to the second group. Aquaculture techniques such as pond culture, if extensively practised, will fall into the second group by virtue of the fact that removal of mangrove vegetation and site excavation for pond construction are inevitable.

2. Since brackishwater pond culture of prawns and fish is expected to become a major use of the mangrove ecosystem in Malaysia, it is imperative that proper guidelines be drawn up to integrate pond cultures into the traditional forestry-coastal fisheries mangrove system with the objectives of enhancing fisheries production and simultaneously conserving the mangroves as functional ecosystems.

3. Wherever possible, ponds should be established in mangrove areas already reclaimed and under-utilised e.g. for agriculture. It must be pointed out that, due to the problem of acid sulphate soils and high soil salinity, a number of these areas are at present either unused or abandoned. It is therefore rational to use such reclaimed areas for pond culture.

4. Should the use of existing mangrove forests be inevitable, then culture ponds should be sited on the landward side of the mangroves or in dryland mangroves (Gedney et al., 1982; Ong, 1982). From the forestry viewpoint, the latter are considered unproductive. By siting pond culture projects on the landward side of mangroves, the more productive *Rhizophora* forests can be retained for forestry production. *Rhizophora* forests along with the natural seafront *Avicennia-Sonneratia* forests will then serve as feeding, nursery and reproductive sites for coastal fisheries and further act as buffers against coastal erosion.

5. Where pond installations have to be constructed in the mangrove forests proper, the least productive areas with trees of poor growth or of uneconomic species should be utilised (Ong et al., 1980). The Forestry Department should be consulted in the selection of such areas so that productive *Rhizophora* forests are retained. In this context, stateland mangroves which are not managed for sustained forest production should be considered. In Malaysia, about 226,000 ha of stateland mangroves are currently available for such purposes. It is recommended that, for the time being at least, only stateland forests be made available for aquaculture and that MANGROVE FOREST RESERVES SHOULD BE KEPT INTACT.

6. There are not enough scientific data for the Committee to be able to categorically recommend the proportion of mangroves that can be converted for pond culture without adversely affecting adjacent ecosystems. In the meantime, should a given mangrove area be considered for conversion, each case should be assessed independently based on environmental impact assessments.

The following guidelines are recommended:

- On the choice of site, the priority should be in the following order:
- Ex-mangrove areas already reclaimed for agriculture purposes, unused or abandoned due to poor soil conditions or production.
- Dryland mangroves on the landward side of mangrove forests where forestry output is poor and where impact on coastal fisheries is the least.
- Stateland forests which are outside the forest reserves and are usually unproductive for forestry.
- Mangrove reserves that are not managed on a sustained yield basis for environmental or economic objectives.

On the size and location of site, the recommendations are:

- There should be a 100 m wide buffer zone along the coast between the pond site and the mean high water level of the sea.
- Not more than 20% of existing mangrove land in a given district can be cleared for pond construction.
- The next project should be constructed at a distance more than 4 times the length of the coastline occupied by the first project.

On pond design and culture techniques, the recommendations are:

- The pond should be constructed with minimum excavations to avoid problems associated with acid sulphate soils.
- The water regimes be managed by pumping rather than be dependent on tidal fluctuations.
- Use pellet feeds rather than raw trash fish.

The CRMP Recommendations for Mangrove Management in South Johor

The Coastal Resources Management Project (CRMP) was funded by USAID and executed by ICLARM. The planned period of this pilot project was from 1986 to 1990. It was designed to strengthen the capability of ASEAN countries to adopt an integrated interdisciplinary and multisectoral approach in developing management plans for coastal resources.

In Malaysia, the site chosen for the CRMP was South Johor. The mangrove management plan formed an important component of the coastal resources management plan.

The following recommendations were made in the mangrove management plan:

1. Conversional uses of mangrove areas
   - Prohibit further conversion of mangrove forest reserves
   - Allow only stateland mangroves for small-scale family aquaculture operations. A maximum of 3 ha forest may be converted while retaining a surrounding area of 12 ha with a 400 m wide seaward belt.
   - Further development of agriculture and pond culture in current mangrove forest areas must cease. The use of non-mangrove coastal areas for such development should be promoted.
2. Development on lands adjacent to mangrove areas
   - The recommended construction setback from mangroves for the different types of development adjacent to mangroves is as follows:

Industries	=	1,000 m
Housing	=	500 m
Tourism	=	100 m
Aquaculture	=	100 m

   - Establish strict pollution controls for development adjacent to mangroves to prevent any effluent discharges or dumping of wastes into the mangroves.
   - Runoff and leaching of waste from disposal sites must be minimised. Effective dikes should therefore be constructed.
   - Development projects adjacent to mangroves should be subjected to Environmental Impact Assessment.
3. Non-conversional uses of mangroves
   - In the waterways within forest reserves where bathymetry, current and water quality conditions are suitable, non conversional aquaculture techniques such

as cage and raft culture should be permitted.

- The Fisheries Department personnel who handle the licensing will be responsible for limiting the size and number of cages or rafts depending on the area.

4. Forestry working plans for sustainable management

   - Forestry working plans should be developed by each forest reserve. The plans should determine management goals and objectives, felling schedules, the annual allowable cut, felling schedules and silvicultural operations. The needs for conservation and protection for critical habitats should also be incorporated.

5. Shoreline and riverbank protection

   - Armour retreating scarps and restore mangrove vegetation in seafront and riverbank areas experiencing severe erosion.
   - Mangrove forests fronting coastal bunds should be gazetted as Protective Forest Reserves. They are to be retained as protective belts against shoreline and riverbank erosion.

The WWF-AWB Guidelines for the Development of Coastal Aquaculture in Selangor

In 1988, WWF Malaysia in conjunction with the Asian Wetland Bureau (AWB) developed a Coastal Aquaculture Action Plan for Selangor at the request of the Selangor State Planning and Development Unit. The objectives of the project was to facilitate wise investment in coastal aquaculture in Selangor. The project identified the options and constraints for brackishwater aquaculture without harming the natural resource base of the State and provided guidance to the Selangor State Government and to potential investors on the appropriate siting of coastal aquaculture projects.

The guidelines given in the report are intended to assist the Selangor State Government in its planning of aquaculture development as part of coastal area management planning and are partly based on the Malaysian NATMANCOM's guidelines. They are as follows:

1. On the choice of site, the priority should be in the following order:

   - non-mangrove coastal areas
   - mangrove areas already reclaimed for agricultural purposes but unused, abandoned or unproductive
   - landward site of unproductive stateland mangroves (not Forest Reserves)

2. There should be no further alienation of land for coastal aquaculture within Forest Reserves or within areas designated as conservation sites.

3. The following buffer zones apply to all aquaculture projects

   - in non-mangrove or ex-mangrove areas, there should be a 100 m wide buffer zone along the coast between the pond site and the mean high water level of the sea
   - in stateland mangrove forests along accreting shorelines, there should be a 200 m wide buffer zone along the coast between the pond site and the seaward edge of the mangrove forest
   - in stateland mangrove forests along stable and eroding shorelines, there should be a 400 m wide buffer zone along the coast between the pond site and the seaward edge of the mangrove forest
   - there should be a 50 m wide buffer zone along all rivers between the pond site and the riverbank
   - not more than 20% of the stateland mangrove forest in a given District can be cleared for pond construction
   - in stateland mangrove areas, the adjacent projects should be constructed at a distance of more than 4 times the length of the coastline occupied by the larger of the two projects

4. On pond design and culture techniques, the recommendations are:

   - the pond should be constructed with minimum excavations to avoid problems associated with acid sulphate soils
   - the water regimes be managed by pumping rather than be dependent on tidal

fluctuations. Ponds should be semi-intensively or intensively managed

- pellet feeds be used rather than raw trash fish

5. On the planning of pond development, the recommendations are:

   - all aquaculture projects involving the clearance of mangroves must prepare a preliminary EIA for submission to the State Government, along with the feasibility study
   - brackishwater aquaculture pond development should be considered as one component of integrated coastal area management planning and should only be permitted where it does not conflict with other coastal land uses (e.g. tourism)
   - preference should be given to community-based projects involving the active participation of local inhabitants

6. On the implementation of pond development, the recommendations are:

   - all pond developments larger than 50 ha in area should start with an initial pilot project of not more than 20% of the area. Development should be permitted to proceed only if the pilot project has shown to be viable after a minimum period of two years.
   - only those parts of a development site on which ponds are to be constructed immediately should be cleared of vegetation. Other parts of the site, particularly if under mangrove forest, should be retained.

7. On enforcement of pond development guidelines, the recommendations are:

   - any developer found to be in violation of these guidelines should not be allowed to proceed with the development and/or held responsible for the costs of repair of any environmental damage incurred.

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Mangroves of Thailand: Present status of conservation, use and management.

S. Aksornkoae, N. Paphavasit and G. Wattayakorn

General description

Distribution and extent of mangroves

In Thailand, mangroves occur on the sheltered muddy shores and low-lying boggy ground of the river and stream estuaries at levels between low and high tides along the banks of the Gulf of Thailand and on the west and east coasts of the peninsula (Figure 1). The best developed mangrove forests as the old growth stands remain only the west coast of the peninsula especially in the provinces of Ranong, Phang-nga, and Trang. The mangroves along the coasts of the Gulf of Thailand are mainly classified as young growth stands, because most of these mangrove forests have been heavy selectively cut for many years especially the areas on the upper part of the Gulf of Thailand, for examples in the provinces of Petchaburi, Samut Prakarn, Samut Sakorn and Samut Songkram.

Recently, the Remote Sensing Division, National Research Council of Thailand (IDRC/NRCT/RFD, 1991) estimated the total existing mangrove forests by visual interpretation of LANDSAT-MSS data recorded in 1986-1987 to be approximately 196,429 ha or 1,227,681 rai. Table 1 shows the distribution of mangrove forest areas by provinces in Thailand. Of the estimated total mangrove forest area, approximately 75% is found on the west coast of the peninsula. The province of Phang-nga comprises the biggest mangrove forest area (36,420 ha or 2227,6225 rai) of the country.

Forest types and associated flora

Mangroves have not been classified into different types in Thailand. Only species zonation has been studied. The floristic composition of the mangrove forests in different parts of the country is slightly different. A marked difference of the occurrence of mangrove species in different areas is due to topographic condition, and other important environmental factors such as rainfall, soil and water conditions, and human impacts. Santisuk (1983) recorded that mangrove flora in Thailand consists of 74 species in 53 genera and 35 families. These species are listed in Table 2. According to the country, only few species have a rather limited distribution, such as *Aegialites retundifolia, Heritiera fomes, Rapanea umbellullata.* The species belonging to the family Rhizophoraceae have the widest distribution (Table 2).

The other important associated flora especially the epiphytic flowering plants in mangrove forests in different parts of Thailand has also been studied by Sahavacharin and Boonkerd (1976). They reported 18 species belonging to 13 genera and three families (Asclepiadaceae, Loranthaceae and Orchidaceae). Most of the epiphytic flowering plants (13 species) belong to the family Orchidaceae of the genera *Dendrobium, Bullophyllum* and *Eria*. The species of the genera *Hoya* of the family Asclepiadaceae are also very common in the Thai mangroves. The species of epiphytic flowering plants of mangroves in Thailand are listed in Table 3.

The algal flora is one of the most important groups of associated species in mangrove forest. The survey of algal flora in various parts of Thailand have been studied by Lewmanomont (1983). These algae were divided into two groups based on their habitats. One group is composed of those that are attached on the trunks and roots or pneumatophores of mangrove trees while the other group comprises those that grow on the mudflat or sandy muddy areas in the mangrove forests. The mangrove roots support red algae of the genera *Catenella, Bostrychia* and *Murrayella*. Other species of red algae found in the mangrove forests of Thailand belong to the genera *Gracilaria, Hypnea, Gelidium, Acanthophora, Herposiphonia* and *Laurencia*. On muddy substrate there are green algae of the genera *Cladophora, Chaetomorpha, Enteromorpha, Ulva* and the blue-green algae *Lyngbya, Oscillatoria, Phormidium* and *Calothrix*. Some species of brown algae are also found in the mangrove areas, members of the genera *Ectocarpus, Dictyota* and *Hydroclathrus*. Lewmanomont (1983) recorded about 47 species of algae from the mangrove forests in Thailand (Table 4).

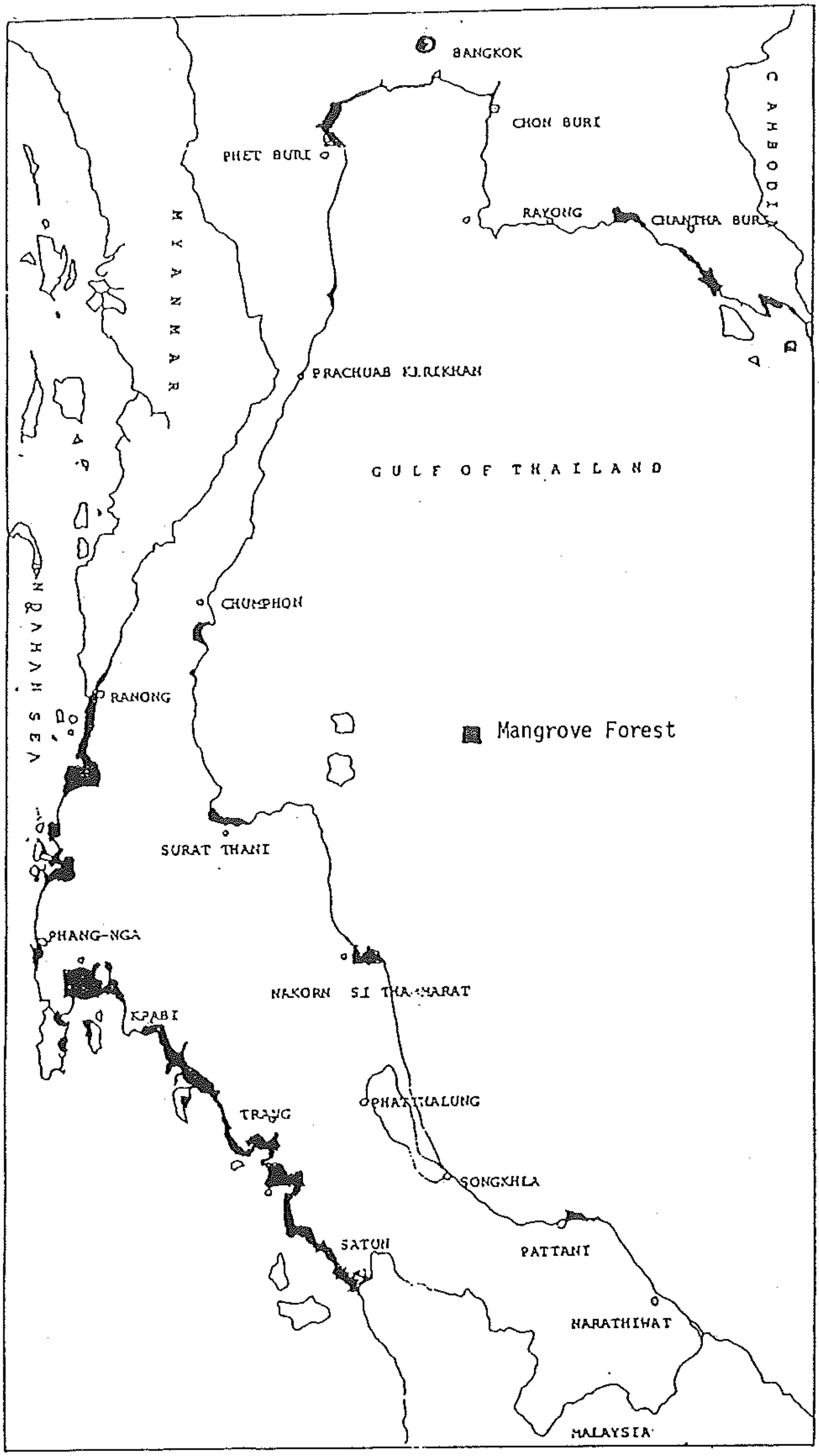

Figure 1. Distribution of the existing mangrove in Thailand

Relative areas of different forest types

Classification of mangroves into different types has not been made in Thailand. However, species zonation has been identified throughout the mangroves of the country. The information on areas of different types of mangroves have not been reported so far.

Fauna found within forest types

Inventory and taxonomy of fauna in the mangrove forests in Thailand have been extensively investigated. Animal production in the mangroves is high due to the availability of food resources and microhabitats for animals to take refuge in. Mangrove ecosystems are known to be important feeding and nursery grounds for many marine commercial species. Mangrove fauna are comprised of representatives from almost all the phyla ranging from protozoa, nematodes, nemertines, polychaetes, gastropods, bivalves, crustaceans, fishes to birds and mammals.

Microorganisms

At present, data on the distribution and activities of microorganisms (fungi, bacteria, viruses) in the mangrove ecosystems of Thailand are very scarce. Some studies have been attempted by Chalermpongse (1985). He observed that *Phellinus pachyphloeus* (Hymenomycetes : Basidiomycotina) causes trunk rot of the old growth of *Rhizophora apiculata* and *R. mucronata*. This disease shows die-back symptoms and reduces timber quality of the natural mangrove stand. The final stage of attack involves the death of the stands. Decay of dead roots of *Rhizophora apiculata* was found to be cansed by *Manglicola guatemalensis* Ascomycotina). Soil-borne fungi were also studied from the mangrove muds and water. Species of representative of Deuteromycotina: *Chaetomium, Eupenicillium, Humicola alopallonella, Myrothecium, Penicillium* and *Trichoderma* were commonly investigated by soil dilution plate techniques.

Kohlkmeyer (1984) collected fungi from mangrove habitats in Thailand, particularly from mangroves with submerged trunks and roots (prop roots and pneumatophores). Among the fungi observed are Deuteromycotina: *Cirrenalia pygmea, Humicola alopallonella* and *Periconia prolifica*, Anastasion; *Halosphaeria cucullalta*; Ascomycotina; *Arenariomyces trifurcatus, Corollospora maritima, C. pulchella, Dactylospora haliotrepha, Halosphaeria quadricornuta, H. salina, Halosarpheia rotnagiriensis, Hydronectria tethys* var. *glabra, Lignicola laevis* and *Lulworthia* sp.; and Basidiomycotina: *Halocyphina villosa*.

Bacteriological examination of soils and waters from natural mangrove forest areas in different parts of Thailand was made recently by Chalermpongse (1985) to determine the presence of autotrophic and heterotrophic microorganisms

Table 1. Mangrove forest area in Thailand by visual interpretation of LANDSAT-MSS data recorded in 1986-1987

No.	Province	Mangrove Forest Area ha	rai	% of Total
Eastern Region				
1	Chachoengsao	740	4,625	0.38
2	Chonburi	1,498	9,362	0.76
3	Rayong	2,417	15,112	1.23
4	Chanthaburi	14,507	90,668	7.39
5	Trat	8,817	55,112	4.49
	Total	27,981	174,881	14.25
Central Region				
6	Samut Prakarn	106	644	0.05
7	Samut Sakhon	142	888	0.07
8	Samut Songkhram	49	306	0.02
	Total	297	1,837	0.14
Eastern Coast of Peninsula				
9	Phetchaburi	577	3,606	0.30
10	Prachuap Khiri Khan	145	906	0.07
11	Chumpon	3,626	22,662	1.84
12	Surat Thani	4,284	26,775	22.18
13	Nakhon Si Thamınrat	8,836	55,225	4.50
14	Phatthalung	105	656	0.05
15	Songkhla	965	6,031	0.50
16	Pattani	1,828	11,425	0.93
	Total	20,366	127,287	10.37
Western Coast of Peninsula				
17	Ranong	21,606	135,037	11.00
18	Phang nga	36,420	227,625	18.54
19	Phuket	1,935	12,093	0.99
20	Krabi	30,312	189,450	15.43
21	Trang	26,276	164,225	13.38
22	Satun	31,239	195,243	15.29
	Total	14,779	92,367	75.25
GRAND TOTAL		196,429	1,227,681	100

Table 2. Trees and shrubs of mangroves in Thailand.

No.	Latin Name	Family	True Mangrove[†]	Life Form	Distribution		
					Central & Southeastern	Peninsula East Coast	Peninsula West Coast
1	*Acanthus ebracteatus*	Acanthaceae	+	S	+	+	+
2	*A. ilicifolius*	Acanthaceae	+	S	+	+	+
3	*Acrostichum aureum*	Pteridaceae	+	F	+	+	+
4	*A. speciosum*	Pteridaceae	+	F	+	-	+
5	*Aegialites rotundifolia*	Plumbaginaceae	+	S	-	-	+
6	*Aegiceras corniculatum*	Myrsinaceae	+	S	+	+	+
7	*Allophylus cobbe*	Sapindaceae		S	+	+	+
8	*Amoora cucullata*	Meliaceae		T	+	+	+
9	*Ardisia littoralis*	Myrsinaceae		S/ST	+	+	+
10	*Avicennia alba*	Avicenniaceae	+	T	+	+	+
11	*A. marina*	Avicenniaceae	+	T	+	+	+
12	*A. officinalis*	Avicenniaceae	+	T	+	+	+
13	*Barringtonia asiatica*	Barringtoniace		Te	+	+	+
14	*B. racemosa*	Barringtoniace		Te	+	+	+
15	*Brownlowia tersa*	Tiliaceae		S/ST	+	+	+
16	*Bruguiera cylindrica*	Rhizophoraceae	+	T	+	+	+
17	*B. gymnorhiza*	Rhizophoraceae	+	T	+	+	+
18	*B. hainesii*	Rhizophoraceae	+	T	+	+	-
19	*B. parvifora*	Rhizophoraceae	+	T	+	+	+
20	*B. sexangula*	Rhizophoraceae	+	T	+	+	+
21	*Cassine viburnifolia*	Celastraceae		ST/S	-	-	+
22	*Cerbera manghas*	Apocynaceae		T	+	+	+
23	*C. odollam*	Apocynaceae		T	+	+	+
24	*Ceriops decandra*	Rhizophoracea	+	S/ST	+	+	+
25	*C. tagal*	Rhizophoraceae	+	T	+	+	+
26	*Clerodendrum inerme*	Verbenaceae		S	+	+	+
27	*Cynometra iripa*	Leguminosae		S/ST	-	-	+
28	*C. ramiflora*	Leguminosae		T	+	+	+
29	*Cycas rumphii*	Cycadaceae		ST	+	+	+
30	*Dendrolobium umbellatum*	Leguminosae		S	+	+	+
31	*Derris indica*	Leguminosae	+	T	+	+	+
32	*Diospyros ferrea*	Ebenaceae		ST/T	+	+	+
33	*Dolichandrone spathacea*	Bignoniaceae		T	+	+	+
34	*Excoecaria agallocha*	Ebenaceae	+	ST/T	+	+	+
35	*Ficus microcarpa*	Moraceae		T	+	+	+
36	*Glochidion littorale*	Euphorbiaceae		ST	+	+	+
37	*Guettarda speciosa*	Rubiaceae		ST	+	+	+
38	*Heritiera formes*	Sterculiaceae	+	T	-	-	+
39	*H. littoralis*	Sterculiaceae	+	T	+	+	+
40	*Hibiscus tiliaceus*	Malvaceae		T	+	+	+
41	*Horsfieldia irya*	Myristicaceae		T	+	+	+
42	*Intsia bijuga*	Leguminosae		T	+	+	+
43	*Kandelia candel*	Rhizophoaceae	+	T	+	+	+
44	*Lumnitzera littorea*	Combretaceae	+	ST/T	+	+	+
45	*L. racemosa*	Combretaceae		ST/T	+	+	+

Table 2. Trees and shrubs of mangroves in Thailand (*Continued*).

No.	Latin Name	Family	True Mangrove[†]	Life Form	Distribution		
					Central & Southeastern	Pensinsula East Coast	Peninsula West Coast
46	*Melaleuca leucodendron*	Myrtaceae		T	+	+	+
47	*Melastoma villosum*	Melastomaceae		P	+	+	+
48	*Nypa fruticans*	Palmae	+	ST	+	+	+
49	*Oncosperma tigillarium*	Palmae		T	-	+	+
50	*Pandanus odoratissimus*	Pandanaceae		ST	+	+	+
51	*Paramignya longispina*	Rutaceae		S	-	-	+
52	*Peltophorum pterocarpum*	Leguminosae		T	+	+	+
53	*Pemphis acidula*	Lythraceae		S	+	+	+
54	*Phoenix paludosa*	Palmae	+	P	+	+	+
55	*Planchonella obovata*	Sapotaceae		T	+	+	+
56	*Pluchea indica*	Compositae		S	+	+	+
57	*Premna obtusifolia*	Verbenaceae		S	+	+	+
58	*Rapanea porteriana*	Myrsinaceae		T	+	+	+
59	*Rapanea. umbellulata*	Myrsinaceae	+	ST/T	-	-	+
60	*Rhizophora apiculata*	Rhizophoraceae	+	T	+	+	+
61	*R. mucronata*	Rhizophoraceae	+	T	+	+	+
62	*Sapium indicum*	Euphorbiaceae	+	ST/T	+	+	+
63	*Scaevola taccada*	Goodeniaceae		S	+	+	+
64	*Scolopia macrophylla*	Flacoutiaceae	+	ST	-	+	+
65	*Scyphiphora hydrophyllacea*	Rubiaceae	+	ST	+	+	+
66	*Sonneratia alba*	Sonneratiaceae	+	T	+	+	+
67	*S. caseolaris*	Sonneratiaceae	+	T	+	+	+
68	*S. griffithii*	Sonneratiaceae	+	T	+	-	+
69	*S. ovata*	Sonneratiaceae	+	T	+	+	+
70	*Suaeda maritima*	Chenopodiaceae	+	US	+	+	+
71	*Thespesia populnea*	Malvaceae		T	+	+	+
72	*Xylocarpus gangeticus*	Meliaceae		T	+	-	-
73	*X. granatum*	Meliaceae	+	T	+	+	+
74	*X. moluccensis*	Meliaceae	+	T	+	+	+

[†] True mangroves are bound to saline or brackish water. The remaining species are mangrove associates, species of the littoral vegetation that regularly occur in the back or more landward mangroves.

Key: T = Tree; S = Shrub; ST = Shrubby tree; US = Undershrub; F = Fern; P = Palm.

using standard methods (Agate. 1984). The autotrophic and heterotrophic bacteria found are:

Autotrophic bacteria (Agate *et al.*, 1985)

1. Sulfur oxidizer (*Thiobacillus thiooxidans*)
2. Iron oxidizer (*Thiobacillus thiooridans*)

Heterotrophic bacteria (Agate, 1984)

1. Gram-positive rods (*Bascillus stearothermophilus, B. megaterium, B. macerans, B. firmus*
2. Gram-positive cocci (*Staphylococcus* sp., *Micrococcus varians, M. luteus, Planococcus* sp.)
3. Gram-negative rods (*Proteus vulgaris, Citrobacter* spp., *Proteus mirabilis, Escherichia coli, Klebsiella* spp.

The bacteriological studies showed that the dominant (above 30%) aerobic heterotrophic bacterial flora at Ranong belongs mainly to 7 genera, viz. *Bacillus, Staphylococcus, Micrococcus, Planococcus, Proteus, Vibrio* and *Escherischia coli*; the first 4 genera being present mostly in soils and the other 3 in water (UNDP/UNESCO, 1991).

The total bacterial count of mangrove soils and water varied from 1.5×10^6 - 1.85×10^7 respectively in normal undisturbed areas; whereas it showed a lower level, ranging from 1.8×10^4 - 4.8×10^4, for mangrove soils and water in areas disturbed by mining practices, thus indicating a negative impact of such activities on the microflora. In this group, the presence of potentially pathogenic bacteria such as *Vibrio* or *E. coli* again reconfirmed the negative impact of human activity on mangrove areas.

When the autotrophic to heterotrophic bacterial ratio was determined, it was found that in the mining-disturbed mangrove areas, the autotrophs predominate, whereas the heterotrophs proliferate in normal mangroves. This suggests that disturbance leads to the selection and subsequent predomination of autotrophic bacterial populations which can obtain their energy from oxidation of inorganic compounds and resist high metal concentrations in mining-disturbed areas contaminated with metals and their salts.

It was found that a complete sulfur cycle driven by bacteria exists in the mangrove ecosystem. Anaerobic, sulfate reducing bacteria belonging to the genera *Desulfovibrio* and *Desulfotomaculum*, plus sulfur oxidizers, were readily isolated from mangrove soils and water. These are economically important microorganisms.

Table 3. Epiphytes of mangroves in Thailand.

No.	Latin Name	Family
1	*Hoya parasitica*	Asclepiadiaceae
2	*H. lacunosa*	Asclepiadiaceae
3	*Dishcidia rafflesian*	Asclepiadiaceae
4	*Dendrophthoe pentandra*	Loranthaceae
5	*Viscum ovalifolium*	Loranthaceae
6	*Bulbophyllum parpuracens*	Orchidaceae
7	*B. dixoni*	Orchidaceae
8	*Dendrobium cremenatum*	Orchidaceae
9	*D. individum*	Orchidaceae
10	*D. subulatum*	Orchidaceae
11	*Eria albedo-tometosa*	Orchidaceae
12	*E. ornata*	Orchidaceae
13	*Eulophia keithii*	Orchidaceae
14	*Luisia zolligeri*	Orchidaceae
15	*Paphiopedilum exul*	Orchidaceae
16	*Pholidota imbricata*	Orchidaceae
17	*Pomatocalpa siamensis*	Orchidaceae
18	*Trihoglottis misera*	Orchidaceae

Source: Sahavacharin and Boonkerd (1976).

Mangrove plankton communities

Although mangrove detritus rather than phytoplankton is the primary food source for aquatic organisms in the mangrove ecosystem, diatoms, bluegreen algae and dinoflagellates are common in mangroves especially on mudflats. For example, diatoms dominate the mangrove waters of Phang-nga bay (Boonruang 1985) and Khung Kraben, Chantaburi Province (Marumo *et al.* 1985). Boonruang (1985) reported that five oceanic species of diatoms were present as indicators of oceanic water admixture in the mangrove forest waters at Phang-nga. Marumo *et al.* (1985) reported that diatoms as the dominant group of phytoplankton, might be a necessary food source in the food chain at Khung Kraben mangrove forest for molluscan and crustacean larvae, as well as for herbivorous copepods, which in turn are fed upon by carnivorous copepods and chaetognaths.

During wet season conditions in Klong Ngao, Ranong mangrove forest the phytoplankton was rich in term of abundance and diversity, with 124 species being recorded. Diatoms were the principal group in the samples as found in other mangroves (Walsh, 1967; Suvapepun *et al.*, 1980; Boonruang, 1985 and Marumo *et al.*, 1985). Most abundant species were *Coscinodiscus granii, C. asteromphalus, C. nobilios, Hemidiscus* sp., *Skeletonema costatum, Lauderia* spp., *Thalassiosira hyalina, T. subtilis* and *Chaetoceros compressus.* Other common species in the area were *Biddulphia sinensis, Ditylum sol, Triceratium favus, Eucampia* spp., *Syneda* sp., *Thalassionema nitzschioides Thalassiothrix fraquenfeldii, Thalassiothrix longissima, Nitzchia pacifica* and *N. paradoxa.* Dinoflagellates in the Klong Ngao mangroves were found in small numbers. The common species were *Pyrocystis noctiluca, P. namulus, Ceratium pentagonum, Ceratium* spp. and *Dinophysis caudata.*

Zooplankton play an important and varied role as an intermediate link between primary and tertiary level production in the mangroves. This large

Table 4. Algal flora of mangroves of Thailand.

No.	Latin Name	Family
1	*Catenella nipae*	Rhabdoniaceae
2	*Catenella repens*	Rhabdoniaceae
3	*Bostrychia tenella*	Rhabdoniaceae
4	*Bostrychia binderi*	Rhabdoniaceae
5	*Bostrychia radicans*	Rhabdoniaceae
6	*Murrayella periclados*	Rhabdoniaceae
7	*Laurencia papillosa*	Rhabdoniaceae
8	*Laurencia pavipapillosa*	Rhabdoniaceae
9	*Laurencia obtusa*	Rhabdoniaceae
10	*Herposiphonia spp.*	Rhabdoniaceae
11	*Acanthophora specifera*	Rhabdoniaceae
12	*Gracilaria verrucosa*	Gracilariaceae
13	*Gracilaria crassa*	Gracilariaceae
14	*Gracilaria salicornis*	Gracilariaceae
15	*Hypnea esperi*	Hypneaceae
16	*Hypnea cervicornis*	Hypneaceae
17	*Hypnea musciformis*	Hypneaceae
18	*Centroceras clavulatum*	Ceramiaceae
19	*Spyridia filamentosa*	Ceramiaceae
20	*Lyngbya spp.*	Oscillatoriaceae
21	*Symploca spp.*	Oscillatoriaceae
22	*Phormidium spp.*	Oscillatoriaceae
23	*Calothrix spp.*	Rivulariaceae
24	*Ulva reticulata*	Ulvaceae
25	*Enteromorpha flexuosa*	Ulvaceae
26	*Enteromorpha intestinalis*	Ulvaceae
27	*Cladophora fascicularis*	Cladophoraceae
28	*Cladophora socialis*	Cladophoraceae
29	*Rhizoclonium spp.*	Cladophoraceae
30	*Acetabularia calyculus*	Dasycladaceae
31	*Avrainvillea erecta*	Codiaceae
19	*Spyridia filamentosa*	Ceramiaceae
20	*Lyngbya spp.*	Oscillatoriaceae
21	*Symploca spp.*	Oscillatoriaceae
22	*Phormidium spp.*	Oscillatoriaceae
23	*Calothrix spp.*	Rivulariaceae
24	*Ulva reticulata*	Ulvaceae
25	*Enteromorpha flexuosa*	Ulvaceae
26	*Enteromorpha intestinalis*	Ulvaceae
27	*Cladophora fascicularis*	Cladophoraceae
28	*Cladophora socialis*	Cladophoraceae
29	*Rhizoclonium spp.*	Cladophoraceae
30	*Acetabularia calyculus*	Dasycladaceae
31	*Avrainvillea erecta*	Codiaceae
32	*Halimeda incrassata*	Codiaceae
33	*Bryopsis spp.*	Bryopsidaceae
34	*Caulerpa racemosa*	Caulerpaceae

Table 4. (*Continued*)

No.	Latin Name	Family
35	*Caulerpa verticillata*	Caulerpaceae
36	*Caulerpa peltata*	Caulerpaceae
37	*Ectocarpus sp.*	Ectocarpaceae
38	*Dictyota dichotoma*	Dictyotaceae
39	*Dictyota cervicornia*	Dictyotaceae
40	*Padina boryana*	Dictyotaceae
41	*Padina gymnospora*	Dictyotaceae
42	*Padina tetrastromatica*	Dictyotaceae
43	*Sargassum sp.*	Sargassaceae
44	*Hydroclathrus clathratus*	Scytosiphonaceae
45	*Turbinaria coniodes*	Sargassaceae
46	*Turbinaria ornatas*	Sargassaceae
47	*Turbinaria decurrens*	Sargassaceae

Source: Lewmanomont, 1983.

group includes both permanent planktonic organisms such as copepods, and a temporary fauna which includes larval dispersal stages of many intertidal mangrove animals, as well as larval and post-larval fish, crustaceans and molluscs.

Suvapepun *et al.* (1979) reported on the species composition and distribution of zooplankton communities in the mangrove forest at Leam Pak Biah in Phetchaburi Province. Copepod and decapod larvae were the dominant groups. Marumo *et al.* (1985) also found that copepods dominated in the epipelagic zooplankton community at Khung Kraben, Chanthaburi Province, Thailand. Boonruang (1985) carried out a survey on zooplankton communities in coastal water adjacent to the mangrove forest in Phang-nga Bay and the east coast of Phuket Island. The highest density of zooplankton recorded was 1,047 organisms/m^3, this peak occurring during the north-east monsoon from January to April. Copepods were the most numerically abundant group ranging from 30 - 45% of the plankton population; *Lucifer* spp. were second in importance ranging from 7 - 30%. Boonruang (1987) reported on the biomass and abundance of aquatic larvae along the Andaman coastline from Ranong to Satun Province. The plankters recorded in maximum number were siphonophores, copepods, chaetognathids, and salps. In abundance the most important aquatic larvae consisted of brachyurans, stomatopods and fish.

Many species of penaeid shrimp use mangrove forests as shelter and nursery grounds for at least part of their life cycle. Chaitiamvong (1983) reported on the species of shrimps found in the mangrove and adjacent areas. There are 15 species migrating from marine to coastal areas near mangroves and these species mainly belong to the genera *Metapenaeopsis*, *Metapenaues*, and *Parapenaeopsis*. About 16 species of shrimps migrate from marine to brackish water (mangroves) and the main genera are *Metapenaeus*, *Penaeus* and *Acetes*. The common species of shrimps found in the mangrove forests are *Macrobrachium equidens*, *Palaeander* sp. and *Palaemonetes* sp. Few species of shrimp migrating from fresh water to brackish water (mangrove area) were recorded and the common species are *Macrobrachium rosenbergii* and *Leptocarpus potamiseus*.

The dominant planktonic shrimps in the Ranong mangrove forest are species of *Lucifer* and *Acetes*. Other small shrimp include *Rhiphalophthalmus* spp., *Acanthomysis* spp. *Mesopodopsis* spp. and other mysids. The larger penaeid shrimps present are *P. semisulcatus*, *P. monodon*, *P. merguiensis*, *Metapenaeus lysianassa*, *Metapenaeus* spp., *Trachypenaeus* spp. and *Parapenaeopsis* spp.

Brachyuran larvae, including both the zoea and megalopa stages, were recorded in high density in the zooplankton communities throughout Ranong mangrove forest during all sampling periods. Brachyuran larvae were represented by seven families: Corystidae, Dorripidae, Grapsidae, Hymenosomatidae, Leucosiidae, Majidae and Pinnotheridae.

Other crustacean larvae common in the Klong Ngao mangrove forest were anomuran larvae, thallasinid larvae and caridean larvae. Anomuran larvae were represented by three families, Diogenidae, Paguridae and Porcellanidae and caridean larvae by the families Alpheidae and Hippolytidae. *Jaxea* spp. were the dominant thallasinid larvae. Alima larvae (Squillidae) and phyllosoma larvae (Scyllaridae) were also observed in the zooplankton communities. Gastropod larvae formed the main component of the mollusc larvae in this area. Copepods were abundant throughout the area. The major predatory zooplankters common in the area were chaethognaths, siphonophores, ctenophores and medusae.

Mangrove meiofauna

Meiofauna are detrital feeders or indiscriminate feeders on bacteria and benthic diatom. Few studies have been done on these organisms due to the difficulties in sampling procedures and taxonomic works. There is also a complexity in the meiofaunal food web. Each major taxonomic group may have different feeding types, with each species feeding on various material in the sediment. Small turbellarians may be the top of the food chain in some systems. As active predators they will attack larger forms and either swallow their prey whole or suck out the prey with strong jaws and a muscular pharynx, respectively. The study on mangrove meiofauna often emphasis on the known importance of this group in the dynamics of detritus production and in energy turnover especially mangrove soil nematodes.

Nozawa *et al.* (1983) investigated the mangrove meiofauna at Ko Lao Island and Klong Ngao in Ranong. The major organisms found were Nematoda and Harpacticoid Copepoda. Nematoda, however, were observed in abundance at all sampling points with the averaged percentage of 78%. The other organisms of frequent occurrence but in a small number were Kinorhyncha, Foraminifera, Ostracoda, Polychaeta and Mollusca.

Up to 12 groups were represented in the meiofaunal communities in Ranong (1991) but only foraminiferans, nematodes and copepods were widely distributed and abundant in wet and dry seasons. Nematodes and copepods accounted for 90.5 and 85.6% of the total meiofauna (excluding foraminiferans) population numerically and 65.1 and 69.3% in terms of biomass (wet and dry seasons, respectively).

Seasonally, the meiofauna showed little qualitative change, but in terms of abundance there was a considerable reduction in the meiofauna from the dry season to wet season. The average density (No./10 cm^2) decreased from 68-256 per study site in March to 18-164 per study site in August. The foraminiferans were most affected. In response to high salinity, foraminiferans were abundant in the seaward most study sites (1 and 2) in the dry season (2028/10 cm^2 at Study Site 2), but were much reduced in numbers in the wet season (<100/10 cm^2) presumably because of the lowered salinity conditions throughout Klong Ngao.

With the foraminiferans excluded, the distribution of meiofauna, shows some relationship to habitat type. Their abundance was highest in the *Avicennia* forest, but rather variable at the other sites between the wet and dry seasons. The minor groups of the meiofauna, which are mainly turbellarians, polychaetes, oligochaetes, acarids and juvenile bivalves, were most plentiful at Study Site 1, which probably reflects the fact that this is the site least affected by low salinity as it borders the open coast.

Intertidal macrofauna

The distribution, abundance and biomass of major species or groups of the intertidal mangrove fauna have long been intensively studied, especially the mangrove macrofauna of Phuket Island, Phang-nga Bay, Ranong and Chantaburi. Frith *et al.* (1976) investigated horizontal and vertical zonation and abundance of macrofauna at Ao Nam Bor, a mangrove on the Phuket seashore. The macrofauna consisted of predominantly crustaceans (55 species), molluscs (42 species) and polychaetes (22 species), fish (6 species), coelenterates (4 species), nemertines (5 species), sipunculids (2 species), echinoderms (2 species), platyhelminths (1 species) and brachiopods (1 species). Substratum preference and to a lesser extent length of the exposure period at low tide were the most important factors to limit the distributions of species on this shore. Macrofauna, totalling 51 species was found at Ko Surin Nua, Phuket (Frith, 1977). Nateewatana and Tantichodok (1980) reported on the macrofaunal communities in the mangrove forest, sand flats, mud flats and seagrass beds at Ko Yao Yai. Polychaete annelids, crustaceans and molluscs were the dominant groups. Tantichodok (1981) concluded that the species composition of the macrofauna in the mangroves of Ko Maphrao was similar to that found in other areas of Phuket. Types of substrates (water content, organic content and particle size of sediments). which differed from station to station, and tidal inundation (or exposure to air) were the two major factors controlling the animal distribution and abundance.

Paphavasit and Setti (1981) reported on the marine benthic communities with emphasis on epifauna in the mangrove ecosystem of Phang-nga Bay. They found that the benthic production in this area was as rich as in Phuket. The macrofauna consisted predominantly of molluscs (44 species) and crustaceans (18 species), and also included coelenterates, polychaetes, annellids, sipunculids, chitons and ehinoderms were also recorded. No significant differences were found in the epifaunal biomass among seasons and among the three sampling sites, namely the limestone, sandstone, shale and quartz areas. However, the epifaunal densities and species diversity indices were significantly different among seasons and sampling sites. Salinity was the most important factor in determining species composition and abundance in the epifaunal communities. The infaunal benthic communities in the same area consisted of the three dominant groups of annelids, crustaceans and molluscs. (Paphavasit and Setti, 1985).

Shokita *et al.* (1983) investigated the distribution of the macrofauna at Smare Kaow, Chanthaburi and Ranong Provinces during February to March, 1982. A total of 154 species of invertebrate macrofauna were found in both study sites : Coelenterata (2), Nemertini (1), Sipunculidae (1), Sipunculidae (1), Mollusca (60), Annellida (28), Arthropoda (57), Echinodermata (3), and Hemichordata (1) Mollusca and decapod crustaceans were the dominant group. Species diversity was lower in the mangrove biotope than in the mud flat biotope. The standing stock in the mangrove biotope was very high due to the abundant gastropod fauna. Species diversity of the mangrove fauna in Ranong was relatively high and similar to that reported for Phuket Island. Polychaeta were abundant in the Ranong mangrove area.

UNDP/UNESCO (1991) reported on the striking features of the Ranong intertidal fauna (a) the highly variable and localized association of species; (b) the low incidence of encrusting tree fauna (c) the predominance throughout the mangrove of burrowing crustaceans, mainly in the form of brachyuran crabs and mudlobsters.

The distribution and variable abundance of species reflects the variation in habitat through the mangrove particularly in respect to soil texture and tidal level. Tree felling and regeneration was responsible for much of the observed disturbance and variation in the fauna composition. In the absence of a consistent shore zonation, the distribution of fauna in the Ranong mangroves is most conveniently classified according to the main habitats available for animals to colonize, with their localized distribution therein reflecting heterogeneity at the micro-habitat level.

a) Mudflat zone

There is a narrow but very significant mudflat zone extending along Klong Ngao which is only uncovered at low tide. The fine, unconsolidated soil at this level is free of any plant cover and has a distinctive faunal community composed almost entirely of surface detritivores. The most conspicuous evidence of their presence are large vertical burrows which belong to the fiddler crab *Uca dussumieri spinata* and smaller, sloping burrows constructed by *Metaplax elegans*. Semi-aquatic organisms are also common, such as the mantis shrimp *Chorida macrophthalma* and mudskippers. The small gastropod *Assiminea* is very abundant, while other snails found here include the common mud snail *Cerithidea*.

The infauna is also abundant, and the detritus-feeding sipunculid *Phascolosoma lurco* occurs widely in this zone along with polychaetes (e.g. *Diopatra, Glycera* and *Nephtys* species). These animals are typical inhabitants of soft, immature mangrove substrates with strongly reducing conditions due to hydrogen sulphide.

b) Sand flat zone

There is a major change in soil texture in the middle reaches of Klong Ngao where marine rather than alluvial sediments characterize the substratum particularly along the seaward facing fringe of the estuary, but also upstream to Had Sai Khao village, there are extensive areas of low-lying muddy sand.

The sand flat zone below Study Site 1 supports a substantial marine fauna including animals not normally associated with mangroves, such as holothurians (*Hulothuria nigra*), the brachyuran crab, *Dotilla* and chitons. Pagurid crabs (*Clibanarius, Diogenes*) which feed by scavenging are also abundant. Within the estuary, the sand flats feature crabs which are adapted to scouring food from large sand particles, chiefly the sand fiddler crabs *Uca lactea annulipes* and *U. vocans vocans*. A small community of oysters (*Crassostrea* spp.) and the small black mussel, *Brachi odontes*, colonize any hard substrate scattered in the sand flats, including *Avicennia* pneumatophores.

c) River levee zone

A major topographical feature of the Ranong mangroves is the presence of a raised bank, or levee, along extensive parts of Klong Ngao. This rises sharply from the mud flat zone to form a nearly vertical bank of consolidated, highly structured soil significantly elevated above the average level of the mangrove forest behind it. The levee bank is riddled with crab burrows, mainly *Metaplax elegans*, *Uca forcipata*, *U. triangularis*, juvenile sesarmids, plus other common burrowers including the isopod *Annina* and the small mudlobster *Wolffogebia phuketensis*, which builds characteristic galleries in the soil.

d) Mangrove forest ground fauna

The forest ground fauna which consists principally of species adapted for burrowing, is significant throughout the Ranong mangrove with localized variation in species and abundance reflecting differences mainly in soil texture and water availability. The former tin mining areas, have a less diverse fauna, reflecting the lack of topographical development in these immature sediments (which have only accumulated since tin-mining ceased) and their strongly sulphitic reducing conditions which only certain groups of animals can tolerate.

These poorly consolidated sediments appear however, to be the habitat at Ranong with the greatest concentration of macrofauna per unit area but this is due mainly to the high density of *Cerithidea* snails on the soil surface. It is probable that the soil textural qualities of such areas change rapidly once mangrove vegetation becomes established and that burrowing crustaceans are an important element in the process which leads to the soil becoming suitable for more species to colonize.

Burrowing organisms are best represented in the reserve forest at Ranong as a consequence of the mature, well consolidated substratum in this area. There is a high biomass of sesarmid crabs e.g. *Episesarma versicolor*, *Chiromanthes onychophorum*, *Sesarma mederi* and burrowing lobsters of the groups *Upogebia*, *Wolfogebia*, *Callanassa* and *Thalassina*. The latter, through construction of its characteristically massive burrow mounds, has strongly influenced the topography of the Ranong mangrove forest, especially in the upstream regions of Klong Ngao. The burrowing mangrove sipunculid *Phascolosoma lurco* is present, but in much lower numbers than in equivalent mangrove areas in Malaysia (Berry, 1972). This is probably due to the relative dryness and hardness of the Ranong soil, as *Phascolosoma* feeds by siphoning mud from the soil surface and seems to require fairly wet conditions for this.

These soil and water conditions are more favourable for pulmonate snails and the species *Cassidula aurisfelis*, *C. aurisjudae* and *Ellobium aurisjudae* are fairly common. *Cassidula* was abundant both on the ground (1-6/m^2) and in the trees of the main forest zones (60-180 m transect points) in all study sites except the tin-mining area. Neritinid snails (*Dostia*, *Nerita*) were also widely distributed in the forest.

The high-level mangrove forest zone is divided up by many small creeks and gullies. Fiddle crabs and *Metaplax elegans* are the major members of the crab community; they replace sesarmids in the lower lying, wetter mud areas along creek banks and erosion areas within the forest. Densities of 10-15 crabs/m^2 were recorded in these habitats which are normal for other mangrove areas in Southeast Asia where crabs are known to be significant in the productivity of the system (Macintosh, 1984).

The small, red snail, *Assimincea* is very abundant in the same type of location, with densities commonly of 10-25 animals/m^2. In view of its small size (3-4 mm), fragile shell and high visibility on the soil surface, *Assiminea* is presumed to be an important item of food for many fishes grazing at high tide; and for mudskippers, birds and other predators at low tide. *Assiminea* is usually widespread and abundant in estuarine mangroves and must rank as an important consumer of the benthic microbial/detritus food source in the Ranong System.

e) Tree fauna

Gastropod snails dominate the mangrove tree fauna of Ranong. Bivalves are relatively scarce, except for the seaward zone of Klong Ngao estuary where there are clusters of the edible oyster *Crassostrea* low down on the trees, together with the mussel *Brachidontes*. The general absence of oysters within the main forest areas is probably due to the effects of high average shore level. Since the forest zone is fairly high in the tidal range, these animals which are filter feeders would be exposed to air and would not be able to feed for prolonged periods. Salinity is probably not a factor as mangrove species of *Crassostrea* are tolerant of salinities down to about 12 ppt (Macintosh, 1983). Salinity conditions in Klong Ngao range above 20 ppt at high tide, even in the upstream reaches in the wet season.

The most common tree-dwelling gastropod is the littorinid snail, *Littorinopsis scabra*. This climbs to considerable heights on the trees. Several other snails are common: *Dostia violacea*, *Cassidula* spp., *Nerita articulata*, *Thais tissoti*, *L. melanostoma*, but they are not particularly abundant. The average density of snails on the trees, estimated from the 5 m x 5 m plots in the study sites ranged from 2 to 4/m^2.

Most of the tree-dwelling snails also occurred widely in the study sites on the mangrove soil surface. *Dostia* and *Litterinopsis* were noted to be pests by herbivory on the foliage of young seedlings in the mangrove plantation areas.

Srisuchart (1981) described the benthic communities in the mangrove forests at Amphoe Khlung, Chantaburi Province. Thirty five species of macrofauna were recorded mainly crustaceans and polychaete annelids. Total organic content, tidal inundation and salinity were the three factors controlling the animal distribution.

Bunpavivhit (1979) has studied the taxonomy and distribution of fiddler crabs Thailand. The concluded that the distribution patterns of *Uca* crabs were directly related to the nature of sediment and soil salinities. Fiddler crabs of the subgenus *Deltuca* were common on landward mud flats receiving less amount of brackish water. Crabs of the subgenus *Thalassuca* were most abundant along the coastal sand-mud beaches. While crabs of the subgenus *Celuca* were widely distributed on the sand-mud substrate closed to the sea and away from the sea. Paphavasit *et al.* (1986) has studied physiological ecology of selected mangrove crabs. Four species of mangrove crabs, *Uca* (*Celuca*) *lactea annulipes*, *Uca* (*Deltuca*) *dussumieri spinata*, *Chiromanthes eumolpe* and *Metaplax dentipes* were commonly found in the mangrove forests at Ang Sila, Chon Buri Province. Their natural distributions at Muang-mai and Bang-Plong mangrove forests were studied in relation to environmental factors, and physiological tolerance limits to salinity, temperature, sulfide and sediment grain size were determined by bioassay experiments. The results demonstrated that these crabs have a high and wide range of tolerance as compared with prevailing environmental variations in their natural habitat. Sex is one of the major factors in determining the tolerance to environmental factors and preference to substrate texture is also clearly demonstrated.

A survey of crabs in mangroves and adjacent areas was carried out by Naiyanetr (1983). Seven families with 54 species were recorded. Majority of these mangrove crabs belong to the families Grapsidae and Ocypodidae. The common genera of Grapsidae are *Sesarma, Parasesarma, Chiromentos, Sarmatium* and *Metaplax*. The family Ocypodidae is mostly composed of genera *Macrophthalmus, Ilyoplax* and *Uca*. Few species were found to belong to the families Portunidae, Gecarcinidae, Paguridae, Coenobitidae and Xiphosuridae.

Mangrove molluscs in Thailand, both gastropods and pelecypods (bivalves), were studied by Isarankura (1976). Molluscs were observed to be either attached to stems, roots and leaves of the mangroves or living on mangrove soil (floor). There are 10 species of gastrapods and three species of bivalves living on trees and eight species of gastrapods and two species of bivalves living on mangrove soils. Two species of gastrapods. (*Cassidula aurisfelis* and *Onchidium* sp. were found at both habitats but only one species of bivalve (*Isognomon ephippium*) was observed.

Analysis of loss of mangroves due to various other kinds of land use

Mangrove forests in Thailand have been converted to other uses to satisfy various human demands since earlier times. Aquaculture, tin mining, salt pond, human resettlement and industrial sites have been established within the mangrove areas. During the past between the year 1961 to 1979, the total area of mangrove forests converted for these purposes was about 80,592 ha (Klankamsorn and Charupat, 1982). The rate of destruction of mangrove forest was quite high from 1975 to 1979 of approximately 6,348 ha/yr. as compared with 3,943 ha/yr. from 1961 to 1975.

Table 5. Losses of mangroves in Thailand from 1961 to 1989.

Coastal Region	No. of Province with mangrove forests	Area of mangrove (ha)	%
Andaman Coastline	6	142,173	79
Lower Gulf of Thailand	6	17,084	9
Central Thailand	2	596	0
Eastern Thailand	5	20,709	11
Total	19	180,559	100

The survey on the mangrove condition in Thailand which was conducted in 1986 revealed the total remaining mangrove forest of 1,964.29 km^2 or 196,427.84 ha. The rate of destruction from the year 1979 to 1986 was incredibly high of 12,981.92 ha/yr. The highest rate of mangrove destruction occurred in the southern part of Thailand and in the eastern part and the central part in respective degree. Forest clearance and land reclamation for aquaculture especially shrimp ponds, urban settlement and industrial sites have played vital roles in diminishing mangrove forests of Thailand.

The status of mangrove loss due to human activities in Thailand from 1961 to 1989 within the 28 years period, the total remaining mangrove forests was 180,559 ha. Only 19 provinces left with the mangrove forests. The mangrove forests in three provinces namely Samut Prakan, Samut Sakorn and Samut Songkram are totally denuded. The rate of depletion from the year 1961 to 1989 was 50.92 in percentage of approximately 6691 ha/yr.

From LANDSAT TM imageries analysis in 1991 revealed that the mangrove forests along the eastern coastline (Chanthaburi, Trad, Rayong, Chon Buri and Chacheongsao provinces) had declined from 20,708.8 ha in the year 1989 to 11,258 ha in 1991. The rate of depletion was 9450.8 ha within the two years period. The most astonishing statistics were the depletion of mangrove forests in Chanthaburi and Rayong provinces mainly due to shrimp ponds of 71.83 and 91.24 in percentage respectively.

In the 14 year period between 1975 and 1986 only 49,530 ha of mangrove forest was lost along the Andaman coastline. Thus in sbsolute terms the loss of mangrove forest has been lowest along the Andaman coastline, which presently accounts for about 80% of the mangrove forests of Thailand. Population growth, conversion to aquaculture and coastal development were the major reasons for mangrove loss in Thailand. Scale of mangrove loss due to various other kinds of landuse is summarized in Table 6.

Table 6. Scale of mangrove loss in Thailand due to various kinds of land`use based on the statistics of the year 1986.

Activity	Area (ha)	Percentage of landuse
Aquaculture	110,259	64
Tin mining	5,451	3
Salt ponds	10,560	6
Coastal developments	45,202	26
Total	171,472	100

In spite of the mangrove destruction, the two provinces in Thailand, Pattani and Surat Thani, were recorded with increasing mangrove area. From the period of 1975 - 1989, the mangrove forests of Pattani increased from 1100 ha to 1759 ha. with the rate of increase of 4.28 in percentage per year. It should be noted that Pattani is the province with the least area of mangrove forest in Thailand. Surat Thani has shown an increase of mangrove forest of 67 ha with the rate of increase of 0.13 in percentage per year.

Shoreline changes due to accretion and erosion

Due to expansion of several activities in the mangrove areas, especially aquaculture (shrimp and fish farms), agriculture, resettlement and industrial sites and mining (both in the mangrove and onshore areas), soil erosion in the coastal area, as well as marine coastal transgression have been reported to occur in a number of places, for example, in the mangrove fringe along the inner part of the Upper Gulf of Thailand (Samut Prakarn, Samut Sakorn and Samut Songkram provinces).

In the southern coast of Thailand, coastal erosion has been reported to occur in some localities along the coast of the Andaman Sea. Chunkoa *et al.* (1982) found that soil erosion or sediment yield of active tin mining from the representative area in Ranong Province was about 9,800 tons/km^2/year. They also estimated the sediment transport to the Gulf of Thailand from the central, eastern and southern parts of the country at about 267 tons/km^2/year. Soil erosion or sedimentation has affected the mangrove ecosystem, particularly the species composition, productivity and natural regeneration (Aksornkoae *et al.*, 1982; Havanond, 1985). has increased. Large amounts of sediment enter the sea via the mangrove forest.

Comprehensive coastal erosion and coastal deposition studies, with the use of remote sensing techniques, were done for the Upper and Lower Gulf coasts (NRCT, 1989). The results show that most of the shorelines investigated are eroding at alarming rates. For the Upper Gulf coast, such as the west of the Chao Phraya river, between 1969 to 1987 the maximum erosion was found to be 500 m, or about 28 m/year. Ban Bang Kaew and Ban Tanod Noi of Petchaburi in the Lower Gulf, the maximum erosion of 240 m was observed during 1954 to 1974, while the maximum erosion of 200 m was found at Hua Hin during the same period of time.

Erosion can also take place under natural conditions in the sense that it proceeds without the influence of human activities. Violent water circulation, which is generated by the interaction between river discharge and tidal influx, results in the erosion of the river banks at certain places, turging the river mouth into broad basin. However, experience in mangrove areas of the Chao Phraya delta points to the physical effects of a significant rise in sea-level on this shoreline (Somboon, 1990). The effect of sea-level rise dating back to the 18th century (1797-1856) had caused the shoreline to shift about 4 km to the south, at an average rate of about 70 m per year. Comparing the charts of 1856 and 1960, howevr, it apperas that in the past hundred years or so, the eastern shoreline has practically kept its place, while the western shore adjacent to the river mouth has grown in a southeastern direction over a distance of approximately half a kilometer, at an average rate of about 5 m per year. The projected sea-level rise for the Chao Phraya delta ha seen as one of the major factor which will lead to coastal erosion and redistribution of sediments, wetland submergence, floodplain water logging and salt intrusion into coastal aquifers (Somboon, 1990).

Socio-economic values and patterns of use

In Thailand where population and economic pressure on the coastal zone is very strong, mangrove forests have become one of the primary targets for development. For many decades, mangrove forests in Thailand have been traditionally used by the local people for a variety of uses. Woods from mangroves are utilized for firewood, charcoal-making, poles, construction materials, fishing gear, or tannin extraction. Some mangrove species are source of medicines. The local people also utilize the mangrove forests for capture and culture fisheries. Conversion of mangrove areas for shrimp farming is popularly practiced in Thailand; also, small areas are utilized as agricultural land and salt pans.

Forestry

Timber exploitation from mangrove forests in Thailand is not done on a commercial scale. Most of the timbers harvested are used for domestic house construction by the local people.

Charcoal

Wood from mangrove forest in Thailand is mainly harvested (90%) for charcoal production. Although it was originally used for daily cooking by the coastal villagers, in recent years it has developed also into a commercial product, even for export. Thus, unlike firewood extraction from a mangrove forest, charcoal-making usually is a traditionally legal industry under licence from the government. Various species of the Rhizophoraceae can be used for charcoal-making but *Rhizophora apiculata* and *R. mucronata* are the preferred species. The reason is that wood of these species is heavy, dense and hard with a high calorific value which, when burned, produces little smoke. Other species like *Bruguiera* spp. and *Ceriops* sp. are also used but the quality of their wood is low. The minimum diameter of stems for charcoal-making is about five centimeters. The average harvest of wood is approximately 783,780 m^3/year which produces about 387,800 m^3 of charcoal on the basis of 680 kg/m^3 computation (Phuritat, 1975). This volume of charcoal is produced from about 1,273 kilns located in or near the mangrove areas. The typical charcoal kiln is dome-shaped and is made of clay and brick with the capacity of about 50 to 200 cubic meters. The average wood production, number of charcoal kilns and charcoal production in different parts of the country are presented in Table 7. The annual production and value of wood and charcoal from the mangrove forests are presented in Table 8. About 60% of the total charcoal produced from mangrove wood is used for domestic consumption and the rest is exported to neighboring countries, particularly to Penang (Malaysia), Singapore and Hong Kong.

Poles and firewood

Poles are used mainly for foundation piling, ore rinsing troughs and fishing stakes. Some traditional fishing gear, especially the large and fixed structures, are constructed of mangrove trunks. Most prominent among them is the weir, which is essentially a large fish trap. To construct this large fish trap, a large stack of mangrove stems is required. The quantity of poles used for these purposes is minimal and no data are available. The common mangrove species used for poles are *Rhizophora apiculata*, R. *mucronata*, *Ceriops* sp., *Bruguiera* sp. and *Excoecaria agallocha*. E. *agallocha* seems to be more widely used for poles than the others.

Mangrove wood is still widely used as source of fuel by coastal villagers. It is used for cooking their daily meal. Firewood gathering is commonly

Table 7. Average wood production number of charcoal kilns and charcoal production in Thailand from 1978 to 1982 (Royal Forest Department, 1983)

Region	Wood production (m^3 yr^{-1})	No. of charcoal kilns	Capacity (m3/kiln)	Burning cycles per year	Charcoal production (m^3 yr^{-1})
Suratthani	198,806	249	50-200	5-10	95,258
Nakornsri-thammarat	382,905	540	100-180	6-7	191,507
Songkhla	181,886	451	120-170	4-5	90,943
Pattani	2,785	4	100	7	1,393
Sriracha	17,398	29	70-195	5-6	8,699
Total	783,780	1273	-	-	387,800

Table 8. Wood and charcoal production in Thailand from 1970-1984 (Royal Forest Department, 1986; FAO, 1986)

Year	Wood Production (m^3) (a)			Charcoal production		Value (d) (10^6 baht)
	Managed forest (RFD)	Private plantation	Total	m^3 (b)	tonne (c)	
1970	578,237	-	578,237	289,118	196,600	393
1971	620,713	-	620,713	310,356	211,042	422
1972	683,265	-	683,265	341,632	232,309	465
1973	708,229	-	708,229	354,114	240,797	482
1974	658,045	-	658,045	329,022	223,734	448
1975	685,570	54,000	739,570	369,785	251,453	503
1976	714,413	54,000	768,413	384,206	261,260	523
1977	759,914	54,000	813,914	406,957	276,730	554
1978	770,872	54,000	824,872	412,436	280,456	561
1979	810,535	54,000	864,535	432,267	293,941	588
1980	813,287	54,000	867,287	433,643	294,877	590
1981	752,395	54,000	806,395	403,197	274,173	548
1982	772,343	54,000	826,343	413,171	280,956	562
1983	782,147	54,000	836,147	418,073	284,289	569
1984	776,765	54,000	830,765	415,382	282,459	565

Notes: (a) Wood for charcoal production only.

(1) based on 50% of wood production (Kongsangchai 1982).

(2) based on 680kg m^{-3} of charcoal (Phuritat 1975).

(3) based on present value (2 baht per kg of charcoal) at production areas.

done by using axe. There is no estimate as to the volume of the mangrove firewood consumption in Thailand. Christensen (1982) estimated the average household firewood consumption in Thailand to be about 9 m^3/year. Fifty percent of it was for cooking and the rest for boiling shrimps and crabs. However, Aksornkoae *et al.* (1984) from their studies on the socio-economics of two villages of mangrove dwellers in Ranong, southern Thailand, reported that the average household consumption of mangrove firewood was about 2 m^3/year, equivalent to 1,500 sticks/year (assuming the size of stick to be about 40 cm long and 4-6 cm in diameter). Most firewood is used for cooking and the rest is burned to repel mosquito and other insects. The mangrove species commonly used for firewood belong to the genera *Avicennia, Xylocarpus, Excoecaria, Bruguiera* and *Lumnitzera* species. *Rhizophora* spp. are also used for this purpose but the quantity is only minimal because these species are otherwise preferred for charcoal production. In some areas, firewood from mangroves is offered for sale in the local market.

Construction materials

Living near the coast, fishermen build their house on raised platforms supported by piles. The traditional house in a mangrove community is entirely made of mangrove products. Wood of various mangrove species can be used for different parts of the house. The wood of *Rhizophora, Avicennia, Bruguiera* and *Xylocarpus* is commonly used for columns, bracing, wall beam and roof frames. Floors and platforms are made of the wood of *Rhizophora* and *Bruguiera* species, while the roof is of *Nypa* thatch. Aksornkoae *et al.* (1984) estimated the requirement of mangrove wood for the construction of a typical mangrove dweller's house in Ranong province to be about 9-20 cubic meters.

Wood distillation

The only distillation plant in Thailand, built a few years ago, is situated at Kapur, Ranong province, on the west coast of Thailand. Raw distillate from mangrove wood (*Rhizophora apiculata*) is collected from the vents of a charcoal kiln by condensation. This raw condensate is essentially pyroligneous acid. A more complicated process is required to fractionate it into acetic acid, methanol and wood tar. The percentages of acetic acid, methanol and wood tar that can be extracted from pyroligneous acid are 5.5, 3.4 and 6.5 percent, respectively. The operation is, however not economical since the extraction technique adopted is still inefficient one.

Tannin extraction

Tannin is one of the mangrove forest products and has a variety of uses, such as in the manufacture of ink, plastic and glue. This dye is extracted from the barks of mangrove trees. However, it uses have slowly diminished as better quality dyes have been produced artificially. Hence, utilization of mangrove tree barks for tannin is a rather rare practice in Thailand nowadays. Traditionally, tannin extracted from the barks of *Rhizophora* and *Ceriops* was used by fishermen for dyeing their fishing nets. The use of tannin for this purpose has almost ceased since nylon nets are mainly used for fishing equipment now.

Medicines

Another traditional use of the mangrove is for medicine. Various parts of certain species of mangrove contain active substances that have the property of curing various ailments. For example the bark of *Xylocarpus* spp. may cure diarrhea and cough, the leaves of *Excoecaria agallocha* may cure epilepsy, the leaf juice of *Acanthus* spp. may relieve rheumatism. However, these traditional medicinal practices have not been supported by scientific investigations and experiments. Aksornkoae *et al.* (1984) interviewed mangrove dwellers in Ranong province and found that three mangrove species are being used for medicinal purposes. These are *Acanthus* spp., *Bruguiera parviflora* and *Avicennia alba*. *Acanthus* is used to treat kidney stones, and *Bruguiera* is used to relieve constipation and the heartwood of *Avicennia alba* is used to treat thrush in children.

Other products

Various types of fishing gear are used by mangrove dwellers, and some of the equipment is constructed of mangrove wood. Most of the mangrove poles from *Rhizophora* spp. are used for crab traps. The most common crab caught in the mangrove is *Scylla serrata*. The drift gill-nets and the winged set-bag are other types of fishing gear that are made of mangrove posts, and common species used are *Rhizophora apiculata* and *Bruguiera* spp. The total volume of wood used for fishing gear has never been estimated.

The mangrove palm, *Nypa fruticans*, is also a valuable species. The main use of the leaves is for thatch materials. Young and unopened nipa leaves are also used as cigarette wrappers. The extraction of alcohol from nipa sap has not been carried out in Thailand.

Capture fisheries

The mangrove waters are usually rich in detritus and suitable as a potential area for fishing. The major fishery sources in these waters are detritivorous species of fish, crabs, crustaceans, and molluscs.

In Thailand, capture fisheries are spread throughout the marine, estuarine areas and coastal waters. On the average, more than 1.8 million tons of marine fish were landed annually between 1978-1982, of which almost 130,000 tons were shrimps (Table 9). Many of the shrimps from the capture fisheries in the country are mangrove-dependent species (e.g. *Penaeus nierguiensis*, P. *monodon*, and *Metapenaeus* spp.).

Mangroves also support the artisanal fisheries. The people who live in or near the mangrove forests catch fish, shrimp, crabs and molluscs daily around the estuarine areas where mangrove exists. Unfortunately, there are no data available on the quantity of the catch so far. The most important species in the fish catch are mullet (*Mugil dussumieri*), sea bass (*Lates calcarifer*), tilapia (*Tilapia mossambica*), snake eel (*Ophichthyus microcephalus*), catfish eel (*Plotosus canius*), and milk fish (*Chanos chanos*); the most common species of shrimp are *Penaeus merguiensis*, P. *monodon* and *Metapenaeus* spp.; crabs are represented by only one species, *Scylla serrata*, while the important species of molluscs are *Nerita* sp., *Anadara* sp. and *Crassostrea commercialis*.

The major traps used for mangrove fishing are push nets, barrier nets, crab net traps, gill nets, winged set-bag-nets, hooks and long-lines, stake nets, cast nets, and hand picking.

Table 9. Marine fisheries catch in Thailand 1978-1982 (Department of Fisheries 1983)

Year	Total catch ($t\ yr^{-1}$)	Shrimp catch ($t\ yr^{-1}$)
1978	1,957,785	127,404
1979	1,813,158	116,456
1980	1,647,958	118,341
1981	1,824,444	133,435
1982	1,986,571	166,614
Average	1,845,983	132,614

Table 10. Shrimp culture production in Thailand 1976-1982 (Department of Fisheries 1983).

Year	Area (rai)	No. of shrimp farms	Production (tonnes)	Yield ($kg\ rai^{-1}$)
1976	76,850	1,536	1,533	32.96
1977	77,567	1,438	1,590	20.49
1978	151,055	3,045	6,395	42.33
1979	154,222	3,378	7,064	45.80
1980	162,727	3,572	8,063	49.55
1981	171,619	3,657	10,728	62.51
1982	192,453	3,943	10,090	52.43

Note: 1 ha = 6.25 rai

Aquaculture

Most of the aquaculture located in mangrove areas are shrimp farms. The shrimp farms are mainly found in Samut Sakorn, Samut Songkram, Samut Prakan, Surat Thani and Nakhon Si Thammarat provinces. Most of these farms have been built during the last fifteen years. There was a boom in shrimp farming in 1978 due to the introduction of new economic zones in neighboring countries which has adversely affected capture fisheries.

The 10,090 tons of shrimp produced in 1982 came from 3,943 farms, occupying a total area of about 192,453 rai (Table 10). It is estimated that some 144,750 rai of the total of mangrove area in Thailand are suitable for shrimp aquaculture (Brohamanonda, 1985), so there is a large potential for expansion. The present average production is about 52 kg/rai. Some farms operate on a subsistence basis, which are only productive for the first three or four years and are then abandoned. This inefficient and wasteful practice results in the degradation of large areas of mangroves and it may adversely affect the yield of the coastal shrimp capture fisheries. In recent years, however, there has been a significant improvement in the average yield achieved by such aquaculture operations. This is due to better management and widespread introduction of pumping system. However, to conserve mangroves, intensive and semi-intensive culture should be emphasized to maximize more yield and benefit, rather than extensive culture or extended farm areas, which produce low yields and fewer benefits.

Molluscs have also been cultivated on the mudflats around mangrove areas for many years. Even though molluscs are not raised in the mangrove areas themselves, mangroves are still very important as a source of dissolved and suspended nutrients for the growth and productivity of molluscs. The total area of mollusc culture is quite limited, as in Rayong, Chantaburi, Chumporn, Phang-nga, Krabi and Satun provinces. Table 11 shows the area devoted to the culture and production of the major varieties of molluscs from 1987 through 1982. Production is subject to wide annual fluctuation, but in general it declined in this period. The Department of Fisheries now plans to extend production to other suitable mudflat areas near mangrove forests.

The important species of mollusc culture in Thailand include horse mussel (*Modiota senhausenii*), green mussel (*Perna veridis*), blood cockle (*Anadara granosa*) and oyster (*Crassostrea commercialis*).

Agriculture

Mangrove soils can be considered a marginal resource for sustained development of agriculture, particularly rice cultivation. In Thailand, major crops usually cultivated on reclaimed mangrove-lands are coconut, oil palm, and rice. However, the conversion of mangrove forest to paddy field is quite limited. In the southern part of Thailand, some mangrove areas have been

Table 11. Mollusc culture production in Thailand, 1978-1982 (Department of Fisheries, 1983)

Year	Horse mussel		Green mussel		Blood cockle		Oyster	
	Area (rai)	Production ($t\ yr^{-1}$)	Area (rai)	Production ($t\ yr^{-1}$)	Area (rai)	Production ($t\ yr^{-1}$)	Area (rai)	Production ($t\ yr^{-1}$)
1978	911	9,563	6,376	30,280	5,053	15,769	4,416	14,385
1979	600	8,351	6,162	25,283	6,846	18,611	4,449	9,301
1980	564	3,429	5,081	6,917	7,842	13,566	5,299	5,339
1981	326	4,388	2,768	18,320	6,172	22,710	5,894	7,728
1982	326	538	2,455	23,009	7,006	5,542	6,331	3,617

Note: 1 ha = 6.25 rai

planted with oil palm and coconut. However, in terms of yield per ha. per annum, reclaimed mangrove lands are usually much inferior to that of non-mangrove soils. No estimate of the total area of mangroves converted to agricultural land is available.

Residential and industrial development

The destruction of mangrove forest due to urbanization and industrial expansion is one of the major problem in developing countries, and Thailand is no exception. By virtue of its strategic location and its reputation of being waste-land, mangrove is naturally the easiest target for satisfying the shortage of relatively cheap lands for industrial sites, ports, etc. Once such development centers are completed, migration of a large rural population follows immediately, resulting in acute shortage of houses and other urban amenities. These, in turn, create an additional pressure on the adjacent mangrove areas. In Thailand, urbanization and industrial expansion have placed tremendous stress on the mangrove forests in the Inner Gulf of Thailand, i.e. in Samut Prakarn, Samut Songkram, Samut Sakorn, Chacheongsao and Cholburi provinces. Road construction and land modification are maximal and the on-site mangroves are totally reclaimed. These types of development have not only eliminated the mangroves directly affected, but more importantly also degrade the quality of the remaining mangroves and other coastal habitats adjacent to the developed area through a variety of ways.

Port and harbour are constructed in mangrove areas along the coastline. Various parts of mangrove areas in the country will be reclaimed for these purposes in the near future.

Resort development

Utilization of mangrove areas in terms of resort development is not a common practice in Thailand. The only mangrove forest that has been used for such purpose is that at the Phang-nga Bay mangrove forest where a resort hotel was constructed and has been operated by the local authorities. Since then, the government through its related agencies has tried to issue and improve rules, regulations and controlling measures for special use of mangrove forest as well as to facilitate the supervision and control of the use of mangrove forest, and no other mangrove forests will ever be allowed to be developed as the resort area again.

Ecological and environmental values

Mangrove forests serve as a link between marine and terrestrial ecosystems. These communities are clearly important to the stability and maintenance of various adjoining ecosystems e.g. seagrass beds, coral reefs, and marine. Mangroves represent a unique habitat for a diverse variety of marine and terrestrial animals. The amount of organic matter produced by mangrove communities will support not only the mangrove ecosystem itself but also other related ecosystems. Moreover, mangroves also play an important role in stabilizing shorelines in coastal streams and estuaries by protecting them against tidal bores, and soil erosion.

It is believed that if the mangrove communities along the banks of estuaries and coastlines are disturbed, or were to be completely cut, there would be no habitats or adequate food to support the organisms in these areas. Consequently, the loss of these mangrove-related ecosystems would disturb the natural ecological systems over a considerable area. Thus mangrove forests are important in maintaining natural ecological balance.

Coastal protection

Mangrove forests play a vital role in coastal stability against erosion and storms. Their tangled root system is important in land building because they trap sediment and the mangroves are extended. The physical and chemical studies conducted in Klong Ngao, Ranong mangrove forest showed that the Ranong mangroves serve two key functions in the coastal ecosystem (a) the mangroves trap fine sediments carried into the coastal zone by flood waters and (b) there is a significant net export of nutrients from the mangroves into the coastal zone, which acts as a source of enrichment for the marine environment. It was demonstrated that the bulk of fine sediments washed into the Klong Ngao mangroves by local floods, settled rapidly and were trapped by the mangrove vegetation. Only about 12 hours was required for sediment-laden water in the estuary to become clear. In high rainfall areas with significant sediment displacement such as in Ranong, mangroves act as natural sedimentation tanks, protecting other coastal environments from the harmful consequences of sediment discharge. In areas suffering from inland deforestation and soil erosion, this role of the mangroves becomes even more vital.

Feeding and nursery grounds for fisheries

Mangrove waterways are of immense and traditional importance for fisheries. They provide food and shelter for many species and particularly serve as nursery areas for juvenile fish and shrimps.

Several studies of mangrove-associated fish populations in Thailand provide evidence that Thai mangrove forests are used by fish as a) nursery grounds; b) as permanent habitats or c) as breeding grounds in the case of some coastal species. Vatanachai (1979) reported that the species composition and abundance of fish eggs and larvae in the Laem Pak Biak mangroves (Petchaburi) were dependent on the nutrient supply in the area. More than 30 families of fish that include species of economic importance such as *Lates calcarifer* and *Chanos chanos* were recorded from the area. Larval fish of several species of economical importance: tarpon (*Megalops cyprinoides, M. atlantica*) lady fish (*Elops hawaiensis, E. saurus*), groupers (*Epinephelus tauvina*) and snappers (*Lutianus johni*) were recorded from the mangrove forest in Klong Wan, Prachuab Khiri Khan Province (Sontirat, 1982). On the Andaman coastline, Janekarn and Boonruang (1986) have carried out a fish larval survey in mangrove areas of Phang Nga Bay. Fourty four families of fish larvae were present, gobiids being the most abundant, accounting for 64% of all specimens; engraulid and clupeid larvae were also relatively common. Janekarn and Sawangarreruk (1987) reported on the fish larvae collected along the west coast of Thailand (Andaman Sea) from Phuket to Satun province. More than 60 families were recorded, the major ones being Carangidae, Gobiidae, Clupeidae, Monacanthidae and Callionymidae.

Paphavasit *et al.* (1991) reported that fish larval diversity in the Ranong mangrove forest was as high as those described from other mangrove forests along the coast of Thailand. It is believed that the early life stages of fish require access to rich food sources to support their high rate of metabolism and growth. They also require shelter from predators. The mangroves bordering the many creeks and waterways adjoining Klong Ngao seem to offer an ideal habitat for these purposes. The export of organic matter during the wet season and the high abundance of planktonic larvae released by the mangrove intertidal fauna are the important food sources for these young fish stages. Another important feature of the Ranong mangroves is that the entire forest is flooded by the highest tides each month. This means that ichthyofauna has complete access to the intertidal mangrove zone at these times, a situation which must increase opportunities for feeding and allow wide dispersal of young fishes through the mangrove ecosystem.

The importance of mangrove forests for artisanal fisheries is widely recognized. Mud crabs, *Scylla serrata*, are one of the most important fishery resources harvested commercially from the mangrove forests of Thailand. During the years 1977 - 1984, the production of mud crabs in Thailand was estimated 119 million baht, and a large amount of mud crabs were caught at on the average of 4,525 tons each year. (Marine Fisheries Statistics, 1986). The total catches of *Scylla serrata* at Bangla mangrove area, Phuket province, approximately 600 hectares, in 1986 were 2,675 kg as revealed by Poovachiranon (1987). The production was about 5 kg per hectare. In Satun province, Onkong *et al.* (1987) surveyed on the annual mud crab production amounted to 454 tons. The total of mud crab *Scylla serrata* at Ranong mangrove forest (UNDP/UNESCO, 1991) was estimated to 109 tons annually. This crab fishery supports seventy full time crab fishermen from four fishing villages. It should be noted of the 109 tons harvested, 50 tons of crabs smaller than 10 cm are estimated to be harvested from Ranong mangroves, valued at 500,000 Baht, plus 45.8 tons crabs larger than 10 cm, valued at 1.38 million Baht and 13 tons of berried females, valued at 650,000 Baht. The total income shared between 70 fishermen from the four villages amounts to approximately 2.53 million Baht. Not only the 70 families of these fisherman but also another 10 crab dealers are solely dependent on this fishery for their livelihood. The direct yearly monetary benefit from the Ranong mangroves, in terms of the crab fishery, is about 2.53 million Baht.

Foraging and stop-over sites for migratory birds

Mangrove forests also serve as the feeding and nursery grounds for several birds. Survey of vertebrates except fishes was carried out by Sittilert *et al.* (1976) revealed 7 species of mammals, 42 species of birds, 2 species of reptile and one amphibian. These animals were found to live at the edge of the mangrove and to enter it to feed on mangrove animals. Four species of migrating birds moved in during different seasons of the year. Nateetapat (1982) in his ecological studies of birds in Songkhla Lake, Southern Thailand revealed that there were 25 families with 90 species of birds in the area. Of these, 70% and 20% were respectively residents and seasonal migrants. Most birds observed in the area usually feed on open grazed land. Birds of the families Bucerotidae, Picidae and Pittidae often found in the natural mangrove forest, were absent from the exploited mangrove forest. Bhovichitra *et al.* (1982) reported 42 bird species from Ranong mangroves.

Primary and secondary productivity

Information on the productivity of both plants and animals in Thailand mangroves is very limited. The only information available so far on the productivity of the forest are mainly derived from the plantation of *Rhizophora apiculata*. Aksornkoae (1975) studied the plantation of *Rhizophora apiculata* in Chantaburi Province, southeastern Thailand, with spacing of 1 x 1 m and found that the mean annual increment (MAI) of 14 year old stands was approximately 15.7 m^3/ha/yr with dry weight of stem estimated at 9.7 mt/ha/year. Christensen (1978) reported an above-ground figure of 159 mt/ha in a 15-year old stand of *Rhizophora apiculata* dominated mangrove or an increment of about 10.6 mt/ha/yr. Figures on the productivity of trees in natural mangroves in Thailand are scarce. Aksornkoae *et al.* (1988), using the light attenuation method to estimate net primary productivity, found values for net productivity ranging from 4 to 25 kg $C.ha^{-1}$ day^{-1} in mangrove forests at Krabi, Satun and Samut Songkram in Thailand. Net primary productivity recorded in the Ranong mangrove forest ranged from 1 - 25 kg $C.ha^{-1}$ day^{-1}.

On the productivity of litter fall in mangrove ecosystem in Thailand, Aksornkoae and Khemnark (1980) reported a mean litter fall in the mangrove forest at Chantaburi of about 9.3 t/ha/year. In his study, Christensen (1978) obtained a value of 6.7 t/ha/yr of litter fall in a 15-year old *Rhizophora apiculata* forest in Phuket. UNDP/UNESCO (1991) reported the productivity of litter fall in Ranong mangrove forest.

Litter fall was highly variable both within and between study sites. There was no consistent trend in litter fall with distance in any of the study sites. For Study Site 1, the lowest litter fall (588 g dry $wt.m^{-2}.yr^{-1}$) was found at the seaward forest margin, which is dominated by smaller trees of *Rhizophora apiculata*. This area is prone to strong winds, and it is possible that the litter traps did not collect a representative sample. Further inland, at a distance of 100 - 160 m, the forest is dominated by large (>30 m high) trees of *R. apiculata*. This area had an annual litter fall of 623 to 1,088 g dry $wt.m^{-2}$. The presence of deciduous trees like *Xylocarpus* spp. or *Excoecaria* sp. may have contributed to the high annual litter fall at 80 m (1,665 g dry $wit.m^{-2}$) (see Fig.). Average annual litter fall for Study Site 1 was 890 g dry $wt.m^{-2}$, of which leaves accounted for 80%, fruit 6.5% flowers 7.2% and branches 6.3%.

For Study Site 2, total annual litter fall ranged from 365 g dry $wt.m^{-2}$, at 40 m from the seaward margin, to 950 g dry $wt.m^{-2}$ at a distance of 160 m, where the deciduous species *Xylocarpus moluccensis* is conspicuous. The overall average for

Study Site 2 was 742 g dry wt.m^{-2}, of which leaves accounted for 91%, fruit 1.2%, flowers 3%, and branches 4.8%. The somewhat lower total litter production in this transect compared to Study Site 1 could be associated with the dominance of *Bruguiera cylindrica* and *B. parviflora* in this transect.

Total annual litter fall for Study Site 4 ranged from 411 g dry wt.m^{-2} at a distance of 100 m from the seaward margin, to 1,145 g dry wt.m^{-2} at a distance of 160 m. The overall average for Study Site 4 was 720 g dry wt.m^{-2}, of which leaves accounted for 90%, fruit 0.8%, flowers 4.9% and branches 4.3%.

For Study Site 5, total annual litter fall ranged from 660 g dry wt.m^{-2} at a distance of 160 - 180 m from the seaward margin, to 1,224 g dry wit.m^{-2} at the seaward margin. The overall average for Study Site 5 was 937 g dry wit.m^{-2}, of which leaves accounted for 87.6%, fruit 3.1%, flowers 3.5% and branches 5.8%.

Productivity studies of mangrove aquatic fauna in Thailand are quite limited and the emphasis is on biomass. The biomass of benthic animals may be a good indicator of the degree of biological productivity of the area. Paphavasit and Setti (1982) studied the benthic fauna of three estuaries at Phang-nga Province and found that the average biomass was about 381 g wet-wt/m^2 and *Holuothuria atra* formed the highest component. Nateewatana and Tantichodock (1980) compared the biomass of macrofauna from different habitats of mangrove forest in Ko Yao Yai, southern Thailand. Benthic macrofauna in mangrove had a biomass of 3 to 10 g dry wt/m^2; the mudflat had 10 g dry wt/m^2 while sandflats and grassbeds had 5.3 and 3.6 g dry wt/m^2, respectively.

The mangrove fauna of Ranong shows a standing biomass per unit area comparable to other mangrove sites studied which are considered productive. Tree fauna (mainly gastropod snails) occur at densities of 2 - 4 g/m^2, and burrowing crustaceans (crabs and mudlobsters) up to 55 g/m^2 has been shown to indicate a significant physical and biological role by the macrofauna in structural development of the mangrove habitat and in energy flow and nutrient cycling.

Management and conservation

Forest policy and legislation

Following the record of forest existing in Thailand by the Royal Forest Department it shows that during 1976-1989 the reserved forest of the whole kingdom (513, 511 sq.km.) was only 143,417 km^2 or 27.95%, in which mangrove forest is also included. According to the National Forestry Policy, forty percent of the country area shall be kept under forest. The forest area shall be divided into 15% of "Protected Forest" and 25% of "Production Forest". Therefore, a campaign for reforestation has been urged and implementing programmes have been undertaken by the government agencies directly concerned with financial support to achieve the ultimate goal.

In the past, mangrove and its products were long recognized by local people for good quality of charcoal-making, firewood and housing construction. According to population growth and economic pressure mangrove forest in Thailand has been converted to other uses to satisfy human needs. Aquaculture, tin mining, salt pans, human settlements and industrial sites have been established within mangrove areas. Without a proper controlling measure these activities led to degradation of other environmental surroundings. Realizing the importance and usefulness of mangroves, which are distributed along 2,500 kilometers of coastline, the government through its responding agencies had created different measures to cease invasion of mangrove forests. So far a recovering remedy and development for sustainable yield have been established. It was found that in 1975 the total mangrove area was about 3,127 km^2 (NRCT and RFD, 1982) and in 1991 only 1736.08 km^2 was left (IDRC/NCT/RFD, 1991). Therefore, in view of mangrove conservation, the Seventh National Economic and Social Plan (1992-1996) is aiming at maintaining this remaining area of 1,736.08 km^2 in good condition. Moreover, an increase of 400 km^2 of mangrove area is the target during the given period of time.

However, a plan to campaign the public and private sectors for a better understanding of mangrove ecosystem and its roles is being carried out. People have been convinced to participate in conservation programmes of the Office of National Environment Board.

Roles of forestry agencies

With the supports of laws, regulations and cabinet resolutions, the Royal Forest Department is directly responsible for taking over all kinds of forests and facilitating field operation at all levels. As the cabinet adopted a resolution on 4 June 1991 concerning the immediate controlling measure for utilization of coastal resources, mangrove and coral reef - additional mangrove controlling measures were set up. Protection, reafforestation and conservation plans were improved by expanding and increasing numbers of the mangroves management units (34 to 36 units) in provinces where mangroves are existing. More manpower are provided to run mangrove development programmes. To promote reafforestation plan, in 1992 the Royal Forest Department establishes "Mangrove Seed and Seedling Production Centers" one in the Eastern Province - Trad and the other 3 centers in Southern Provinces - Phang-nga, Nakorn Si Thammarat and Satun.

As it appeared that during 1975 to 1979 the rate of destruction of mangrove forest for various forms of uses is about 253.92 sq.km./yr with a high average annual depletion rate of 8.12% (IDRC/NRCT/RFD, 1991). And it was believed that the Royal Forest Department alone does not have the capacity to handle mangrove forest all over the country but those government agencies concerned should share responsibilities on conserving, reclaiming and campaigning for a better environmental development of mangrove forest. Accordingly, the cabinet adopted the resolution on January 5, 1977 to establish the National Committee on Mangrove Resources (NATMANCOM) with a number of membership representing 19 concerned institutions, the committee was given the tasks to:

1. Coordinate with the National Committee on Marine Science on matters pertaining to mangrove resources;
2. Advise the office of the National Research Council of Thailand (NRCT) on allocation of mangrove research project;
3. Give advice on the planning and implementation of technical projects and determination of existing problems on mangrove resources;
4. Determine the problems in relation to mangrove conservation; and
5. Coordinate with national and international concerned institutions.

So far the National Committee on Mangrove Resources has received very good cooperation from committee members and from concerned institutions. This cooperation enabled the committee to work in accordance with government policy and accomplish notable undertakings concerning management, utilization, conservation and research activities on mangrove ecosystems.

Regarding the adoption of cabinet resolution on 27 June 1978 - another main function given to the committee is to consider possibilities in terms of technical views and environmental conservation for utilization and development activities in mangrove forest. The committee also had been given a chance to propose the cabinet the concept of having mangrove land-use zonation all over the country. Its advantages and disadvantages were thoroughly discussed. Finally the cabinet agreed at its meeting on 15 December 1987 to accept mangrove land-use zonation with financial allocation.

A strong effort has been made to incorporate with national and international institutions for cooperative research on mangrove ecology or other disciplines related. Young scientists and technical officers were invited to join with the projects so that they could bring back with them knowledge and new technology for improving their existing responsibilities/works. However, to exchange ideas and view points on management, conservation and development, the committee in cooperation with the Royal Forestry Department, Fisheries Department, the Office of the National Environment Board and universities had organized the national seminars on mangrove ecology in various provinces along the coastline at every two year intervals. So far 7 national seminars were held and more than 250 participants from government agencies and private sectors attended at a time.

Another government agency who plays an important role on mangrove conservation and development is the Office of the National Environment Board (ONEB). This office works side by side with NATMANCOM/NRCT. Actually, ONEB has a direct responsibility for examining quality of environment directly or indirectly affected by development activities along the coastal zone including mangrove areas. ONEB has also joined with RFD, Fisheries Department, Royal Thai Navy and Provincial Administration to create mangrove conservation campaigning programme approved by the cabinet with financial support. Besides, mangrove ecology was introduced in the curriculum of primary, elementary and pre-university school levels and universities.

Furthermore, the government agencies which have their regional offices in the local provinces along the coastal zone, for instances Land Development Department, Fisheries Department and Office of Policy and Planning, Ministry of Interior have been represented by their delegates in Provincial Mangrove Committee in order to operate conservation and management of mangrove forest at local level as plan given and solve problems arisen from the process of utilization and development of mangrove resources.

Forest management

In Thailand, the management of mangrove forest is based on the following important principles:

1. To manage mangrove as a renewable resource on a sustainable use basis for direct and indirect products.
2. To manage mangrove in case for direct products being an important and potentially sustainable source of wood and charcoal to meet the increasing needs for domestic use and export.
3. To manage mangroves in case for indirect products being an importance of primary food source for aquatic organisms in estuaries, providing habitats for various important fishery species, spawning grounds and nurseries for marine animal and coastal soil erosion protection.
4. To manage mangroves as an integral part of the coastal zone ecosystem rather than as an ecosystem surviving in isolation. Therefore, management of mangroves will be made on the basis of sustainable use and ecological balance of coastal resources.

In order to achieve the ultimate goals of mangrove management, on 15 December 1987, the cabinet approved a guideline of mangrove land use zones designated by the National Committee on Mangrove Resources (NATMANCOM). According to these guidelines, mangrove land is divided into the following zones:

1. **Preservation Zone**: Protected areas for nature conservation and/or environmental conservation. Such areas include:
   - areas for the preservation of economically important flora and fauna
   - areas of value for reproduction of flora and faunal breeding areas
   - areas subject to soil erosion and land degradation, such as beaches and sand bars, mud flats, islets, caves and coral reefs.
   - areas of historical or archaeological value.
   - areas that represent a local symbol
   - national parks and wildlife sanctuary
   - areas for wind protection
   - areas for environmental and ecosystem preservation
   - all areas within 2 m of the natural riverside and with 75 m of the coastline.
2. **Economic Zone A**: Areas that are allowable for utilization for forest resources and are to be managed for sustainable long-term yield. These include:
   - concession forest
   - public forest other than concession forest for local uses
   - state and public forest plantations
3. **Economic Zone B**: Mangrove areas in which other development is allowable after careful consideration of the impact on the environment. These include areas converted for:
   - agriculture, including crops, animal farming, fisheries and salt production
   - industry, including mining, industrial development, urban and residential developments, seaboard development, and other industrial and commercial activities.

The management of mangrove forests (Economic zone A) is divided into 2 main areas; managed mangrove forest and managed mangrove plantation.

Table 12. Areas of mangrove land use zones by province in Thailand.

Province	Preservation Zone (rai)	Economic Zone A (rai)	Economic Zone B (rai)	Total (rai)
Trad	7,706	56,600	26,352	90,663
Chantaburi	8,350	119,425	48,406	176,181
Rayong	2,806	12,744	12,100	27,650
Cholburi	481	-	23,425	23,906
Chacherngsao	494	-	23,888	24,381
Samutprakarn	4,719	2,519	71,619	78,856
Bangkok	969	-	10,956	11,925
Nakornpathom	25	-	550	575
Samutsakhon	6,913	681	168,925	176,519
Samutsongkhram	5,319	819	62,200	68,338
Phetchaburi	5,313	1,889	68,100	74,301
Prachuapkhirikhan	1,163	169	6,794	8,125
Chumporn	5,719	36,350	24,381	66,450
Suratthani	9,594	8,763	55,413	73,769
Nakhonsrithammarat	13,781	60,531	60,794	135,106
Phatthalung	988	275	14,556	15,819
Songkhla	4,775	550	32,669	37,994
Pattani	3,806	13,606	6,256	23,669
Ranong	27,150	138,200	3,613	168,963
Phangnga	68,025	195,081	11,763	224,869
Phuket	2,756	14,556	-	17,313
Krabi	32,275	205,563	11,650	249,488
Trang	26,425	191,538	31,369	249,331
Satun	27,188	188,200	28,225	253,613
Total	266,737	1248,056	813,006	2,327,800

Note: 1 ha = 6.25 rai

The areal extent and distribution of each of these zones is presented in Table 12.

Managed mangrove forest

At present 1,186,563 rai (189,850 ha) of mangrove forest is managed by the Royal Forest Department. The major use of mangrove woods is for fuel and charcoal production, the latter consuming approximately 90% of the total wood production. The 5 Regional Forest Offices will be responsible for the management of mangrove forests of the countries 36 Mangrove Management Units, each unit beingl fully responsible for managing, controlling and in technical assistance to the concessionaires in logging, planting and maintaining, for forest protection and improvement and also for research activities. The administration of mangrove forests in Thailand is shown in Table 13. The direct utilization or logging operation of mangrove forests will be carried out by the concessionaires under the terms and conditions of the mangrove forest concession.

Terms and conditions of the mangrove forest concession

The terms and conditions of the mangrove forest concession currently in effect was established by the Royal Forest Act B.E. 2484 (1941) allowing the Ministry of Agriculture and Cooperatives with the approval of the government to serve as the "concessioner". The significant details and conditions are as follows:

Section 1: The concessioner shall permit the concessionaire to operate mangrove forest for a definite period of time.

Table 13. Administration of mangrove forests in Thailand (Royal Forest Department, 1980; Aksornkoae *et al.*, 1980).

Region	Working plan area		Management units			Felling series		
			No.	Average area		No.	Average area	
	(ha)	(rai)		(ha)	(rai)		(ha)	(rai)
Suratthani	30,873	192,959	4	7,718	48,239	31	996	6,224
Nakhonsithammarat	78,069	487,932	20	3,903	243,97	188	415	2,595
Songkhla	63,335	395,841	9	7,037	439,82	81	782	4,887
Pattani	752	4,700		752	4,700	1	752	4,700
Sriracha	16,821	105,131	2	8,411	52,565	9	1,869	11,681
Total (average)	189,850	1,186,563	36			310		

Note: 1 ha = 6.25 rai

Section 2: The concessionaire shall operate the mangrove forest within the given area specified by a map with clear extent and boundary.

Section 3: The concessioner shall divide the concessioned forest area in Section 2 into coupe (cutting area) and set the successive order of operation, coupe by coupe. The operation period for each coupe shall not exceed one year.

Upon the termination of the operation period of each coupe according to the above clause the concessionaire must immediately cease operation on the coupe. The concessioner is empowered to sell the remaining timber as deemed appropriate without paying any compensation to the concessionaire.

If the concessionaire requests for an extension and the concessioner considers it allowable, the latter is authorized to grant permission in writing as appropriate, but not exceeding the requested period.

Section 4: The concessionaire must harvest the mangrove forest according to following conditions and method:

1. The timber in each annual coupe must be clearly felled in alternate strips. The strip is 40 m wide forming 45 angle to the tide. The authorized Royal Forest Department officer shall set and mark the boundary before the concessionaire starts operation in each coupe.

   The concessionaire is not permitted to cut the trees outside the coupe boundary.

2. Trees of all kinds and sizes in the strip must be cut, replanting and maintenance work must be done as required by the Royal Forest Department.

The unused or undesirable timber and wood pieces must be brought out of the cutting strip or cut into small pieces that they would not obstruct the replanting and maintenance.

Section 5: The concessionaire must follow the conditions below:

1. Complete the operation in each coupe (Section 3) within the given period.

2. Cut trees to the lowest stump and shear the wood for maximum utilization as advised by the official operation supervisor from the Royal Forest Department.

3. The utilization or machinery or tools for cutting, felling, shearing, transporting or others must not endanger or damage forest.

   If the concessionaire fails to meet the regulations, the concessionaire must be fined as follows:

   a) For condition (1) the fine rate shall be 100 baht/m^3 maximum calculated from the termination of the operation period of each strip.

   b) For condition (2) the fine rate shall be 100 baht/m^3 maximum calculated from the volume of the timber felled not according to (2).

   c) For condition (3) the fine rate shall be 500 baht/m^3 maximum calculated from the volume of the endangered or damaged forest.

Section 6: The concessionaire must submit to the local forester (Chief of the Mangrove Management Unit) a monthly report on felling and logging, number of trees, timber, and volume of wood, charcoal or bark by using the form issued by the concessioner.

Section 7: The concessionaire must pay the royalty for the timber according to the types and rates set by the announcement, Forestry or National Reserved Forest Law, issued by the Ministry of Agriculture and Cooperatives;

The royalty is calculated by using the rate effective at the time of inspection and calculation of the wood volume for royalty payment.

If the change of royalty rate has been announced, the concessionaire shall pay at the new rate for timber not yet inspected by the officer for royalty payment.

The royalty shall be paid at the District office or Provincial Forest office where the concessioned forest is located.

Section 8: The concessionaire shall be able to take out the timber for charcoal production only upon written approval by the authorized Royal Forest Department officer.

If the concessionaire fails to meet the above condition, the concessionaire is subject to be fined by 2,000 baht plus daily fine at the rate of 1,000 baht maximum till the condition has been met.

Section 9: The concessionaire shall make payment to the Royal Forest Department in the amount of 2,000 baht per year to cover the expenses on area surveying, mapping, planning and calculating of annual wood extraction, till the termination of the concession period. The first payment shall be made upon the effective date of the concession, payment for the following years shall be made within the first month of each concession year at the provincial Forest office where the concessioned forest is located.

Section 10: The concessionaire shall plan and maintain the forest so that it would remain in its perfect condition for sustainable production. The concessionaire shall be responsible for the operation and all the expenses incurred.

1. Plant the tree to fill the whole area of the cutting strip,
2. Set up the forest plantation or plant and maintain the natural forest in the concession area according to the methods set forth by the Royal Forest Department within the budget amounting to three folds of the royalty value.
3. Small canals shall be dug especially on the elevated area possibly flooded by sea water to regulate the growth and the regeneration of mangrove forest in the concession area according to the methods set forth by the Royal Forest Department.

To enable the above action to proceed right to the principle of reforestation and maintenance the concessionaire shall allow for the convenience and strictly follow the advice of the logging supervisor.

Section 11: The right over all timber shall be transferred to the concessionaire when all payments specified in the concession contract have been made, producing the receipts and royalty stamp on the timber, except for the firewood and charcoal making, as evidence.

Section 12: The concessionaire shall arrange the logging manual for the workers or employees in the concession to be carried with them while working according to the Forestry Law or National Reserved Forest Law.

If the concessionaire fails to meet the said condition, the concessionaire is subject to a fine at the rate of 200 baht/head plus daily fine at 100 baht/head maximum till the condition has been met.

Section 13: At least 75% of workers/employees of the concession must be of Thai nationality.

Failure to meet the said condition shall cause the concessionaire to pay a fine to the concessioner at the rate of 1,000 baht maximum plus daily fine of 500 baht maximum until the condition has been met.

Section 14: The concessionaire must be careful and take precaution measures to prevent possible damage or obstruction to land or water transportation, construction or other materials for irrigation or communication purposes.

If there are damages resulting from failure to meet the said condition, the concessionaire shall take responsibility for all the compensation cost. If he dose not solve the problems but lets the authorized Royal Forest Department officer do the job, all expenses incurred shall be borne by the concessionaire.

Section 15: The concessionaire is not allowed to do the rock mining, canal digging, or building a dam to obstruct the water ways in the concession area, which may cause the change of water volume or current, unless the concessionaire has been granted an approval in writing from the authorized Royal Forest Department officer.

If the concessionaire fails to meet the said condition, the concessionaire must be fined at the rate of 1,000 baht plus daily fine of 500 baht until it has been corrected.

Any damages incurred must be relieved by the concessionaire. If he fails to do so, the authorized Royal Forest Department officer must take action on the expense of the concessionaire.

Section 16: The concessionaire must repair and maintain the path or bridge used in logging to keep it in good condition. When the concessionaire finishes with the logging in the assigned cutting coupe, the concessionaire must transfer the right over the path or bridge in good condition to the authorized Royal Forest Department officer without claiming any compensation.

Section 17: If the timber from the concessioned forests obstruct the waterway and the concessionaire has been informed about this effect in writing by the Royal Forest Department officer or by any other sources, the concessionaire shall be responsible to immediately remove the timbers out of the waterway.

If the concessionaire fails to abide by the condition within 30 days starting from the date of acknowledgement, the concessionaire is subject to a fine not exceeding 1,000 baht plus daily fine of 500 baht maximum until the problem has been corrected.

In case the authorized Royal Forest Department officer considers it necessary to prevent possible damage or danger, the concessioner is empowered to eliminate the said timbers on the expense of the concessionaire.

Section 18: The Royal Forest Department officer who is authorized to inspect the operation in the concession area is empowered to enter the concessionaire's office from sunrise to sunset to examine the documents and accounts on operation or to order the concessionaire to provide required document or account. If the concessionaire does not allow for the convenience or fails to abide by the order without proper reason the concessionaire must pay the fine of 1,000 baht maximum with the daily fine of 500 baht until the problem has been solved.

Section 19: The concessionaire shall be responsible for failure to meet the concession conditions or any action against the Forestry or National Reserved Forest Law committed by any person during the concession period, unless the concessionaire could prove that such failure or conviction has been caused by other person without his or his worker/employee's knowing.

The concessionaire must share the responsibility with his employee in case the latter does not abide by the concession agreement on Forestry/National Reserved Forest Law.

Section 20: The Royal Forest Department authorized officer is empowered to set the fine rate related to the concession and notify the concessionaire in writing to make payment within 30 days after the receipt of notice.

The concessionaire has the right to petition to the Minister of Agriculture and Cooperatives within 30 days after receiving the notice. The Minister's jurisdiction is considered final.

Section 21: The concessionaire must deposit the amount of 10,000 baht with the concessioner as a guarantee for the payment of the fine.

Section 22: The concessioner is empowered to revoke the awarded concession if it is evident that:

1. The concessionaire, in any case, leases or transfers all or some of the privileges obtained under the concession or performs any acts proven that he does not operate the concession on his own.

2. The concessionaire intentionally fails to abide by the terms and conditions resulting with severe damage to the state or often fails to meet the terms and conditions. The concessioner has considered that the concessionaire would not in any way follow suit even though he has been fined and warned.

3. The concessionaire by order of the court becomes a bankrupt or has been revoked of his legal status.

4. The concessionaire fails to abide by Section 6,10 or 22.

5. The concessionaire works against Section 5(3) Clause 2 causing severe damage.

6. The concessionaire neglects the concession operation, and inspite of written warning by

the concessioner fails to comply with the warning.

Section 23: When the concessionaire dies, disappears, or becomes disabled or disabled-like, and if the heir or the guardian wishes to continue operating the concession, he must submit his request to the officer within 90 days after the concessionaire's death or the day the concessionaire is ordered by the court as disappeared or disabled or disabled-like. If the concessioner has considered it appropriate and the request has been approved by the state, the concessionaire is empowered to permit the heir or guardian to continue operating the concession for the remaining period.

If the request has not been submitted within the given period, or the heir or guardian has not been approved to continue the concession according to the above Clause, the concession is considered cancelled.

Section 24: If the concession has been revoked as in Section 22 or canceled as in Section 23 the concessionaire or guardian must cease to operate the concession at once. For the timber already moved to the log pond for inspection and royalty calculation as stipulated in Section 3 prior to the date of revoke or cancellation, the heir or guardian is allowed to manage upon making payment of the royalties and unpaid debt caused by the concession.

Section 25: If the concessionaire wishes to cancel the concession before the termination date as stipulated in Section 1, he must notify the concessioner in writing indicating the date of cancellation and he must cease operation from that date. However, he has the obligation to abide by the concession up to the cancellation date set by the concessioner.

Section 26: For the benefit of the state the concessioner is empowered to ask the concessionaire to add or adjust the terms and conditions of the concession as necessary. If the latter declines to comply with the request, it shall be considered that he wishes to cancel the concession and Section 25 shall be applied accordingly.

The Royal Forest Department has established 36 Mangrove Management Units in various provinces under the supervision of the Regional Forestry Office to investigate and control the operation in the mangrove forests in the working plan so that the concessions should be operated according to the regulations and the terms and conditions, as well as to guard against the encroachment and to do the research on mangrove forests.

Managed mangrove plantations

Mangrove plantations in Thailand are owned by the Royal Forest Department and the private sector. At present 184,490 rai (29,518 ha) established by the RFD are not yet economically managed. The total area of government plantation will be kept for ecological protection and seed production. However, in the future, the RFD plans to manage the plantation on sustainable basis by applying 15 years cutting rotation. The operation will be also made by the concessionaire under terms and conditions of plantation concession which is being prepared by the Royal Forest Department.

The mangrove plantation owned by the private or public sectors are harvested by the owners annually. The cutting rotation depends on the end-user product and money needed. At Samut Songkram, the owners of plantations will harvest the timbers at ages between 10 - 15 years depending on the sizes of trees which can be used for charcoal burning. In Chumporn, trees from plantations will be cut at ages of about 4 - 5 years for the stakes of mussel culture and also for firewood. The mangrove plantations owned by Yeesarn villagers, Samut Songkram province is the best management on sustainable basis in Thailand (Aksornkoae *et al.*, 1992) and details of management will be discussed later as a case study of sustainable management practices.

Silvicultural systems

Silvicultural systems for managing mangrove forest

Silvicultural systems applied for management of mangrove forest in Thailand were developed from time to time in order to achieve sustainable management and to supervise and control concessionaires effectively. Detailed development of silvicultural systems can be discussed as follows:

1. *Silvicultural system before 1961: shelterwood with minimum girth and 10 year rotation.*

Before 1961, the sole objective of management was to log the forests for charcoal burning. Working plans were made by the Royal Forest Department. Generally, the rotation and the felling cycle was set to 10 years, the forest area being divided into 10 annual coupes of approximately equal area. Each year one annual coupe was granted for extraction under a short-term (one year) permit. The silvicultural system was a shelterwood system, but the prescriptions were rather sketchy. Trees of above 30 cm girth at breast height (gbh) (10 cm dbh) could be cut, but 30 - 40 big trees had to be left standing for each rai (0.16 ha).

2. *Silvicultural system between 1961 - 65: shelterwood with minimum girth and 15 year rotation.*

In 1961, the Royal Forest Department revised the mangrove working plans to suit auction licensing. The shelterwood system with minimum girth limit was retained, but a number of additional prescriptions were added:

1. In areas where the general stem size is below 20 cm gbh (dbh < 6 cm) the spacing of the trees left as shelter must not exceed 2 m.
2. In areas with a stem size of 21 - 30 cm gbh (dbh 6 - 10 cm) spacing of trees left must not exceed 5 m.
3. In areas with a stem size of 31 - 40 cm gbh (dbh 10 - 13 cm) spacing of trees left must not exceed 10 m.
4. In areas with a stem size of 41 cm gbh and over (dbh > 13 cm) shelter trees should be left in groups of 3 - 4 trees with a spacing between the groups not exceeding 20 m.

It was also prescribed that in empty patches within the area, shelter trees had to be left in groups of 2 - 5 trees. Only valuable species, in particular *Rhizophora*, were to be used as shelter trees. Felling was not permitted within a distance of 5 metres from banks in order to prevent erosion. Felling cycles were set for 15 years with 15 annual coupes. The areas were to be auctioned every three years.

Yields were estimated by measuring felled trees in sample plots leaving shelter trees as prescribed. Sample plots size varied from 1 rai (0.16 ha) to 12 rai (1.92 ha) depending on the size of the coupe.

3. *Present silvicultural system (since1965): clear-felling in alternate strips with 30 year rotation.*

Experience showed that the shelterwood system was difficult to supervise and control in the field. In many areas the stock was depleted and the site deteriorated. Some areas had dried up and were covered with undesirable undergrowth which was so severe that regeneration of mangrove species was prevented. Some areas were left with only non-commercial species of trees. Another drawback of the shelterwood system was that it was impossible to harvest the shelter trees without damaging the natural or planted regeneration. To solve these problems, the Royal Forest Department revised the management plan. The new plan shows promising results. Its salient features are:

1. The silvicultural system is clear-felling cycle of 15 years.
2. Rotation is set at 30 years with a felling cycle of 15 years. This is practiced by dividing the area into 15 coupes, each of which is further divided into 40 m wide strips forming an angle of 45° with the tide. Alternate strips are cut every 15 years, thus giving a rotation of 30 years.
3. The strips in the annual coupe are to be marked prior to felling.
4. The felling strips will be planted by using the species of *Rhizophora* especially *Rhizophora apiculata* at a spacing of 1 x 1 m.

Silvicultural systems for managing mangrove plantation

Mangrove plantation established by the Royal Forest Department has not yet been managed for any economic benefit. At present the establishment of mangrove plantation is only aimed at environmental protection. However, in the future, the management of mangrove plantation for commercial purposes will be carried out when the area is sufficient to be harvested on sustained yield basis. The silvicultural systems applied for mangrove plantation management particularly *Rhizophora* plantation on sustainable basis can be adopted with the following recommendations:

1) The silvicultural system is a clear-felling system.
2) Rotation is set at 15 years.
3) Two thinning will be operated at ages of 8 and 11 years with application of mechanical

thinning system in order to maximize productivity of plantation at 15 years cutting rotation.

4) After harvesting, mangrove trees, *Rhizophora* species particularly *R. apiculata* will be planted immediately with spacing 1 x 1 m.

5) Maintenance of plantation especially enrichment planting, weeding, pest and disease control, should be carried out at least 3 years after planting to ensure survival of all planted trees.

Regarding private mangrove plantations, the application of silvicultural system especially cutting rotation period varies according to the end-use products of planted tree species and the financial return needed by the owners. At present the silvicultural systems applied for management of private mangrove plantations are as follows:

1) The silvicultural system is a clear-felling system.

2) Cutting rotation period is set up depending on the planted tree species and end-use products:

   a) at 4 years cutting rotation for *Ceriops tagal* and *Bruguiera* spp. plantations used for stakes of mussel culture and firewood at Chumporn province.

   b) at between 8 - 15 years cutting rotation for *Rhizophora apiculata* plantation using for firewood and charcoal at Samut Songkram province.

   c) at 15 years cutting rotation for *Rhizophora* spp. plantation used for charcoal at Pattani province.

3) After harvesting, planting will be made immediately.

4) Maintenance of plantation is made only the first year after planting.

5) No thinning has been operated for private mangrove plantations of any rotations.

Reforestation

In Thailand mangrove reforestation will be carried out in 4 main conditions; strips clear-felled strips annually under logging concessions, unproductive mangrove areas, ecological protected areas and private areas. Details of reforestation of each area can be discussed as follows:

The annual clear-felling strips under logging concession.

According to the "clear-felling with alternate strips" logging system for mangrove forest in Thailand, a total area of approximately 41,602 rai (6,656 ha) is to be planted annually. The planting in this area is to be fully carried out by the concessionaire with the technological assistance of the RFD by the Chief of Mangrove Management Units. The concessionaires have to look after all trees for at least three years after planting in order to ensure their survival. Inspections of these activities will be made by the Chief of Mangrove Management Units.

Unproductive mangrove forests

The unproductive mangrove forests (yield below 5 - 10 m^3 per rai (30 - 65m^3 ha^{-1}) are usually not included in the annual felling series. These mangrove forest are estimated to cover 122,756 rai (19,641 ha).

The Division of Silviculture of the Royal Forest Department is carrying out a programme of enrichment planting in those unmanaged mangrove areas where regeneration is fairly poor. Mangrove areas that have been severely destroyed will also be replanted. In this way it is hoped to increase yields and eventually put these areas under concession, provided trees are big enough for commercial uses. However, due to the limitation of budget, only about 2,400 rai (384 ha) can be planted in this area annually. Under the areas of annual clear-felling strips and in unproductive mangrove areas, only two species of *Rhizophora; Rhizophora apiculata* and *R. mucronata* are planted. The mangrove plantation in these areas is aimed to produce firewood and charcoal. Woods from these two species give the best quality and high prices compared with other mangrove species or other inland tree species. However, the planting in the areas of annual clear-felling will follow the terms and conditions under logging concession.

Ecological protected areas

The Royal Forest Department by the Chief of Mangrove management Units is also responsible to replant mangroves in ecological protected areas. The most important ecological protected areas to be planted in accordance to the mangrove forest land use zoning designated by the National

Mangrove Committee on Mangrove Resources with the approval of Cabinet's meeting on December 15, 1987 are the areas within 20 m from natural riverbank and within 75 m from the coastline, the areas for wind protection, the areas for protection of soil erosion and the areas for marine animals breeding. The existing ecological protected areas include degraded mangrove forests and mudflats. The reforestation on these areas has received special government funding from Budget Bureau for a period offive years to cover all expenses incurred from planting of approximately 10,000 rai (1,600 ha) per annum. The bureau was also assigned to monitor and evaluate its implementation.

In protected areas, the mangrove species will be carefully selected to plant in suitable area followed by species zonation. *Rhizophora apiculata* and *R. mucronata* will be planted on muddy and flooded areas along the riverbank or coastline. *Ceriops tagal* and *Bruguiera* spp. can be planted on elevated areas with soft soils. *Xylocarpus* spp. and *Lumnitzera* are good for the hard soils and less tidal flooded areas. Details of species zonation of mangrove forests in Thailand can be found from the studies of Aksornkoae (1975) and Miyawaki *et al.*, (1986).

Private areas

Private mangrove plantations comprise approximately 17,500 rai (2,800 ha). They are mainly found in the upper part of the Gulf of Thailand, particularly in the provinces Sumut Sakorn, Samut Songkram and Samut Prakarn. In southern Thailand, private mangrove plantations exist in Chomporn and Pattani provinces but the total area is very limited. Most of the plantations consists of *Rhizophora apiculata* for charcoal production (90%) and for posts and firewood (10%), except the private mangrove plantation in Chumporn where *Bruguiera* spp and *Ceriops tagal* are planted for stakes for mussel culture. The management of private mangrove plantation on sustainable basis can be found only in Samut Songkram province (Aksornkoae *et al.*, 1992). However, the establishment of private mangrove plantations will be technically assisted by the Royal Forest Department particularly for planting, maintaining and harvesting techniques.

Forest conservation

For administration of forest land and regulation of the utilization of forest products, direct or indirect, various laws and regulations have been issued. There has been an increasing rate of illegal conversion of mangrove forest for other purposes. Between 1979 and 1986, this caused a reduction in mangrove area of about 129.83 km^2 yr^{-1}, an annual depletion rate of 4.52% (IDRC/NRCT/RFD, 1991). It affected fisheries production and the coastal environment. The government through its related agencies has tried to issue and improve rules, regulations and controlling measures for special use of mangrove forest as well as to facilitate the supervision and control of the use of mangrove forest. Those relating to mangrove forest are:

Forest Act (FA) - the first Forest Act was enacted in B.E. 24184 (1941). There have been four amendments since. The latest amendment was in B.E. 2518 (1975). Since the use of mangrove forest has been mainly harvesting of wood for charcoal-making, this act directly concerns the mangrove.

National Forest Reserve Acts (NFR) - All mangrove forest are declared resource forest under this Act or the Acts preceding this Acts by its Article 6. Therefore this act controls all activities carried out in the mangrove forest. The first Forest Reserve and Protected Forest Act was enacted in B.E. 1481 (1938). Only Four amendments have been made since. The last one called the National Forest Reserve Act of B.E. 2507 (1964).

Policy for Mangrove Conservation - the government has a firm and persistent policy for mangrove conservation since 1978. Controlling measures being issued for special use of mangrove resources can be summarised as follows.

27 June 1987: NATMANCOM and NEB have been assigned to consider and screen all mangrove development projects of government agencies and private sectors for managed to achieve and maintain optimum sustainable productivity without degrading the integrity of other ecosystems with which they coexist.

19 August 1980: In case it is necessary for a certain project to be carried out in a mangrove area, its impact must be evaluated to give appropriate control, and a Land Right Certificate shall not be issued for exploitation of mangrove area.

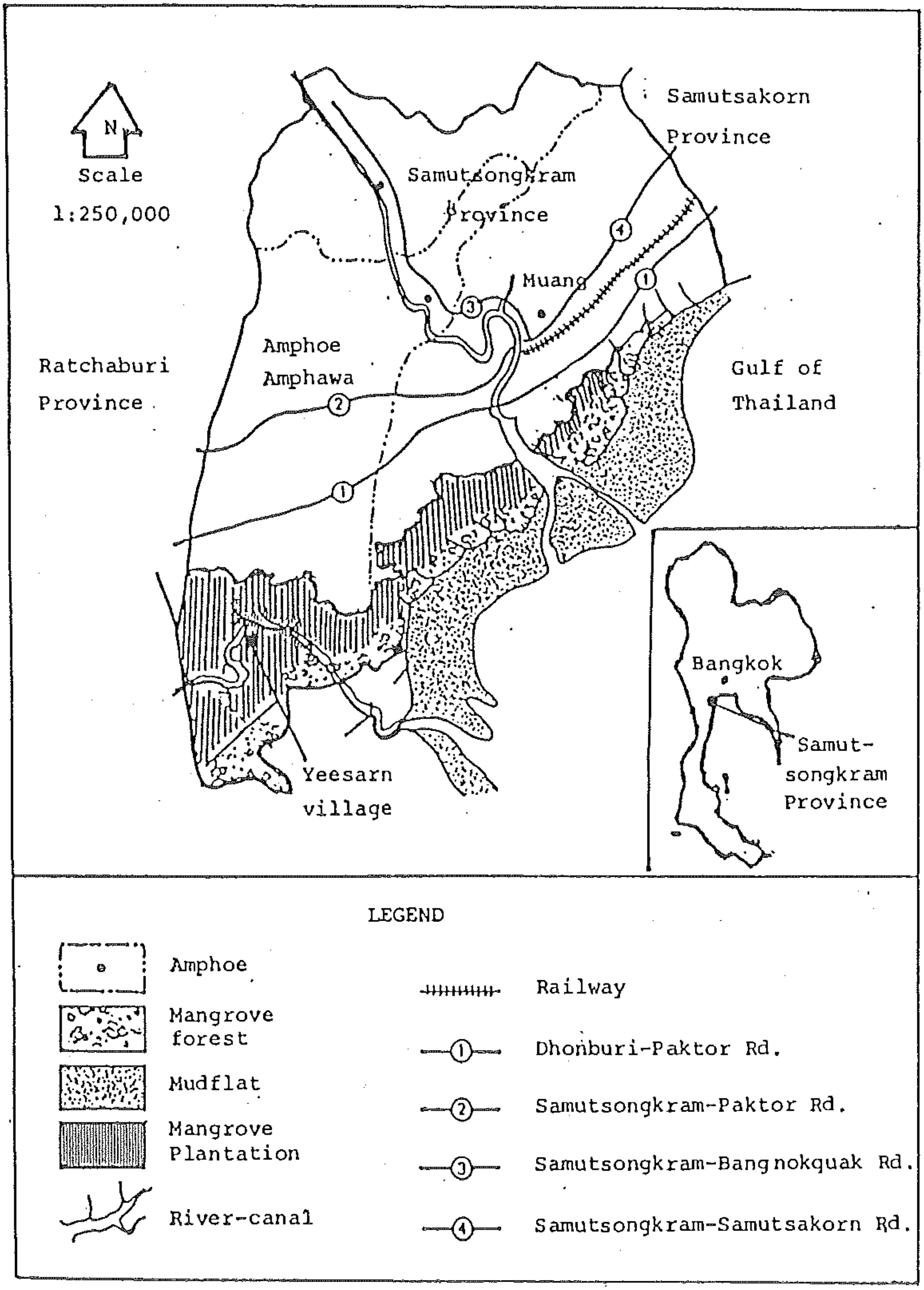

Figure 2. Location of the study area.

29 June 1982: If it is necessary, Landmark and boundary should be clearly made for the projects which are allowed to be taken place in mangrove reserved areas.

1 May 1984: Mangrove zonation should be clearly managed with based on the studies of its ecosystems involved and recovering degraded mangrove forest should be urged in either government agencies or private sectors.

15 December 1987: The cabinet agreed with a guideline of mangrove area classification (zonation) which was divided into 3 zones - conservation, economic A and economic B in which controlling measures of each zone were clearly established.

1 August 1989: The cabinet agreed to principles presented by the Ministry of Science Technology and Environment that mangrove reclamation and protection of all remaining mangrove areas in Surat Thani and Nakorn Si Thammarat should be undertaken with financial support for establishment of additional mangrove management and protection units.

6 February 1990: The cabinet agreed with measures for improving invaded mangrove forest in the Eastern provinces - utilization of Economic Zone A is allowed only up to 1993 under the given provisions.

4 June 1991: The cabinet agreed with the recommendations presented by Ministry of Science, Technology and Environment to accelerate mangrove management programme in accordance with immediate control measures for utilization of coastal resources, mangroves and coral reefs. The government financially supports mangrove plans for reforestation, public relations, conservation and local management.

23 July 1991: Permission to convert mangrove forest will no longer be given. A committee consisting of officials representing all departments concerned was established at provincial level to prevent illegal invasion and problems of mangrove utilization.

These protective measures have been reasonably successful in establishing zoning for mangroves and controls that limit impacts on the environment of local people. For example, during 1975 to 1986 the rate of destruction of mangrove forest was 105.7 km^2 yr^{-1} (from 3,127 to 1,964.2 km^2 or 1,162.7 km^2), compared with that of 45.6 km^2 (from 1964.3 to 1,732.1 km^2 or 228.2 km^2) between 1987 and 1991, after application of mangrove zonation management (IDRC/NRCT/RFD, 1991).

Even though the government has used different measures to limit mangrove exploitation, illegal invasion is still possible in some localities. The government gave budgetary support of 747.01 million baht to the mangrove reclamation policy during 1992-1996. Mangrove replantation, development of manpower and campaigning for a better understanding of the role of mangrove to local people have been worked out, together with educating the public and private sectors/NGOs to participate in mangrove conservation and reclamation programme. Presently, their participation is desirable at certain level. Some local communities already promote reforestation of deteriorated mangrove areas in Trang province.

Regarding development of personnel, the government through its responsible agencies has promoted an exchange of knowledge programmes with international organizations such as UNESCO, UNDP, JSPS, MAB and ISME in convening seminars, training courses and workshops at both national and regional levels. These will help very much to improve manpower with high qualification working for mangrove conservation and management.

Case study of sustainable management practices

The following case study deals with the sustainable management of mangrove plantations for charcoal production at Yeesarn Village, Samut Songkram Province (Aksornkoae, 1984).

Introduction

In Thailand, mangrove plantations along the coastal areas are an important source of energy. These plantations, small and large scale, were established a long time ago by the Royal Forest Department (RFD) and local people as a charcoal source for the local, urban and export markets. Mangrove replantation while a most important forest development policy programme has not received adequate attention from natural resource planners and agencies. One constraint is the lack of information on how the mangrove system operates.

One model from which a mangrove vegetation community and its economic contribution can be profiled is "Yeesarn Village" in Samut Songkram

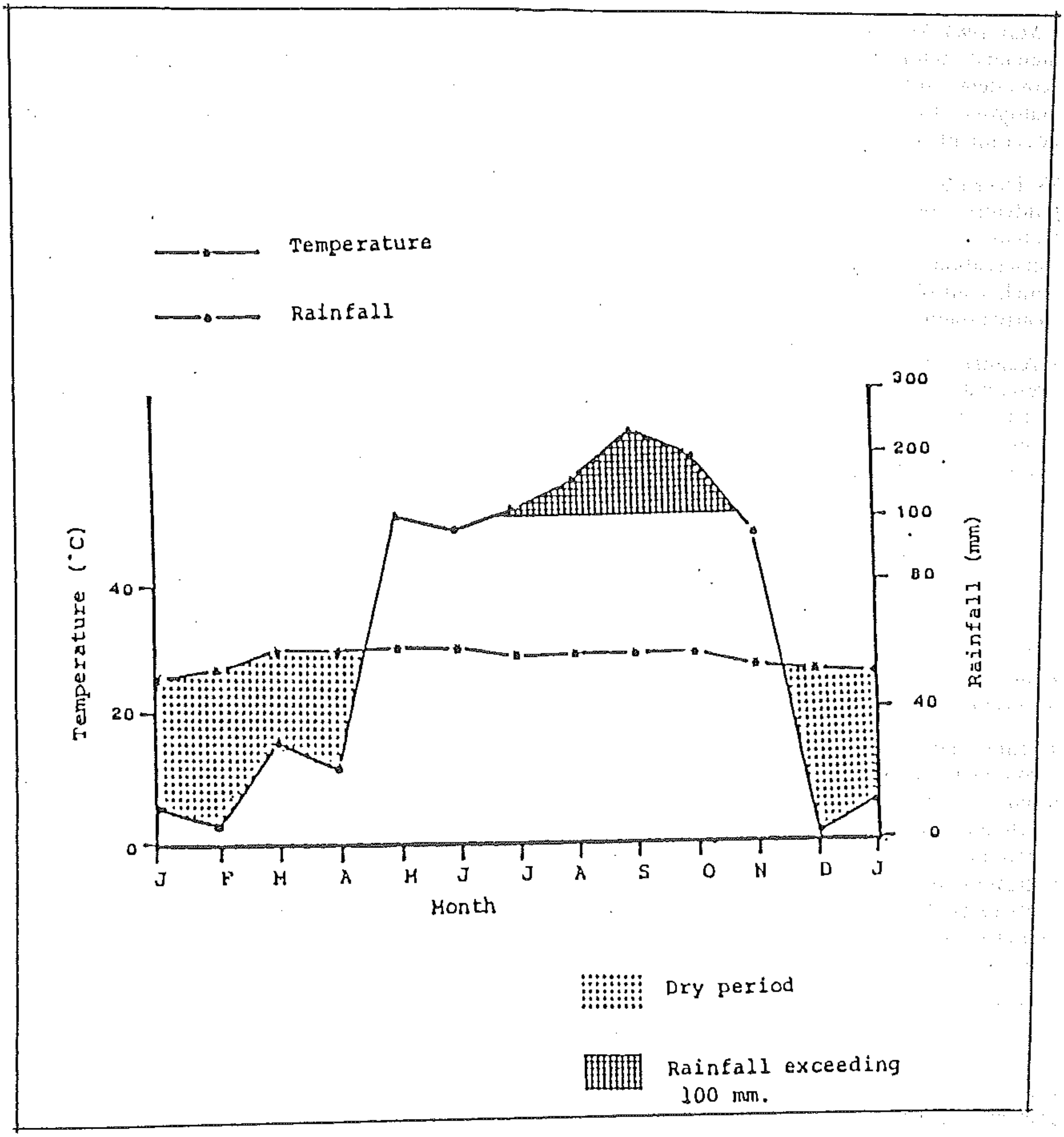

Figure 3. Temperature and rainfall means of Samut Songkram province, 1956 - 1985 (From Meteorological Department, Ministry of Communications, Bangkok, Thailand)

province. This village has cultivated and managed mangrove plantation for charcoal and other minor products for as long as 50 years. We have monitored and evaluated the area for 5 years and believe it is a good example of small-scale investment of mangrove plantation on sustainable management. Therefore, the purpose of this report is to present our findings for use in better planning and it required public interventions. We further believe this information, much of it new, can be used by managers to formulate integrated national mangrove management schemes, particularly when energy, land, economic and socioeconomic are the key issues.

Geography of the study area

Yeesarn village is located in Amphoe Amphawa, Samut Songkram province, 60 km. southwest of Bangkok on the western coastline of the Gulf of Thailand. The village lies between latitudes 13° 16' to 13° 19' N and longitudes 99° 52' to 99° 56' E (Figure 2).

Climate

The climate is tropical savanna with little variation in mean monthly temperatures. The average temperature is about 28°C. The annual rainfall is 1,050 mm. September is the wettest month with amount of rainfall of about 237 mm (Figure 3). The total rainy days are about 63 days per year.

Mangrove forest

1.1.2.1 Natural

The natural mangrove forest was once very productive and occupied a large area along the coast of Samut Songkram province. In 1975, the total mangrove area in the province was approximately 51,250 rais or 8,200 hectares (Klankamsorn and Charuppat, 1982). In the past 15 years, most of the mangrove areas have been converted into shrimp farms. Today a narrow belt of only 2,800 rais or 448 hectares remains along the coast and the mouth of the Mae Klong River. Because of intensive selective cutting for pole, charcoal and firewood, most of the remaining forests are composed of small-sized trees. Most of the left big trees are on the banks of the water ways providing coastline protection against wind and tidal action. The natural stands consist of *Rhizophora apiculata*, *R. mucronata*. spp. *Bruguiera gymnorrhiza*, *Lumnitzera racemosa*, *Ceriops tagal*, *Xylocarpus granatum* and *Excoecaria agallocha*.

1.1.2.2 Plantation

A 1987 inventory estimated the private mangrove plantation was at 16,000 rais or 2,560 hectares under 144 owners. Most of these were established in 1932 with the *Rhizophora apiculata* monotype. The primary wood production is for charcoal burning (95%) and the rest for poles and firewood.

Importance

Mangrove plays a very important role to the economy and daily life of the Yeesarn village people. Charcoal production, especially from the private plantation, is sold to the Bangkok market and neighboring provinces. Economic and socio-economic importance will be later elaborated in the text. While no definite data have been recorded. Local fishermen know the value of mangrove to the fisheries. Mangrove forests function as a nursery and feeding grounds for many commercially important shrimp species especially *Penaeus merguensis* and P. *monodon*. Therefore, this area is very important in ensuring the production of shrimp seeds for the area plays an important role in protecting the shore lands against tidal bores, cyclones and soil erosion.

Plantation silvicultural operations, productivity and management

Silvicultural

Plantation silvicultural operations (Rhizophora apiculata) included site preparation, collection of seedlings, planting methods, plantation tending and pests and disease control.

Site Preparation

Areas to be planted are normally demarcated with easily identifiable post to prevent clearing of adjacent areas that will not be converted to plantation. Site preparation is carried out in July and August. However, if clearing has left excessive slash, it is advisable to eliminate or reduce the debris first, to create space for the new plants. The plantation owners lop and heap the slash in rows, perpendicular to the waterways. In some areas, the slash will be burned, if possible. Undesirable species especially *Acrostichum aureum*, *Acanthus ilicifolius* and *Derris trifoliata* should be

† 25 Baht ≈ US$1.00

‡ 6.25 rai = 1 ha

weeded out before planting. On an areas to be planted with *Rhizophora apiculata*, above the tide influence, small canals about 3 m in width and 1 to 2 m in depth will be constructed to allow sea-water flooding.

Collection of seedlings

Rhizophora apiculata seedlings are best collected by hiring local inhabitants (men and women). Seedlings will be collected directly from the trees or from the forest floor. They are also collected from the stream by using boats. In Yeesarn village, peak seedling production occurs in September through November. Guidance must be given to the collectors to insure that quality seedlings are collected.

The planting of *Rhizophora apiculata* is very simple and quick and can be carried out by untrained laborers with brief, but clear, instructions. Generally, at Yeesan village, each laborer carries a small sack of propagules or seedlings on their hip. As they walk, they stick one seedling into the soft mud at their feet and then step forward with spacing of approximately 0.63 m. The row spacing is also 0.63 m. Therefore, in one rai (1,600 m^2) about 4,000 seedlings are planted. Planting is usually carried out in September to December when seedlings of *Rhizophora apiculata* are available. If needed the seedlings can be stored in the shade for 1 - 1.5 months before planting.

Plantation tending

Plantation tending includes weeding, cleaning, pruning and thinning. During the first two years of establishment only weeding is done in order to reduce competition. Undesirable species such as *Acrostichum aureum*, *Acanthus ilicifolius* and *Derris trifoliata* are the primary competitors. In reality, *Rhizophora apiculata* plantation does not require intensive care and normally there is little need for weeding.

Pest and disease control

Pests and diseases are not a serious problem in establishing mangrove plantations. However, crab, *Sesarma* spp., may destroy young seedlings of *Rhizophora apiculata* by eating the bark above the collar, but the degree of damage is minor. Nevertheless, two species of insects, the mangrove defoliator (*Cleora injectaria*) and the mangrove seed borer (*Ecilips fallax*), are commonly found in mangrove plantations (Chaiglom, 1982), and

Table 14. Cost of mangrove plantation establishment and maintenance at Yeesarn Village, Samut Songkram Province.

Activities	Baht/Rai	US$/Rai
Establishment (1st Year)		
Site preparation	224	8.96
Seedling (propagules) cost	200	8.00
Planting	70	2.80
Seedling delivery cost	14	0.56
Land renting	50	2.00
Total	558	22.32
Maintenance (2nd Year)		
Seedling replacement cost	20	0.80
Weeding cleaning & replanting	23	0.92
3 - 12 years	None	None
Total	43	1.72

stands should be periodically examined for possible outbreaks. *Rhizophora apiculata* plantations in this area, have shown very low adverse effects from pest and disease as mentioned earlier and they were observed to be successful with a survival rate of over 80 percent (Wechakit, 1987).

Direct costs of plantation establishment and maintenance

The costs of plantation establishment and maintenance is approximately 558 baht per rai. This estimate is based on 1987 establishment costs. The costs per rai is discussed as follows:

Site preparation cost

The cost of site preparation is about 224 baht[†] per rai[‡]. This includes the cost of weeding and cleaning of undesirable plant species, collecting of debris remaining after harvesting, and construction of small canals in the plantation site. This cost is based on hiring one laborer for weeding and cleaning. One laborer can finish about 5 rais per day. The wage of labour is 70 baht per day. Therefore, the cost for weeding and clearing is 14 baht per rai. For digging of small canals, 3 laborers can accomplish one rai a day, therefore, the cost of this activity is about 210 baht per rai.

Table 15. Average diameter at breast height (DBH) and height of *Rhizophora apiculata* in plantations at Yeesarn Village.

Age (yr)	DBH (cm)	Average DBH Increment (cm yr^{-1})	Height (m)	Height Increment (m y^{-1})
1	-	-	0.45	0.45
2	-	-	1.07	0.54
3	0.19	0 .31	1.76	0.59
4	1.59	0.40	2.36	0.59
5	2.26	0.45	3.71	0.74
6	2.5	0.42	4.41	0.74
7	2.83	0.40	4.92	0.70
8	2.97	0.37	5.58	0.70
9	3.26	0.36	6.82	0.76
10	3.65	0.37	7.30	0.73
11	4.31	0.39	8.94	0.81
12	5.18	0.43	10.19	0.85

Source: Wechakit, 1987.

Seedling costs

Normally, the plantation owners purchase a propagules or viviparous seedlings from local suppliers at 5 baht per 100 seedlings. At the planting rate of 4,000 seedlings per rai, the propagule cost per rai is 200 baht. In case of propagule surplus, they can be stored under shade and will be transplanted, if needed.

Table 16. Average Yield of *R. apiculata* plantation at different ages at Yeesarn Village.

Age (yr)	Stem weight (oven-dry)		Commercial volume	
	Standing (t ha^{-1})	Production (t ha^{-1} yr^{-1})	Standing (m^3 ha^{-1})	Production (m^3 ha^{-1} y^{-1})
4	11.60	2.90	2.15	0.54
5	27.26	5.45	18.38	3.68
6	34.67	5.78	26.03	4.34
7	49.94	7.13	41.68	5.95
8	56.85	7.11	49.29	6.16
9	74.24	8.25	69.30	7.70
10	91.28	9.13	88.39	8.84
11	125.63	11.38	128.28	11.66
12	150.75	12.56	156.87	13.06

Source: Wechakit, 1987.

Planting costs

The planting cost per rai is 70 baht. This cost is based on hiring one worker to plant one rai a day. The planting technique is mentioned earlier in the text.

Seedling delivery costs

The cost of seedling (propagule) delivery from the storage site to the planting area is 14 baht per rai. This cost is based on hiring one worker (70 baht per day) to deliver enough seedlings to plant about five rais per day.

Land renting costs

Although plantations are established on private land, the cost of land has to be considered as part of a cost of establishment. At Yeesarn village, the cost of renting land for mangrove plantation is 50 baht per rai per year.

Costs of plantation maintenance

Generally, the maintenance of mangrove plantation is carried out only in the second year. The cost of maintenance includes the cost of seedling replacement of 20 baht (400 seedlings per rai) and the cost of hiring local laborers for weeding and cleaning of undesirable plant species at the rate of 23 baht per rai. This cost is based on one worker completing three rais a day.

Table 14 summarizes the expenditures for first and second year mangrove plantation establishment per rai at Yeesarn village.

Plantation productivity

The productivity of Yeesarn's mangrove plantation in terms of diameter, height growth, stem volume and biomass was intensively studied by Wechakit (1987). He estimated that the plantation of *Rhizophora apiculata* species, in this area, reaches the average 5.18 cm breast height diameter (dbh) and a height of 10.19 m in 12 years, i.e., a diameter and height increments of about 0.43 cm yr^{-1} and 0.85 m yr^{-1}. respectively (Table 15).

The plantation yield for a 12 year period as actually measured is presented in Table 16. The oven-dry stem weight during the 12 years was 150.7 t ha^{-1} or 12.6 t ha^{-1} yr^{-1}. The commercial volume, which does not include leaves and small branches, was 156.8 m^3 ha^{-1} or 13.1 m^3 ha^{-1} y^{r-1}. This compares favorably with the findings of Wechakit (1987) who reported an above-ground biomass (stem branch, leaf and prop-root) of 197.6 t dry weight ha^{-1} and a primary production of 16.47 t ha^{-1} yr^{-1} in a 12 year old stand.

Table 17. Number and diameter of kilns in Yeesarn Village.

Unit	No. of kilns	Diameter of kiln (m)		Remarks
		5	3.5	
1	8	7	1	
2	10	7	3	3 owners/ partnerships
3	10	10	-	
4	6	4	2	
5	6	6	-	
6	8	6	2	2 owners/ partnerships
7	5	1	4	
8	6	6	-	2 owners/ partnerships
9	4	4	-	
10	4	4	-	
Total	67	55	12	

Plantation management

Area

The total private mangrove plantations in Yeesarn village is about 16,000 rais or 2,560 ha. Only species of *R. apiculata* has been planted in this area. This is because the majority of wood (95%) used for charcoal burning is *R. apiculata*, one of the most important species that gives a high charcoal quality as compared with other mangrove species.

Rotational age

The rotation or cutting cycle in the management of the plantation is fixed at 12 years. This is because the end use is charcoal. The optimum sizes of trees used for this purpose is about 4.0 cm to 8.0 cm in diameter at breast height (dbh). The time required for the trees (*R. apiculata*) to reach this size is about 12 years.

Harvesting or felling techniques

As mentioned earlier, the optimum size of trees to be cut for charcoal burning is about 4.0 to 8.0 cm in diameter. Felling is carried out manually in which all trees with diameter exceeding 4.0 cm are cut by axe or machete. After felling, the trees are cut into 1.30 to 2.0 m long billets. The use of chainsaws for felling is very rare in this area.

Debarking

Debarking is a very common practice in Yeesarn village. Billets need to be debarked before burning for conversion to charcoal. Debarking is done by using a wooden hammer or stick.

Harvestable volume

The area to be harvested per year was estimated to be 1,330 rai or 212 ha (total plantation 16,000 rai with 12 year cutting rotation period). The average annual wood harvest from the mangrove plantations in this area was about 33,250 m^3 or 25 m^3/rai (156.8 m^3/ha).

Transportation to the charcoal conversion center

Wood from the mangrove plantation to the charcoal kiln is usually transported by boat. After the trees have been felled and cut into 1.30 to 2.0 m long, debarked billets are carried from the plantation and loaded into a motorboat to the charcoal kilns.

Wood price

Generally, plantation owners in Yeesarn village estimate the price of wood based on stem volume per area (rai). The standing firewood price from plantations in this area is about 8,000 - 12,000 baht per rai at the rotation age of 12 years.

Charcoal production from mangrove plantations

Type and number of kilns

Brick beehive is the only type of kiln used in Yeesarn village. These kilns are dome shaped. The usual diameters of the kiln are 3.5 m and 5.0 m. In addition to the "door", the kiln is constructed with 5 small vents. The kilns are built next to each other inside sheds built of bamboo with nipa-thatched roofs. In this village there are 10 production centers and each having a battery of 4 to 10 kilns (Table 17).

Charcoal burning process

At Yeesarn village, the debarked mangrove billets 1.30 - 2.00 m long and 4 to 8 cm diameter are first packed inside the kiln vertically at ground level and later horizontally on the top portion. The carbonization process usually takes 9 - 12 days depending on the wood moisture content and size of the kiln. The process is divided into 2 phases,

(1) the burning phase of 9 to 12 days followed by, (2) a cooling phase for the same period. The carbonization process is monitored by the color and smell of the smoke, often by experienced men or women who spend their life time near the kilns.

Charcoal yield as compared to wood input

The efficiency of the charcoal burning process may be determined by the conversion rate or yield obtained and the quality of charcoal. At Yeesarn village, there are 67 kilns and each kiln at full capacity can process 12 times per year at the average of 30 m^3/kiln/charge. This requires 24,120 m^3 of mangrove billets per year. The remaining amount of woods approximately 9,130 m^3 per year (total wood production 33,250 m^3 per year) will be used for poles, housing materials, firewood and fishing gear. At 41 to 41.9% recovery the individual kiln outputs are between 4,526 kg. to 4,915 kg. (excluding uncarbonized firewood). The brands are 7.1% of firewood used (Chomcharn, *et al.*, 1983).

Charcoal production costs

The costs of charcoal production includes tree felling, bucking, debarking, transportation of the billets from the plantation to the charcoal kiln, loading in the kiln and firing port firewood, hiring coast of the charcoal kiln, unloading from the kiln to the motor boat, transportation to Bangkok and digging of canals, if any. These costs are incurred by the merchants as a usual practice in this area. The total costs per rai for charcoal production until transported to the wholesale market at Bangkok are estimated as follows:

		Baht
1	Tree felling, bucking, debarking	2,000
2	Transportation from plantation to kiln	600
3	Mangrove billets loading	440
4	Kiln hiring and firing port firewood	1,600
5	Unloading from kiln to motor boat	240
6	Transportation to Bangkok	900
7	Digging canals (if any) and miscellaneous	200
	Total	6,040

Charcoal distribution and marketing

Charcoal value

The average yield of mangrove wood is 25 m^3/rai and the charcoal output is 50% or 12.5 m^3/rai. One cubic meter of charcoal weighs 381 kg. which yields 4,762.5 kg/rai of charcoal (Chomcharn, *et al.*, 1983). The value of lump charcoal at the Bangkok wholesale market is 4.30 baht/kg, suggesting an income of 20,478.75 baht per rai. Beside lump charcoal, there is uncarbonized firewood of about 800 kg/rai which can be sold at approximately 1.25 baht/kg for an additional income of 1,000 baht/rai.

Charcoal grading and packing

Well carbonized mangrove charcoal usually keeps its original shape, but the number of cracks, size and color sometimes change. If the shape of the billet is retained without breaking into small pieces and is well carbonized it is graded as "good quality" for both industrial use and cooking. This grade can be packed in bundle without a container. If broken into pieces, it is graded as "second grade" for cooking and packed in a jute sack of 30 kg. Some of the charcoal wastes, in the form of fines and small chips, are often discarded, or used for land filling.

Market place and distance

The main market of charcoal from this village is Bangkok where there is unlimited demand. The charcoal is usually transported to market by boat. The average distance from Yeesarn village to Bangkok is about 120 km at Wat Pratumkongkaram port.

There is also a local market from which the middle-man buys charcoal direct from the kiln site and transports it by pick-up truck or big truck. The pick-up truck will go around the villages and small communities selling at the doors or in local market places, usually in small quantities for household cooking.

Transportation mode and cost

There are 2 kinds of transportation:

1. By big boat which can transport the product from 4 kilns at a time weighing about

Prices quoted are early 1988 values.

18,000-20,000 kg. A fleet may consist of 6 - 10 barges hauled by one motor boat from Samut Songkram province to the Bangkok market. The cost of Transportation is 0.25 baht/kg (or 12 baht per 60 kg.).

2. By small pick-up truck or big truck depending on the quantity and the purpose of transportation. Most of this type of transportation is going to local markets or neighboring provinces where road connections are possible. The cost of transportation by this means depends on the distance.

Price of charcoal at local community and urban markets

The wholesale price of good quality charcoal at the Bangkok market is about 4.30 - 4.35 baht/kg. and brands (unburned firewood) about 1.25 baht/kg.

The price at the kiln site for good quality charcoal is 3.50 - 3.70 baht/kg. and unburned firewood about 1.00 baht/kg.

Analysis of charcoal production, investment return and unit production costs

Sungsuan (1986) studied the benefit/cost ratio of *Rhizophora apiculata* plantation at Samut Songkram province which is summarized in Table 18.

Table 18. Net Present Value of investment cost of *Rhizophora apiculata* plantation.

Year	Investment Cost (Baht/Rai)	Net Present Value at different reduction rates.			
		9%	12%	13%	14%
1	558	511.93	498.21	493.81	498.47
2	94	79.12	74.94	73.62	72.33
3	50	30.61	35.59	34.65	33.75
4	50	35.42	31.35	30.67	29.60
5	50	32.50	28.37	27.14	25.97
6	50	29.81	25.33	24.02	22.78
7	50	27.35	22.62	21.25	19.98
8	50	25.09	20.19	18.81	17.53
9	50	23.02	18.03	16.64	15.38
10	50	21.12	16.10	14.73	13.49
11	50	19.35	14.37	13.03	11.83
12	50	17.78	12.83	11.54	10.38
Total	1,152	861.13	798.36	779.91	762.49

Sungsuan (1986) also estimated the return at 12 years, if the owner sells the mangrove standing firewood at 8,000-10,000 baht/rai. The net present value of the return from this species plantation will be as in Table 19.

Table 19. Net Present Value of the return at 12 years.

Selling Price (Baht/Rai)	Net Present Value at different reduction rates.			
	9%	12%	13%	14%
8,000	2,844.28	2,053.40	1,845.65	1,660.47
9,000	3,199.81	2,310.08	2,076.35	1,868.03
10,000	3,555.35	2,566.75	2,307.06	2,075.59

The benefit/cost ratios of the investment at different selling prices and reduction rates are shown in Table 20.

The result of the investment analysis, using the net present value of investment return, shows that at 12 years rotation and a sell price of standing firewood at 8,000 baht/rai, the net present value will be 1,983.15, 1,255.04, 1,065.74 and 897.98 baht at 9, 12, 13 and 14% reduction rates, respectively. If the sell price increases the net present values of return also increases as shown in Table 21.

The analysis also indicates that the investment on planting *Rhizophora apiculata* at 12 years rotation will give a net return of 23.5, 25.0 and 26.2% if the sell prices of the standing firewood are 8,000, 9,000 and 10,000 baht/rai respectively.

The cost of plantation establishment is 1,152 baht/rai for 12 years. The operational cost from firewood cutting and charcoal burning through to transportation to the market in Bangkok is about 6,040 baht/rai. Therefore, total costs per rai will be 7,192 baht (1,152 + 6,040). The gross income from selling the charcoal is 21,478.75 baht/rai. This gives an income to the tree farmer of 14,286.75 baht/rai for 12 years and most important he operates his own business.

If the tree farmer sells the standing firewood at 10,000 baht/rai to the merchant and the merchant pays 6,040 baht/rai for all the charcoal production operation costs, the merchants will make a profit of 5,438.75 baht/rai (21,478.75 - 16,040).

Table 4.9. Benefit/Cost ration of private mangrove plantations.

Sale Price (Baht/Rai)	Benefit/Cost ratio at different reduction rates.			
	9%	12%	13%	14%
8,000	3.30	2.57	2.37	2.18
9,000	3.72	2.89	2.66	2.45
10,000	4.13	3.22	2.96	2.72

Socio-economic condition

General features and social organization

The village of Yeesarn was established before 1932. At that time the mangrove forests included scattered *Avicennia marina* and *Nypa fruticans*. Residents from that time point out that *Rhizophora apiculata* also occurred naturally on the mudflat areas. In 1943 - 1944, the Royal Forest Department made a survey of the lands in this area and found that plantation of *Rhizophora apiculata* were being established by the inhabitants using their own investments and technology. This kind of land use was classified as agricultural land, therefore, the government decided to offer certificates of ownership in 1955 and again in 1961 and 1973 to the inhabitants. The village was then declared legally established and each family generally owned from 10 to 100 rais. A few families owned more than 100 rais.

Reforestation with *Rhizophora apiculata* in the area started in 1932 after the introduction of a small charcoal kiln constructed by Mr. Samran Phaochinda of nearby Bangtaboon village, Amphoe Banlaem, Petchaburi province following an example from mangrove charcoal production in the southern provinces of Thailand. In 1936, M. Luen Srisai of Yeesarn village built a charcoal kiln and from then on plantations with *R. apiculata* were commonly practiced and many charcoal kilns were built.

The village of Yeesarn is made up of 3 ethnic groups; Buddhists, Muslims and Christians. The majority are Buddhists. Before 1975, there was no road connection to the main road for access to the town. The only means of transportation was by boat which was very inconvenient because of the fluctuating neap and high tides in the canals. In 1975, a new road was constructed to connect the village with the highway at Km 72 - 73 providing road transportation to the market. This new access made it easier to ship agricultural products, including shrimp from farming.

Most of the labour for firewood cutting comes from poor families in the village and northeast Thailand. The wages for cutting, bucking and debarking of 1,000 billets is 300 baht which is quite similar to shrimp farm work. A couple (man and wife) can produce about 800 billets per day plus a premium from selling prop roots and small branches used for firing port firewood to the charcoal kilns. It is possible to earn almost 300 baht/day. The family usually asks for an advance rice ration from the charcoal entrepreneurs or plantation owners for their household consumption while working on firewood cutting. They also catch fish, shrimps or crustaceans from the canals for their daily protein.

Table 4.10. Net Present Value of investment return at different reduction rates and selling prices.

Selling Price (Baht/Rai)	Reduction rate.			
	9%	12%	13%	14%
8,000	1,983.15	1,255.04	1,065.74	897.98
9,000	2,338.68	1,511.72	1,296.44	1,105.54
10,000	1,694.22	1,768.39	1,527.15	1,313.10

Current economic situation

According to interviews with household heads in the village, living conditions are rather good for 75 percent of the villagers who own enough land for mangrove plantation and shrimp farming. A family with 400 rai of mangrove plantation may depend solely on the plantation business for its income. Small size planting area can not provide enough income. Fishing is not a main occupation of the villagers. Several families supplement food for family consumption by fishing in the canal using long-lines and cast-nets. Shrimp paste from this village is well known for its quality and is one of the additional income generators for the diligent families.

For families who own less than 10 rai of land, they must make intensive use of the lands in order to receive a satisfactory income. This may take the form of converting to shrimp farming or intensive farming, depending on their investment capability. An issue to be faced in the future is that if arable lands are intensively converted into shrimp farms, there will be no land left for traditional food production.

Problems/constraints in maintaining/promoting the mangrove plantation system

Problems and constraints

Starting in 1932, with initial plantation establishment technical problems were solved by trial and error. The farmers used to acquire propagules from other sites but found them unsuitable. Therefore, propagules are now collected locally for planting in September to December. Propagules sown after clear-felling are susceptible to attach by white crabs which bite the new seedlings and mortality rates are rather high. There needs to be some research on how to control the white crab.

Except for the question of 'spacing', farmers seem to understand the mangrove plantation practices quite well. From experience in other areas, 1 m x 1 m to 1.5 m x 1.5 m spacing offers the highest tree biomass at ages 15 or 20 years compared with other spacings. Spacing of 0.63 m x 0.63 m, presently practiced, hinders diameter growth of the trees from 5 years old onwards.

The farmers complain about the inconvenience of applying for permits of transporting charcoal from the kiln to the market. This permit is within the authority of the Ampex forest officials. It is suggested that forest official should speed up the permission.

Promotion and maintenance of plantation business

In general, large land owners with more than 400 rais are proud of the sustainable management of their mangrove plantations. They also claim that they are highly satisfied with the incomes from selling 35 to 40 rais/year of 12 year old stock. Some farmers who own charcoal kiln thus, they can earn additional money, rather than selling the unprocessed firewood through merchants or middle-men. The charcoal market demand is unlimited at this time. Merchants are buying charcoal, direct from the kilns, at 4.00 baht/kg.

Conclusions

Mangrove forests are a very important natural resource in Thailand and elsewhere. The establishment of mangrove plantation is usually practiced in government land or land under long term concessions. Private mangrove plantations programme are only reported in some countries in the world.

In Thailand, the Yeesarn villagers, Amphoe Amphawa, Samut Songkram province started their own plantings of *Avicennia marina* only for firewood on the mudflats and flatlands under the influence of sea water prior to 1932. In 1936 small charcoal kilns were introducted into the village. The mangrove species used then changed to *Rhizophora apiculata* which grows faster and can be harvested for a sustainable yield for charcoal production at the age of 10 - 12 years. It was accepted as one promising use of land by many landowners. The planting techniques and management were developed by trial and error. The financial input for a 12 year old plantation is 1,152 baht/rai. If the owner sells the standing firewood, which is about 25 m^3/rai, they will receive about 10,000 baht/rai depending on the tree size and stand density. The middle-men or merchants will pay for the whole charcoal production process, from cutting to transportation to the market in Bangkok at 6,040 baht/rai. They can sell the charcoal and uncarbonized firewood for 21,478.75 baht/rai. Therefore, the middle-men or merchants will make a net profit of 5,438.75 baht/rai.

For the landowners, the economic analysis shows that the investment at 12 years rotation will give a benefit net return of 23.5, 25.0 and 26.2% if the sell price of the standing firewood is 8,000, 9,000 and 10,000 baht/rai, respectively.

The income from the plantation investment seems to satisfy the landowners, kiln owners and wage workers.

The case study of Yeesarn Village shows that the wise use or sustainable management of mangrove plantations for charcoal making by local villagers is possible, and in fact it has been practiced for over 50 years.

Case studies of non-sustainable use

Human activities have direct impact on the deteriorating conditions of natural resources and on the quality of the environment in the mangrove ecosystem. Changes in mangrove community structure in term of abundance, biomass and species composition clearly reveal the response of these species to environmental changes and to human activities. In order to manage the mangrove forest resources properly, more research on the impact is needed. Case studies of non-sustainable use emphasized here are the conversion of mangrove forests to aquaculture ponds and tin mining.

Conversion of mangrove forests to aquaculture ponds especially to shrimp ponds is the major factor leading to extensive loss of mangrove area and their high productivity.

Gajaseni *et al.* (1982) carried out comparative ecological studies of the fauna of disturbed and natural mangrove forest. Species composition, density, biomass of macrofauna and selected environmental factors were monitored in four adjacent habitats of the mangrove ecosystem; natural mangrove forest, mangrove plantation, natural mangrove where *Lumnitzera racemosa* was dominant and mangrove area disturbed for shrimp farming. *Rhizophora apiculata* and nine other associated species dominated the natural forest. In terms of number of species present in the area density, biomass and species diversity index, the natural forest showed the highest values. The crab, *Chiromantes eumolpe* and Gammarid amphipods were most common. These animals were found in various sizes indicating the availability of food and suitable microhabitat for shelter in the natural mangrove forest. Small grapsid crabs were common in the mangrove plantation and aggregated in the flooded areas. Few species of adult crabs were detected in the natural forest where *Lumnitzera racemosa* is dominant and in the disturbed forest. These crabs were *Chiromantes eumolpe, Neoepisesarma mederi* and *Parasesarma lanckesteri*. Species diversity indices calculated for the natural forest ranged 0.00840 - 0.5168 were highest as compared to those of other habitats. Gajaseni *et al.* finally concluded that the impact of natural mangrove destruction was evidenced by the calculations of Similarity, Dominance and Species Diversity on the complexity and Stability of the mangrove ecosystem. Reestablishment of stability seemed to be a discouraging effort. Other negative impacts due to aquaculture are the adverse change in the freshwater regimes of the unreclaimed seaward mangrove and the accumulation of pesticides and organic wastes leading to eutrophic problems in the coastal waters have also been studied recently. Piyakarnchana *et al.* (1979) conducted a comparative study on the mangrove forests along the banks of the Mae Klong River, Samut Songkram Province. On the east bank, the mangrove forests were partly cleared for shrimp farms. The forests were still in good condition. However, the mangrove forests on the west bank were in deteriorating condition due to excessive cutting for fuel. The study revealed that the benthic communities on the east bank were richer in terms of species and abundance than the west bank. Fiddler crabs, grapsid crabs, hermit crabs, alphaeid shrimps, horseshoe crabs and barnacles were dominant.

Reclamation of mangrove forests for aquaculture often raises the question of the cost-benefit analysis of such activities. The economic impact on coastal fisheries especially on the small-scaled fisheries must be taken into serious consideration. Negative impacts due to shrimp farming are extensive loss of mangrove areas and of their high productivity, the accumulation of pollutants especially organic pollutants released from shrimp ponds. Impacts of aquaculture on the mangrove communities have already been demonstrated by Piyakarnchana *et al.* (1979) and Gajaseni *et al.* (1982). Public awareness especially of the villagers living within the vicinity of the mangroves on the importance of mangrove forests as related to fishery resources should be encouraged. For local fishermen, it is hard to accept that the abundance of fishery resources that they have become accustomed to is diminishing to scarcity. It is difficult for them to change their ways of living due to the lack of money and job-training in the new jobs. These people are helpless and slowly slipping into more debts and bankruptcy. They may either migrate to other places as in the case of the people at Ko Lao and Had Sai Khao in the Ranong mangrove forests. They are joining the fate of other small-scale fishermen in Songkhla, Trang and Krabi Provinces. In these places, the mangrove forests have nearly disappeared thus natural abundance is a thing of the past. However the fates of these fishermen have not received as much government attention as the cries from rich commercial shrimp farmers.

Approximately 1.8% of mangrove forests on the Andaman coastline of Thailand especially in

Ranong Phang-nga and Phuket Provinces have been utilized by the mining industry. The major effect of mining activities was the deposition of sediment. Excessive sedimentation is detrimental to mangroves because it blocks the exchange of water, nutrients and gases within the substrate and between the substrate and overlying water. Mining activities also cause increased water turbidity and siltation in the mangroves and in the related coastal waters. These result in changes in primary production and in the structure of the marine benthic community. The effect of water quality on primary production was demonstrated by Bhovichitra *et al.* (1982) and Voramongkol (1984). Bhovichitra *et al.* compared mining effects on mangrove estuarine ecosystems at Ranong Province. Klong Ngao, one of the two study sites, was under the influence of mining disposal, while at Klong Kapur, the mangrove forest was not disturbed by mining. In terms of primary production, they concluded that the undisturbed mangrove forest at Kapur had a suitable nutrient supply for primary producers. The average phytoplankton measured as number of cells per liter at Klong Kapur was 91,090, which is a marked difference from 7,510 cell/liter of Klong Ngao. In contrast, Voramongkol demonstrated by bioassay experiments that when waters from tin mines, which were rich in nutrients were mixed with sea water, the gross primary production increased.

Impacts of mining activities on the mangrove plant communities were studied by Srisawasdi (1982), Aksornkoae (1982), Aksornkoae *et al.* (1982) and Kongsangchai (1984). Reforestation of denuded mangrove areas from mining is currently being done with some success, but the seedlings show slow growth and high mortality (Srisawasdi, 1982), as compared to mangrove plantations in natural disturbed mangrove forests (Aksornkoae, 1982). Kongsangchai (1984) concluded that the growth of mangrove plants on abandoned mining areas in terms of height increment is lower than that of plantations in areas where mining activities have never taken place. With regard to the total dry weight increment, the biomass of 1 - 4 years old plantations on abandoned mining areas (102.5 - 4 dry wt/tree) was lower than that of the 1 - 4 year old plantations in non-mined areas (369.7 - 5,970.1 g dry/wt/tree). The mortality of mangrove seedlings in abandoned mining area was approximately 15 - 20%, whereas in areas where mining had never been done was only 5 to 10%. Structural characteristics of the undisturbed natural mangrove forest and mangrove forest near the mining area were investigated by Aksornkoae *et al.* (1982) at Kapur District and Muang District, Ranong Province, respectively. Species composition, zonation, species diversity, density, volume of the stand, litter production and decomposition rates of the two forests were recorded. The results indicated that the species composition of both mangrove areas including dominant and associate species were similar. However, the number of species was limited in the proximity of the mining area but it was greater in the mangrove far from the mining area. Zonation was different. The *Sonneratia-Aegiceras* community dominated certain zones along the margin of the estuaries or the rivers at the areas nearest to the mining sites while in the undisturbed natural mangrove forests the *Rhizophora-Bruguiera* community prevailed. The *Avicennia* community occupied the landward side of the disturbed forest nearest to the mining site. The community generally occupies the zone along the margin of the estuary or river. The *Avicennia* community was observed on the sediment bank that resulted from excessive sedimentation due to mining. The density of trees with a diameter of 30 cm. above root collar for *Rhizophora* species and diameter at breast height for other species exceeding 4 cm.

Havanond (1985) studied the influence of deposited sediment from mines on structure and productivity of mangrove forest at Klong Had Ki, Amphoe Muang Phang-nga Province. He found high deposits of sediments at the forest edge where the area was rather flat. The amount of deposited sediments decreased from the river bank towards the land side. The rate of deposition of sediment in the mangroves in this area was approximately 2.3 cm/yr. The sediment is mainly composed of clay with low organic content. The species composition was not affected by the sediment but the only species that seems to be very common in this area is *Aegiceras corniculatum*, while it is rare in the undisturbed mangroves. The sediment highly affects species zonation, density and growth rates of tree species and seedlings.

Impacts of mining activity on the animal communities within the mangrove forests are few as compared to those studies on offshore communities. Piyakarnchana (1988) compared the benthic community in the post-mining area in Phang-nga Bay. Three areas were chosen in the study. The first area has been under reforestation program for 10 years, the second was 5 years and the last has been under such program for only 4 months. The biomass of the benthos in the last area was extremely low. However after the period of 9 months, increasing trend of benthic abundance was observed.

Environmental impacts of the offshore mining on the marine benthic community structure in terms of changes in density, diversity and biomass and recolonization processes were demonstrated by Nateewatana *et al.* (1983) Prasertwong *et al.* (1984) and Bussarawit & Prasertwong (1984). Their work was mainly on the impact of mining activities on the benthic communities of the western coast at Phuket. Changes in marine benthic community structures after offshore mining in terms of recolonization also was investigated. Successions in the benthic communities were observed. Nateewatana *et al.* (1982) had monitored the impact of sediment loads from mining on the benthic communities during 1980 - 1982 off the coast of Phuket. They found that there was a remark-able increase of density in several benthic species in 1982 as compared to 1981. This indicated the succession processes that took place in the benthos. Recolonization processes which occurred in the area were complex. This was due to the fact that each benthic species showed different responses to environmental stresses. Prasertwong *et al.* (1984) further investigated the changes in marine benthic community structures in terms of recolonization after offshore mining. The same succession processes were observed. They found that the mining activity caused serious changes in the crustacean, mollusc, echinoderm and fish communities. Polychaetes belonging to the Family Eunicidae were the most tolerant species. This was clearly evidenced by their abundance and wide distribution. Opportunistic groups such as amphipod and polychaetes of the families Orbiniidae and Spionidae reproduce rapidly and are more tolerant to changes in the sediment, recolonize the area quickly before the actual pioneer species build up their populations. Interpretation of the log-normal distribution analysis in this study revealed that the benthic community regained an equilibrium state and returned to a typical log-normal distribution 17 years after the post-mining phase. However this is a new equilibrium with the environment. Recolonization by amphipods after offshore mining, investigated by Bussarawit & Prasertwong (1984), revealed that amphipods rapidly built up their population in terms of density. *Grandidierella megnae* and *Ampelisca misakiensis* were the two opportunistic species. These amphipods burrow in a sand-tube which protects them from predators. These two species reproduced rapidly resulting in an increase in density during the first post-mining year. These amphipods are typically opportunistic species being small in size and with a high reproductive rate; they produce many larvae simultaneously and they are deposit feeders well-adapted to changes in the sediments.

Guideline for sustainable mangrove resources management

Mangrove forest is rich in diverse living resources and it has long been important in the subsistence of a large percentage of population of the country. Mangrove forest also attained great economic significance because of their direct resource utilization in forestry and fisheries products and in view of its potential in protecting coastline and maintaining estuarine ecological balance.

Rapid developments in mangrove forest for various purposes are increasing each year and have led to uncontrolled and destructive use patterns frequently associated with pollution and environmental degradation. Based on these situations, mangrove forest should be reserved for conservation. In fact, the mangrove resources are badly needed for daily life and they can be renewable, therefore, the utilization of these resources are still possible but must be on a sustained yield basis with a minimum of conversion or destruction. To achieve sustainable management of mangrove resources, the following important guidelines are recommended:

1. Mangrove land use zoning should be made in order to avoid the conflict of mangrove land utilization, and the area must be classified into 3 main zones; conservation, management and conversion. In Thailand, 3 mangrove land use zones are declared and details of each zone are already discussed in Section 4.3. Mangrove zones should be outlined for the following activities. Conservation zone must be not allowed for any development activities. This zone must be strictly controlled and backed-up by an effective enforcement mechanism.

   Management zone will cover two parts:

   1. Sustainable management for timber production. A silvicultural system for timber harvesting should minimize environmental impact. Clear felling in alternative strips or in blocks is an appropriate silvicultural system or

harvesting method. Rotation period should be set to maximise production. Logging operation or any mangrove management activities must be strictly followed by laws, regulation, terms and conditions issued by the government.

2. Sustainable management for fisheries production. The forest should maintain the habitat sustaining fish and crustacean, which can be harvested in the mangrove area and in the adjacent estuarine, lagoonal or marine waters. In practice, it should be possible to combine management for both fisheries and forestry products.

2. Conservation zones are provided for other uses, such as aquaculture (fish and shrimp ponds), salt farms, agriculture, urban and industrial development. These zones should be located, as much as possible, away from the shoreline, riverbank and/or behind the mangrove forests. Projects may be permitted in these zones, but an environmental impact assessment is required by the office of the Environment Board to ensure that the proposed projects will not show any effects on environment or mangrove ecosystems as a whole. Only then can projects be granted permission for implementation by the Royal Forest Department.

   1. Reforestation of mangrove should be long-term planned for implementation. The mangrove plantations must be operated not only by the Royal Forest Department but also by public and private sectors.

   2. The multiple-use management system approach. This, rather than the single-use one, should be emphasized for sustainable management of mangrove resources. Some recommended systems for the farmers are as follows:

      a). The integrated management system involving mangrove plantation and aquaculture, fish and shrimp farming used in Indonesia can be applied to avoid clearing mangrove forests for aquaculture purposes only. Called tumpang sari or silvi-fishery system in Indonesia, this system saves natural mangrove formations and provides traditional fisheries products.

      The fish or shrimp ponds are constructed around the plantation by digging a small canal, about 5 m in width and 1.5 m in depth. The ditch area for raising fish or shrimp is approximately 20-30% of the total area. The total area of plantation with ditches is usually about 5 ha. Villagers identified by a government agency take care of the plantation and the fish or shrimp ponds. They collect the fish or shrimp, while the government agency gets the wood from the plantation. It is hoped that by using this integrated management system, proven effective in Indonesia, the clearing of mangrove areas for aquaculture only could be diminished or even stopped in the future.

      b) Management System Using Mangrove Forest for Agriculture. Indonesia is the leading country in practicing this, another tumpang sari system. Basically, it is for growing agricultural crops, especially rice. The inner part of the mangrove forest is used or clear-felled. Then a ditch or small canal 3 - 5 m wide is dug around the cultivation 1 - 2 m above the high-tide mark. When it rains, salt is drained into the ditch. Rice or other agricultural crops are planted when soil conditions are suitable, i.e., in the absence of too much salt in the soil. With this method, the mangrove forest can be permanently used for agriculture, which reaps high returns.

      c). Salt Ponds. Salt production from mangrove forest areas in Thailand has been highly successful. The simple system involves clear-felling the mangrove areas at the driest and saltiest inland site. Ponds 50 cm deep are dug and seawater is pumped, in some areas by windmills. Solar radiation evaporates the seawater, so salt production is done only during the hot season. *Rhizophora* spp. can be grown on the dikes of the salt pond. When these trees are 7 - 10 years old, they can be used as firewood for charcoal burning. The combination of plantation and salt production is a good multiple-use system in which the owner benefits from different products.

3. Basic research of mangrove ecosystems should be continually carried out to satisfy all of the likely needs of effective sustainable management. Research on logging and

extraction method, charcoal burning process, artificial regeneration (plantation), optimum rotation and thinning process, multiple-use system for sustainable management of mangrove resources, socio-economic condition of population utilizing mangrove resources are of important outlines for priority investigation. A national data base of mangrove resources should be created.

4. To fully achieve sustainable management of mangrove resources the following important issues must also be emphasized, in addition to the recommendations mentioned above:

   a) Education: Education helps ensure public support for legislation and for the enforcement of regulations controlling land use of mangrove areas. Special education is necessary for those who live in and near mangrove areas, for public officials, administrators, and also for school children and biology students. Education program should emphasize the ecological and economic values of mangrove ecosystems and natural resources, and should help generate support for regulations protecting the mangroves.

   b) Public participation: Public participation is important for sustainable management of mangrove resources. As the inhabitants are usually the owners and users of natural mangrove forests, their understanding of the mangrove is vital. If they practice management and conservation measures, the destruction of mangrove forest will decrease or can be stopped. New concepts of "social forestry", forest community and agroforestry "silvo-fishery" must be introduced to the public to effect two-way communication.

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Country Report of Fiji on the Economic and Environmental Value of Mangrove Forest and Present Sate of Conservation*

-Report-

1. GENERAL DESCRIPTION - THE FIJI ISLANDS

Fiji comprises of about 840 Islands and islets in the South Pacific Ocean and is part of the Melanesian island group. It lies approximately between 176 degrees 30' East to 177 degrees 00' west of Greenwich and between 12 degrees 30' to 21' 20" south of Equator, and is about 1700 kilometres north of New Zealand.

Although the islands spread across an area of 116,000 square kilometres only about one hundred of these are inhabited. The islands are mostly of volcanic origin and include numerous atolls and reefs. The total land area of the country including the islands of Rotuma, which is a dependency of Fiji, is 18,333 square kilometres. The Islands vary in sizes ranging from the great island of Viti Levu which covers 10,429 square kilometres to mere rocks a few metres in circumference.

The main islands are volcanic, forming steep rocky sided mountains. The volcanic islands contrast strongly with the coral atolls. Starting on a rock foundation near the surface of the sea, layer upon layer of fragile coral polyps grow. Islets formed in this way are generally not very high, but these are protected from the ocean waves by a fringing coral reef which grows around them.

The sheltered lagoons have colourful plants and fish, providing food sources to the people. The volcanic islands (highest point being 1310 metres (4300 feet) above sea level) also have coral reefs growing around their coastline.

Being in the tropics, means there is much sunshine with heavy rainfall as well. Fiji therefore experiences what is known as Tropical Maritime Climate. It is never too hot nor too cold. Temperatures stay mostly between 20 to 30 degrees Celcius. The climate is seasonal, this being more marked on the leeward side of the larger islands. The hot wet season from November to April is characterised by variable wind directions and rainfall, as the intertropical convergence zone swings south. The cool dry season is determined by the steady blowing of the south east trades.

Rainfall is the most important climatic factor in Fiji and determines to a large extent the contrasting vegetation zones found on the major islands. There is high variability in rainfall both from month to month and year to year.

Suva in the windward coast has a mean of 321 mm/month while Nadi on the leeward coast has a mean of 165 mm/monthly (68 year averages); the majority falls in the months from November to April. There is therefore a distinct dry season on the western side of the main islands.

The relative humidity is high throughout the group but not uniform. At Suva the mean relative humidities are 80% and 75% at 0800 hrs and 1400 hrs respectively. The figures are about 10% less at Nadi on the western coast of Viti Levu. In Suva, there is little variation from month to month but on the western side readings as low as 40% may be experienced in the dry season.

The population of Fiji (estimated on 31-12-89) was about 727,104, comprising about 48% Indigenous Fijians, 46% Indians and the balance-Europeans, Chinese and Various other Pacific Islanders. The principal languages are Fijian and Hindi with English as official language.

Administratively, Fiji is divided into four Divisions, geographically. There are the Western Division, Northern Division, the Central Division and the Eastern Division. See Fig. I

1.1 DISTRIBUTION AND EXTENT OF MANGROVES

Mangrove Ecosystems, in Fiji, as elsewhere in the World are generally associated with riverine/esturine deltas and sheltered coastline with low energy waves (Chapman 1977).

The total mangrove area in Fiji has been variably reported as between 19,700 ha (Saenger *et al.* 1983) and 49,777 ha (Fiji Government as cited in Richmond and Ackerman, 1975).

* This report refers to a project entitled Economic and Environmental Value of Mangrove Forest and Present State of Conservation, supported by ITTO and implemented by JIAM.

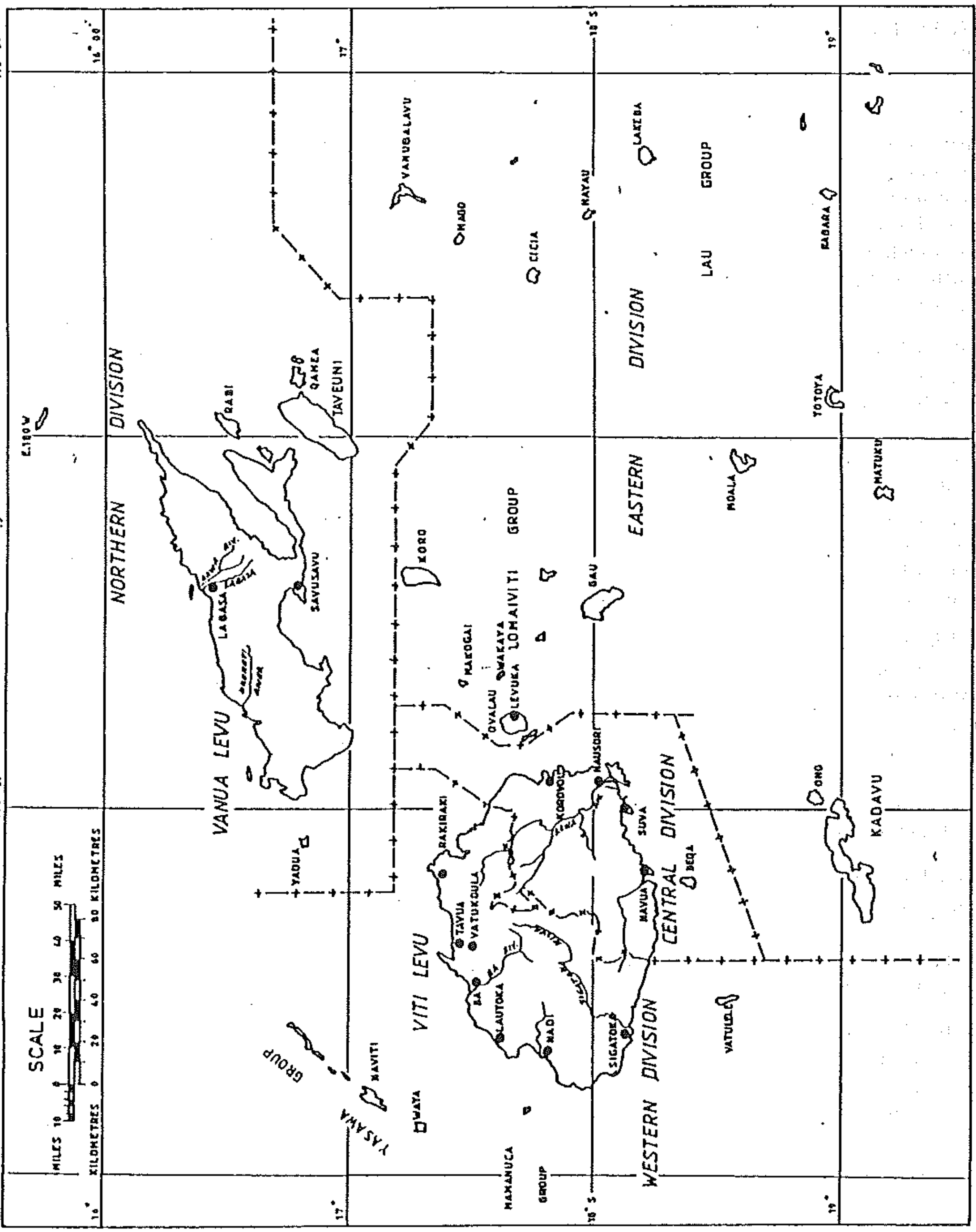

Figure I. Map of Fiji showing the main towns, rivers and divisions.

The present estimate (Watling 1985) of 38,543 ha covers the main islands of Vitilevu and Vanua Levu. Mangroves are also found on other smaller islands but the extent of their distribution is not known. Therefore the figure of 38543 ha is definitely on the lower side, considering the whole of the Fiji group.

Mangroves, being found on the land-water interface, from the basis of an ecosystem which comprises of both terrestrial as well as aquatic subsystems and do not constitute a homogeneous ecosystem. In Fiji detailed scientific information on the fauna and flora associates of the mangrove ecosystem is very scant, with the result that an understanding about the relationships and specific physico-chemical processes within the coastal waters is almost non-existent. However, studies elsewhere in the world have showed that a variety of different communities are found depending on the interaction between factors such as aridity, wave energy, tidal conditions, sedimentation, mineralogy and neotechtonic effects (Jennings and Bird 1967, Oliver 1982, Thom 1982).

1.2 FOREST TYPES AND ASSOCIATED FLORA

Floristically, Fiji's mangroves are simple, being dominated by three species and a putative hybrid, all belonging to the family Rhizophoraceae (Richmond and Ackerman 1975)- *Bruguiera gymnorhiza*, *Rhizophora stylosa*, *R. samoensis* and *R. selala* (Putative hybrid of *R. samoensis* and *R. stylosa*).

Four other commonly found tree species and a fern which is also associated with mangrove forests include:

Xylocarpus granatum, *Lumnitzera littorea*, *Excoecaria agallocha* L., *Heritiera littoralis*, *Acrostichum aureum*. Refer Table I and II.

Descriptions of the zonation of Fijian Mangroves can be found in Richmond and Ackerman (1975), Hassal (1984) and in particular Watling (1985, 1986) which distinguishes 15 mangrove vegetation alliances from five locations.

The underlying structure of mangrove zonation is relatively simple. Climate conditions are important. In the dry, leeward areas, hypersaline mudflats are characteristic feature which are virtually absent from the wetter, windward mangrove areas. The latter mangroves are far more luxuriant than those of the leeward coasts,

Table I. Principal Species of Fijian Mangrove Vegetation.

Common Name	Scientific Names
"Dogo"*	*Bruguiera gymnorhiza* (L.) Lam
"Tiri tabua"*	*Rhizophora stylosa* Griff
"Tiri wai"*	*R. samoensis* (Horchr.) Salvoza (Tomlinson, 1978)
"Selala"*	*R. x selala* Tomlinson putative hybrid of *R. samoensis* and *R. stylosa*
"Dabi"	*Xylocarpus granatum* Koenig
"Saqali"	*Lumnitzera littorea* (Kack) Voigt
"Sinu gaga"	*Excoecaria agallocha* L.
"Kedra ivi na yalewa kalou"	*Heritiera littoralis* Dryand
"Boreti" Ferns	*Acrostichum aureum*

Note: *Dominant species
Source: Richmond and Ackerman (1975)

but in both areas the best developed mangroves are associated with estuarine conditions.

Rhizophora stylosa is dominant in all exposed locations and is particularly associated with sandy or coarse substrates. In leeward dry areas it is found at the seaward leading edge as a narrow fringe of about 5 m, followed by a zone of taller trees up to 15 metres. In extensive mangrove formations, large areas of stunted *R. stylosa* of 1-2 m are found behind these zones and they often surround or lie adjacent to hyper-saline mudflats.

Rhizophora samoensis is most frequently encountered bordering the depositional sides of rivers and creeks, over soft, fine grained substrates, to the virtual but not complete exclusion of *R. stylosa*; the same progression of decreasing height from sea coast to land is also noted from river/coast to land. *R. samoensis* may be co-dominant with *R. stylosa* in some central stunted growth and may also occur in the seaward fringe but never as extensively as *R. stylosa*.

The *selala* hybrid displays wide ecological amplitude occurring either inter-mixed with *R. stylosa* and *R. samoensis* or in stands of its own.

Bruguiera gymnorhiza is dominant with canopy heights up to 18 m in large areas of "Basin Forest" formations of the Rewa Delta and some other localities of the wetter zone. Here it is also found at the landward side of coastal mangrove

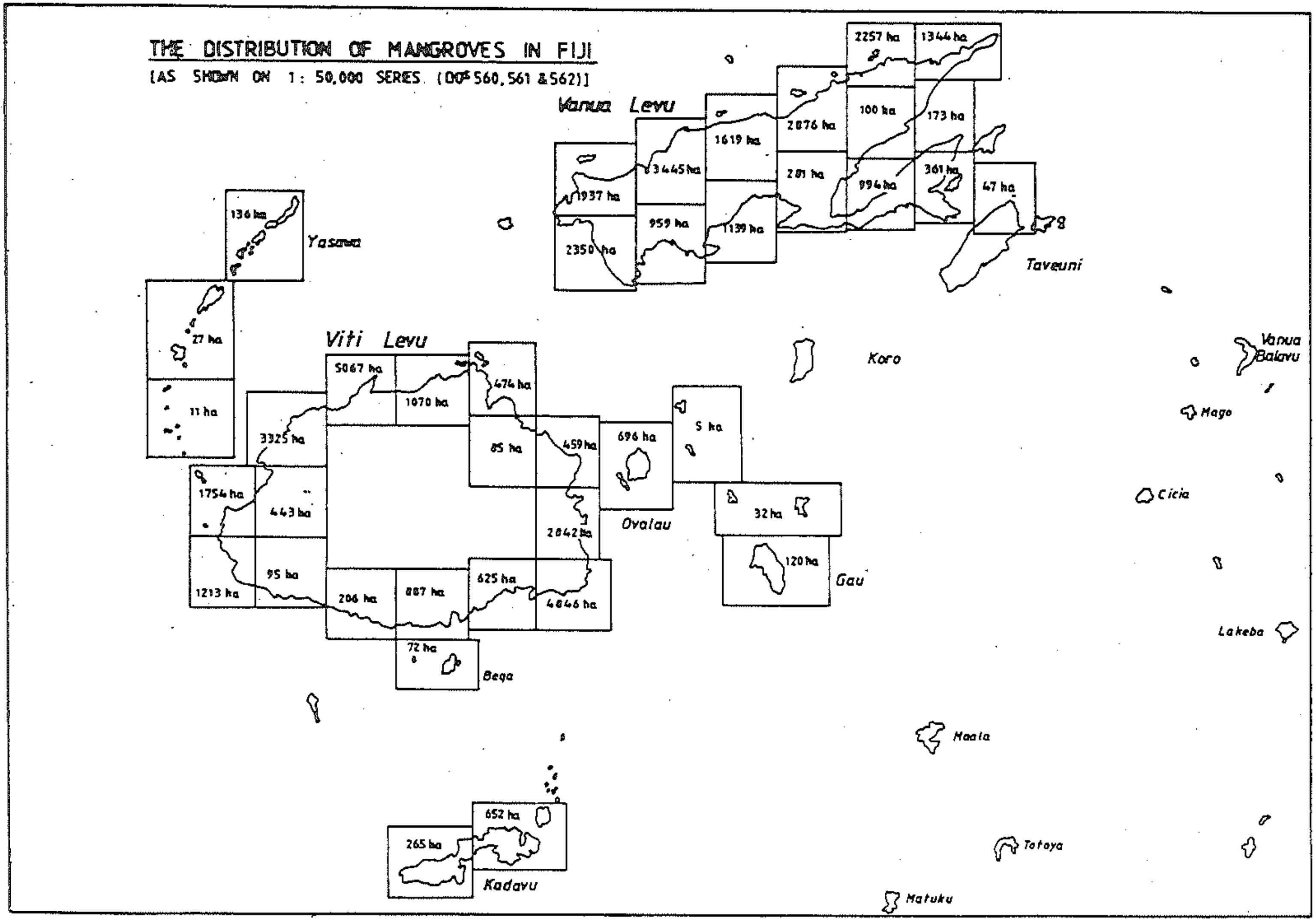

Figure II. The distribution of mangroves in Fiji.

Table II. Shows the common non-exclusive mangrove species together with less common, non-exclusive mangrove species.

Common, non-exclusive mangrove species (*- introduced species)	Less common, non-exclusive mangrove species
Abrus precatorius	*Abrus precatorius*
Acrostichum aureum	*Alleurites mollucana*
*Annona glabra**	*Annona reticulata**
Asplenium australasicum	*Antrophyum subfalcatum*
Barringtonia asiatica	*Artyra brackenridgei*
B. racemosa	*Atuna racemosa*
Bulbophyllum longiscapum	*Barringtonia edulis*
Calophyllum inophyllum	*Brachiara paspaloides**
Cerbera manghas	*Canthium barbatum*
Clerodendrum inerme	*Ctenopteris sp.*
Cocos nucifera	*Dillenia biflora*
Colubrina asiatica	*Drynaria rigidula*
Culcita straminea	*Dysorylum richii*
Davallia sp.	*Elattostachys falcata*
Derris trifoliata	*Eria rostriflora*
Entada phaseoloides	*Fagraea barteriana*
Epipremnum pinnatumn	*Flagellaria indica*
Ficus obliqua	*Ficus vitiensis*
Grammatophyllum elegans	*Freycinetta caudata*
Hibiscus tiliaceus	*Hoya dittera*
Hoya australis	*Pomoea gracilis*
Inocarpus fagiferus	*Ipomoea tuba*
Intsia bijuga	*Macaranga sp.*
Ipomoea brasiliensis	*Merremia peltata*
Lycopodium phlegmaria	*M. umbellata*
L. trifoliata	*Metroxylon vitiense*
Nephrolepis hirsutula	*Mikania micrantha**
Oberonia heliophila	*Morinda citrifolia*
Pandanus pyriformis	*Orchrosia oppositifolia*
Pandanus pyriformis	*Passiflora foetida**
Paspalum distichum	*Piper aduncum**
Pongamia pinnata	*Pittosporum richii*
Pyrossia adnascens	*Premna taitensis*
Sciropendron ghaeri	*Pisidium guajava**
Smythea lanceata	*Solanum torvum**
Stenochlaena palustris	*Sporobulus virginicus*
Thespesia populnea	*Taeniophyllum fasciola*
Vaginularia angustissima	*Terminalia littoralis*
Vitex trifolia	*Thespesia populnea*
Vittaria elongata	*Thuarea involuta*
Xylocarpus moluccensis	

Baines (1979); Garnock Jones (1978); Hassal (1984); Parham (1972); Pillai (1985); Raj and Seeto (1982); Raj *et al.* (1984); Smith (1981); Tomlinson (1978) and Watling (1985, 1986) are major references for Fijian Mangrove vegetation.

formations. *B. gymnorhiza* is present but never dominates in the dry zone.

Xylocarpus granatum, Lumnitzera littorea, Excoecaria agallocha and *Heritiera littoralis* are usually found along levees of rivers and tidal creeks and in the more elevated landward situations.

R. x *selala* (the hybrid of *R. stylosa* and *R. samoensis*) is known to exist only in Fiji and New Caledonia but may occur in Tonga and Samoa (Smith 1982).

R. x *selala* either as a dominant or in association with other species is common in the mangroves of both the wet and dry zones. As noted by Smith (1981), distinguishing *R.* x *selala* is not always easy and this is especially so in the field.

Table I: Shows the native name and; the scientific names of species mentioned above.

1.3 RELATIVE AREAS OF DIFFERENT FOREST TYPES

It is considered desirable to focus on two deltaic areas one being in the wet zone and the other in the dry zone, in order to give a better understanding of different forest types in the two zones.

i). The Mangroves of Rewa Delta (Wet Zone)

The Rewa River drains approximately 2,980 sq. km or about one third of Viti Levu and discharges of the order of 7,897 million cu. m of water a year. It has been estimated that perhaps 1,600 tonnes of suspended sediment are transported to the mouth of the river each year (Watling 1985). This alluvium has formed Fiji's most fertile and productive delta with approximately 5,130 ha of mangrove.

ii). Mangrove Flora of the Rewa Delta

It is probable that the Rewa Delta would be more extensive if it was not situated on the windward side of Viti Levu and so exposed to the continuous, erosive action of wind and wave. This must be one of the reasons that much of the delta mangrove is in backwater locations. These mangrove communities are the most diverse in the country and the high regular rainfall which the delta receives prevents hyper-saline mudflats forming. There are areas of shrub Tiri (*R. stylosa* and *R. samoensis*), but are limited by comparison with those of the leeward mangrove stands. The landward vegetation element is strong and in many locations there is clinal integradation of terrestrial closed forest into the mangroves.

Six alliances have been distinguished:

(a). **The Seaward Alliance**

This alliance is a mixed fringing forest, found predominantly on the more exposed seaward banks but also extending up some of the larger creeks and rivers. *R. stylosa* (2.4m canopy height) often forms a single belt on the seaward edge with taller threes abruptly behind mixed with Selala, Dogo (*B. gymnorhiza*) and *R. samoensis* having a closed canopy height of 5-12m. Levees in these situations support in addition Dabi (*Xylocarpus granatum*). Sinu (*Excoecaria agallocha*) and other landward species including coconut. Area-248.8 ha, 4.9% of the total area.

(b). **The Rewa Tiri (*Rhizophora*) Alliance**

An extensive formation of the northern Rewa Delta consisting of *R. samoensis* dominated shrub forest with a canopy height of 1-4 m.

Stunted Dogo (*B. gymnorhiza*) Dabi (*X. granatum*) and *R. stylosa* are commonly present. A distinct association of this alliance is a fringing forest of predominantly *R. samoensis* in the less exposed coastal areas and along river banks, the closed canopy varies between 5-9 m.

Area-741.9 ha, 14.5% of the total area.

(c). **Dogo Forest (*B. gymnorhiza*)**

This is an uniform closed forest of almost pure Dogo with a canopy height of 9-15 m, some well developed stands are 18 m or more in height. Within the forest occasional Selala occur with Dabi (*X. granatum*) and Saqali (*Lumnitzera littorea*). Both the Landward Alliance and mixed Alliance merge indistinctly into the Dogo Forest in many locations.

Area-1,820 ha, 35.6% of the mangrove area.

(d). **Mixed Alliance**

The mixed Alliance is a heterogenous open forest of variable and mixed composition with an uneven canopy height of 5-15 m. Dogo and Selala are the dominant species, sometimes forming small discrete stands. *R. samoensis* occurs commonly and also forms limited pure stands, occasionally stunted. The presence of Dabi, Saqali, Sinu and landward vegetation varies greatly with location. Small areas of Boreti fern (*Acrostichum aureum*) are included in this alliance.

Area-1,491 ha, 29.1% of the mangrove area.

(e). **Landward Alliance**

A heterogeneous closed forest of mixed composition forming the floristically most diverse mangrove alliance. Found only in the least exposed situations, the presence of an extensive epiphytic and climbing flora indicates that the alliance is stable, well drained and well protected from storm damage. The most common tree species are Dabi, Dogo and Sinu with a canopy of 10-12 m. *R. samoensis* and Selala occur more rarely and on creek banks. Other common trees are *Terminalia littoralis, Heritiera littoralis, Inocarpus frugiferus, Ficus obliqua, Hibiscus tiliaceus, Pandanus pyriformis* and *Cocos nucifera*.

Area-645.4 ha, 12.6% of the mangrove area.

(f). **Boreti Alliance (*Acrostichum aureum*)**

Some large areas of poorly drained flats support a dense growth of the leather fern or Boreti (*Acrostichum aureum*).

Area-182.4 ha, 3.6% of the mangrove area.

iii). **The mangroves of Labasa Delta (Dry Zone)**

The Labasa Delta lies in the Leeward 'dry' zone of Vanua Levu, receiving a mean annual rainfall of 2,309 mm. (1910-1980 annual average) and experience a distinct dry season which is less marked than at Ba.

The delta is an alluvial fan from three river sources, the Labasa, Qawa and Wailevu which drain the fertile Labasa plains and adjacent foothills, an area of approximately 460 sq. km. The combined annual discharge of the rivers is of the order of 1,065 million cu. m a year (Watling 1985).

The total mangrove area is approximately 1,558 ha.

iv) **Mangrove Flora of the Labasa Delta**

The mangroves of the Labasa Delta are floristically more diverse and the greater biomass per unit area indicates greater productivity than those of the Ba delta (an area in the dry zone in Viti Levu).

The seasonal dry climate has resulted in the characteristic formation of hypersaline mud flats with adjacent stunted Tiri (*Rhizophora*) in the less well drained areas.

There are two distinguished alliances:

(a) The Tiri Alliance (*Rhizophora*)

A closed shrub forest of the poorly drained flats well behind the river banks and the seaward edge, generally with hyper-saline mudflats at their centre. *R. samoensis* dominates the association forming pure stands in most places especially towards the centre. Dogo (*B. gymnorhiza*) and Selala are increasingly found at the outer edge where the Alliance merges with the Dogo Alliance. The canopy height declines from 5-8 m at the periphery to 1.2 m near the mudflats.

The area of tiri alliance is approximately 404 ha, 25.9% of the mangrove area.

(b) The Dogo Alliance - (*Bruguiera gymnorhiza*)

Dogo dominates this Alliance and in many areas forms pure stands of 10-15 m canopy height. Selala and *R. samoensis* either separately or combined form a distinct, vigorous association of limited extent along the river and creek banks, canopy height may reach 15 m. They are more in evidence in a mixed association with Dogo in the seaward fringing stands. *R. stylosa* forms a fringing belt along many parts of the seaward edge but is occasionally displaced by pure *R. samoensis*.

Conversely *R. stylosa* occasionally replaces *R. samoensis* in its more usual riverbank locations. The more landward species Dabi, Saqali and Sinu are locally common especially at the head of the delta where there are some small pockets of typically terrestrial vegetation.

The area of this alliance is approximately 1068 ha or 68.6% of the total.

1.4 FAUNA FOUND WITHIN FOREST TYPES

Raj and Seeto (1982) and Raj *et al.* (1984) provide a preliminary list of mangrove associated fauna. However, Lal *et al.* (1982) is the most comprehensive investigation of the mangrove fish fauna in Fiji.

Project Site:

The study undertaken by Lal was at Wairiki Creek, which is about 20 km west of Suva. The subject area was chosen as the project site because of its relatively undisturbed catchment area with only few housed and limited agricultural development. The mean annual precipitation is about 3,048 mm with no marked dry season. The mean neap tidal range is about 0.9 m and the mean spring tidal range 1.3 m. Mangroves in the Wairiki Creek area cover about 60 ha and species belonging to all three families which occur in Fiji, Meliaceae, Rhizophoraceae and Combretaceae have been recorded there. The Mangrove species recorded were *Rhizophora stylosa, R. samoensis, R.* x *selala, Bruguiera gymnorhiza, Xylocarpus granatum* and *Lumnitzera littorea*. Other flora associates such as orchids, ferns and *Pandanus* as recorded by Hassal (1981) were also found. The Wairiki Creek bottom is usually of mud of 0.3 m or deeper along the main creek but along the coast coralline rocky surfaces were also present.

Over the six months period of study 847 individuals belonging to 42 families of fish and two families of crustaceans were caught. Twelve families of fish and crabs comprised 92% of the catch. See Table III.

Crustaceans:

Portunidae was one of the dominant families by number-11.5% as well as by weight 11.6%.

Species Composition:

The total number of species sampled were 87, these belong to 63 genera of which at least 70 species are of direct food value. Refer Table IV.

Table III. Dominant fish families caught in Wairiki Creek May-October 1982.

Families	No. of Indivi-duals	% com-position	Total Wt. (gm)	% com-position
Mugilidae	120	14.4	31925	22.8
Leiognathidae	119	14.3	4957	3.50
Mullidae	94	11.4	21351	14.8
Lutjanidae	83	9.2	15258	10.8
Lethrinidae	63	8.6	10789	7.6
Gerridae	58	6.9	5560	3.9
Carangidae	45	5.3	4361	2.9
Siganidae	45	5.3	6108	4.2
Polynemidae	24	2.8	3395	2.6
Acanthuridae	19	2.4	1648	1.10
Kuhliidae	14	1.7	1580	1.1
Portunidae	96	11.5	16585	11.6
Sub total	780		1235126	
Total	847		142920	

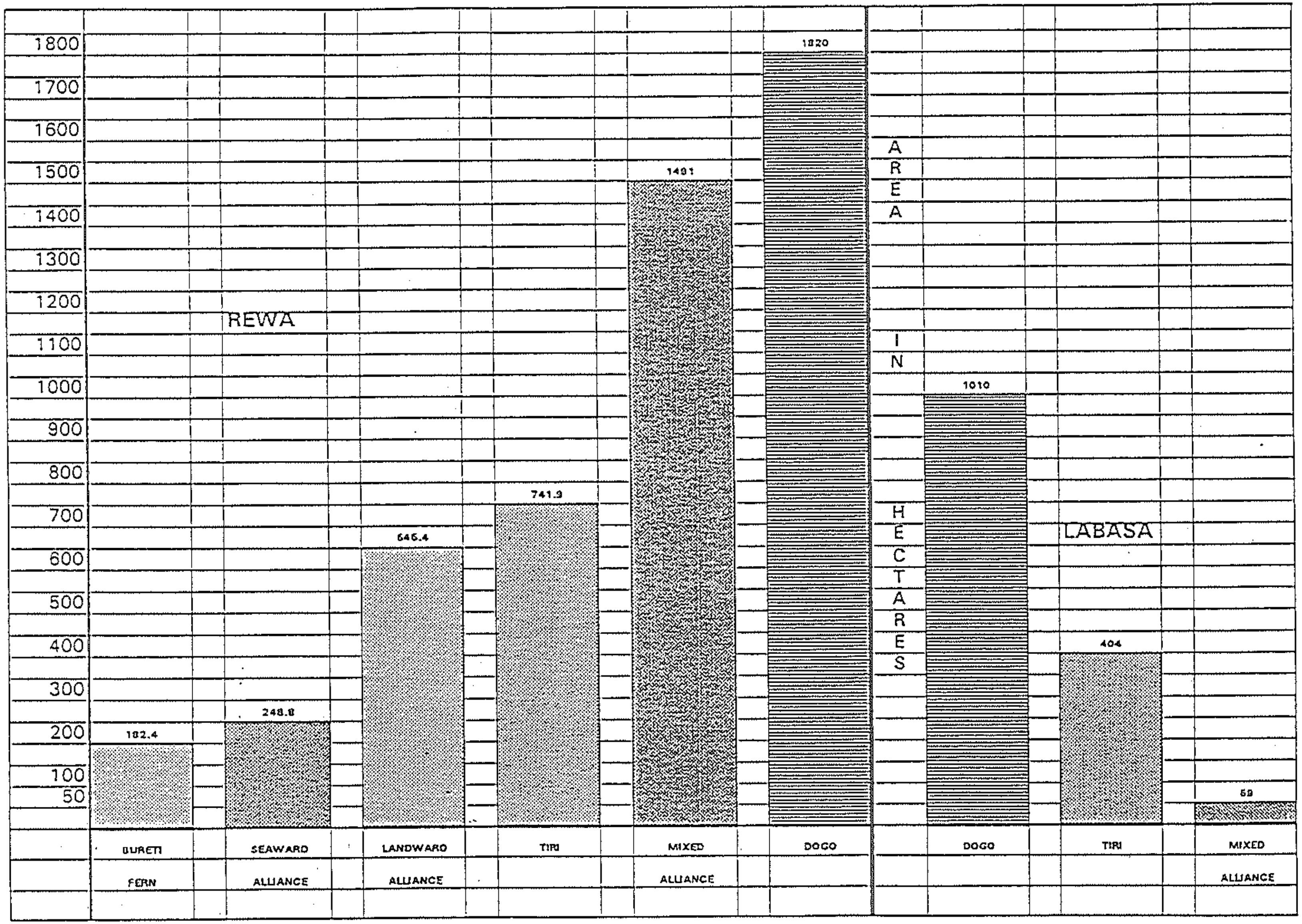

Figure III. Mangrove Forest Composition of Rewa & Labasa Delta.

Table IV. List of fish species caught in Wairiki Creek Mangroves

Scientific Name	English Name	Fijian Name
ACANTHURIDAE		
Acanthurus xanthopterus (Valenciennes)	Rinng-tail Surgeon	Balagi
ANTENNARIIDAE		
Antennarius nummifer (Cuvier)	Ocellated angler fish	
APOGONIIDAE		
+ *Apogon ceramensis* (Bleeker)	Cream Cardinal	Tina
Sphaeramia orbicularis (Cuvier)	Polka-Dot Cardinal Fish	Tina
BELONIDAE		
+ *Strongylura incisa* (Valenciennes)	Large-scaled Long	Saku
BOTHODAE		
+ *Bothus pantherinus* (Ruppell)	Leopard flounder	Dabilai
CARANGIDAE		
+ *Gnathanodon speciosus* (Forskal)	Golden Trevally	Bilu Saqa
+ *Carangoides oblongus* (Cuvier)	Coach-Whip Trevally	Saqa
+ *C. sexfasciatus* (Quoy and Gaimard)	Great Trevally	Saqa
+ *C. ignobilis* (Forskal)	Lowly Trevally	Saqa
+ *C. papuensis* (Alleyne & Mackleay)	Brassy Trevally	Saqa
+ *Tachinotus blochii* (Lacepede)	Snub-nosed dart	Qawaqawa
+ *Scomberoides tol.* (Forskal)	Queen fish	Votonimoli
+ *Scomberoides lysan* (Forskal)	Queen fish	Votonimoli
CARCHARHINIDAE		
+ *Triaenodon obesus* (Ruppell)	Blunt-head Shark	Qio
CHAETODONTIDAE		
Anisochaetodon auriga (Forskal)	Thread-fin Coral Fish	Tivi tivi
A. vagabundus	Vaga bond Coral fish	Tivi tivi
Chaetodon ephippium (Cuvier)	Saddled Coral fish	Tivi tivi
CHIROCENTRIDAE		
+ *Chirocentrus dorab* (Forskal)	Wolf-Herring, Dorab	Voivoi
DACTYLOPTERIDAE		
Dactyloptena orientalis	Purple Flying Gunard	
DASYATIDAI		
+*Amphotistius kuhil* (Muller & Henle)	Blue-spottes stingray	Vai
ELLEOTRIDAE		
+ *Eleotris sp.*		Bo
ENGRAULIDAE		
+ *Stolephorus bataviensis* (Hardenberg)	Golden-belleid anchovy	
EPINEPHELIDAE		
+ *Epinephelus damelii* (Gunther)	Saddles Rock Cod	Kawakawa
+*Epinephelus tauvina* (Forskal)	Greasy Cod	Kawakawa
+ *Epinephelus fuscoguttus* (Forskal)	Flower Cod	Delabulewa
FISTULARIIDAE		
Fistularia petimba (Lacepede)	Smooth Flutemouth	
GERRIDAE		
+*Gerres macrosoma* (Bleeker)	Silver Biddy	Matu
+ *Gerres filamentosus* (Cuvier)	Stopped Silver Biddy	Matu
GOBIIDAE		
Pandaka sp.		
Goby sp.		
HEMIRHAMPHIDAE		
Senarchopterus dispar (Valenciennes)	River Garfish	Busa
+ *Hemirhampus far* (Forskal)	Garfish	Busa
Hemirhampus far (Forskal)	Garfish	Busa
+ *Kuhlia bilunulata* (Here)	Glagtail	Mataba
+ *Kuhlia rupestris* (Lacepede)	Rock Flagtail	Ika droka
KYPHOSIDAE		
Kyphosus vaigiensis (Quoy & Garmard)	Drummer	Sereniwai
LEIOGNATHIDAE		
+ *Gazza minuta* (Bloch)	Common tooth-Poly fish	Kai Kai
+ *Leignathus aquulus* (Forskal)	Common Pony fish	Kai Kai
+ *Letherinus harak* (Bleeker)	Thumb-print Emperor	Kabatia
+ *Mugil cephalus* (Linnaeus)	Mangrove mullet	Kanace
+ *Liza subviridis*		
MURAENIDAE		
+ *Thysoidae macura*		Nawalu
MURAENESOCIDAE		
+ *Muraenox cinereusMur*	Pike eel	Dabea
PERIOPHTHALMIDAE		
Periophthalmus valgaris (Eggert)	Barred mud-skipper	Tiloko
PLATACIEAE		
Platax orbicularis (Forskal)	Narrow-ganded bat fish	Dadrose, vunavuna, naga yalewa
PLECTORHYNCHIDAE		
+ *Psendopristipoma nigra* (Cuvier)	Brown Sweet lips	Sevaseva
PLOTOSIDAE		
+ *Plotosus anguillaris* (Bloch)	Cat-fish eel	Kaboa
POLYNEMIDAE		
+ *Polydactylus plebeius* (Broussonet)	Common thread-fin	Uculuka
+ *Polydactylus microstomus* (Bleeker)	Small-mouthed thread fish	Uculuka
PRIACANTHIDAE		
+ *Priacanthus hamrur* (Forskal)	Lunar-tailed bulkeye	Dovodovo
SCARIDAE		
SCATOPHAGIOAL		
Scatophagus argus (Linnaeus)	Spotted scad	Batikau
SCOMBRIDAE		
+ *Rastrelliger brachysoma* (Bleeker)	Stripped mackerel	Salala
SCORPAENIDAE		
Scropaena aurita		
Dendroscopaena cirrhose (Thuuberg)	Weedy stingfish	
Pterois volitans (Linnaeus)	Redfire fish Scorpion cod	
SIGANIDAE		
+ *Siganus vermiculatus* (Valencieunes)	Vermiculated spine foot	Nuqa
+ *Siganus spinus* (Linnaeus)	Black treevally	Nuqa
SOLEIDAE		
+ *Achirus pavoninus* (Lacepede)	Peococil	Davilai
SPHYRAENIDAE		
+ *Sphyraena barracuda* (Walbauma)	Great Barracuda	Ogo
+ *Sphyraena forsteri* (Cuvier)	Forsters barracuda	Ogo
SYNANCEIIDAE		
Synanceja trachynis (Richardson)	Estuarine stonefish	
SYNODONTIDAE		
Saurida gracilis	Lizard Fish	Utimate
TETRADONTIDAE		
+ *Arothon immaculatus* (Block & Schneider)	Narrow-lined toad fish	Sumusumu
THERAPONIDAE		
+ *Therapon jarbua* (Forskal)	Crescent perch	Qitawa
TRICHIURIDAE		
+ *Trichiurus haumela* (Forskal)	Common hairtail	Tovisi
PORTUNIDAE		
+ *Scylla serrata*	Mangrove crab	qari
Portunus pelagicus		qari
Portunus sanguinolentusq		
XANTHIDAE		
+ *Sesarma sp.*		kuka

+ Food Species

Fiji's artisanal commercial fisheries being dominated by coastal estuaries species are to a large extent dependent on the mangrove ecosystem. Over 60% of our commercially important species at some stage of their life history may utilise mangrove areas. At least 83% of the fish species caught in Wariki Creek's mangroves are utilised as a source of food, while at least two thirds are of commercial importance. (Lal *et al.* 1984).

1.5 ANALYSIS OF LOSS OF MANGROVE DUE TO VARIOUS OTHER KINDS OF LANDUSE

i) Agriculture

Ever since agriculture started in Fiji on a commercial basis there has been small scale in filling of mangrove areas, generally in order to improve field shape or size.

Mangrove reclamation began with the arrival of the Colonial Sugar Refining Company (C.S.R.) which was invited by the then Colonial Government in 1882 to start a sugar industry in the Colony. Obviously the first areas farmed were the flat lands generally found close to the shore or on the banks of the lower reaches of the larger rivers. Cane farming entails the transport of large tonnages of crop, and 90 years ago when roads and road transport in Fiji were not so advanced, the only ways to bring the cane from the fields to the mill were water transport or rail transport, both of which require flat terrain.

Most of the early tramlines were built close to the shore and in some cases the only feasible rail alignment meant constructing an embankment through the mangrove areas.

Mangroves in those days were regarded as useless wasteland and breeding places of mosquitoes.

In 1886 a Mr. Velschow wrote to the General Manager of the Colonial Sugar Refining Company at its Sydney head office of prospects for the agricultural reclamation of Fiji's delta mangroves:

"...... the soil of the Ba delta is exactly similar to soil of the Canton river delta in China, which consists of about 200 square miles of rice and sugar fields all below high water mark (HWM) and able to support a population of more than 2,000,000 people.

The fields of Demarasa (Guyana) are almost entirely below HWM, and I understand that the expense which has been connected with extracting the salt of the soil there has been highly repaid by the luxuriant produce of sugar obtained afterwards.

I have no doubt that these Fiji deltas are more especially suitable for the cultivation of rice, but this circumstances only concern the present question so far as to enable the sugar company eventually to sell these delta fields at a price to rice growers after the company, having first taken possession of them and by developing them, proved their high fertility.

Now it stands to reason that the fertility of these deltas is beyond doubt, and it is only a question of time when they shall be taken up for cultivation and thereby obtain a value which by far supersedes the value of all the rest of the ground in Fiji altogether, and I therefore believe I am justified in recommending the Company to take possession of these deltas at once, while they are lying entirely unregarded......." - Baines 1980.

Before the close of the nineteenth century C.S.R. had responded to Velschow's enthusiasm by initiating mangrove reclamation projects in the Labasa delta. The first licence to cut mangrove was issued to the C.S.R. in 1886 when 486 ha of mangroves in Tabucola in the Northern Division was approved.

This was followed by four other applications in the same Division, further claiming a total of about 1200 ha by the year 1900. Between 1896-1904 a total of 2334 ha of mangroves were reclaimed by the C.S.R. under fifteen different schemes. Part of this area was salt march land with "Boreti" ferns (*Acrostichum sp.*) but the extent of the "Boreti" fern area reclaimed is not known (Lal 1989).

In the early 1970's two pilot projects were initiated by the Lands Department in the Western Division for the reclamation of 308 ha at Raviravi and 150 ha at Penang, Ra. Mangrove reclamation were re-initiated after a period of over 60 years "to make land available for Fiji's rural population under the Fiji Development plan VI" (Livingston 1973). The Raviravi reclamation was expected to support 60 farmers and Penang 30 farmers.

The reclamation of mangrove land for agricultural use involves clearing of mangroves and construction of sea walls, sluice gates and tidal structures to avoid tidal influx. It also requires construction of drainage systems to accelerate drainage, replacement of sodium ions and leaching of salt until salinity is reduced to levels tolerable to crops concerned. In the case of irrigated schemes the process further involves construction of irrigation canals and storage ponds and flooding of soils.

Too often the technical ease with large areas of mangroves can apparently be reclaimed has diverted the attention of the policy makers away from the very many failures and real difficulties involved in bringing mangrove soils into sustained productivity.

The schemes discussed above are good example of this. Although these projects started way back in 1970's, the soils have not yet leached to the level where sugarcane could be commercially grown. However, at present there are large areas at Raviravi where salt tolerant grass has been able to establish itself. This is an indication that salt tolerant sugarcane can be grown in these areas. Having this in mind the Department of Lands is in the process of leasing the land out to farmers at nominal rental for the first five years.

Nonetheless, Fiji is achieving some good sugar cane yields on reclaimed land, specially those areas originally converted by C.S.R. at the turn of the century.

This success, however cannot be attributed to recently reclaimed mangrove soil but to many years of continual cultivation through which the soils have undergone considerable pedogenesis (Seru DP1).

The present view of the Fiji Sugar Corporation (FSC) is that reclamation is economically viable but only in a large scale in access of 50 ha, using salt tolerant varieties of sugar cane. The present policy is to consolidate increasing yields within the existing cane perimeter rather than embarking on new schemes (watling 1985).

Rice is being grown on reclaimed land at Dreketi (150 ha). Acid sulphate soils and poor drainage have been major management problems.

ii) Aquaculture

67 ha of the Raviravi reclaimed area was put to aquaculture use after the initial experimental trials were carried out in 1972-1978. The initial experimental demonstrations on 12 ponds with 7 ha in total surface area were undertaken by the Fiji Government with the assistance of FAO/UNDP funds and personnel (Lichatowich 1978). Different fish and shrimp varieties were used to determine the feasibility of utilising reclaimed mangrove areas for aquaculture in Fiji.

Despite low pH and acid sulphate soils aquaculture on reclaimed soils was considered to be viable and "appeared to have economic potential" (Lichatowich 1978).

Net financial returns were estimated to be about $3,200/ha/year, based on yields from pond which had a polyculture of yawa or milk fish, Chanos and shrimp, *P. monodon*.

Based on these trials, commercial joint venture with "France Aquaculture" a subsidiary of the CNEXO began in 1981 and culture of only two species of shrimps P. monodon and *P. stylirostris* was undertaken in 24 ha of ponds. The project was developed in two stages.

The farming practice involved the use of ponds, the average size of which was 2 ha in surface area and 1 m in depth. These ponds were compacted with earth dikes and had 10% of pond water renewed daily with use of electric pumps (Lal 1989).

At full production the project was expected to produce two crops of prawns with an average yields of 1.25t/ha/crop.

Because of financial constraints and lack of expertise the project has been abandoned since the last two years. Attempt is being made to attract overseas investors with the know how to revive the project.

It is unlikely that major aquaculture development will be considered for Fiji's mangrove. However, if any aquaculture development is to take place in the mangrove, then the first sites to survey and utilise if suitable are the mudflats at the centre and landward edge of mangrove areas, as first advised by Rabanal (1981). Such mud flats are extensive in the mangroves of the dry zone (6.6% of the combined total of the Ba and Labasa deltas). Utilising these sites will have least effect on the overall productivity of the mangroves and the ponds will be protected by the surrounding mangroves.

iii) **Urbanisation**

The location of all major urban areas in Fiji near to the coast and to mangroves have placed great demands on them and this is increasing. Mangroves have been the target of illegal reclamation and squatter settlements which is quite serious in the City of Suva and environs.

Rural-Urban drift of poor people seeking for jobs in Towns have found refuge in the mangroves. Easy access to mangroves and the technology of conversion being simple has resulted in this situation. More importantly mangroves being State land are unalienated and negotiations for leases are straight forward, and until recently when Fishing Rights Compensation payments increased markedly, were cheap by comparison with adjacent land.

Urban development and its associated pollution will always mean that adjacent mangroves are comparatively vulnerable, consequently their contribution to the national mangrove resource is diminished.

Conversions of some areas is necessary. In recent years demands for mangrove reclamation in urban areas have increased dramatically (Watling 1985). The majority of these are from individuals or companies for residential or industrial purposes, but several large Government schemes for industrial development have been undertaken.

Much of the development has been piecemeal with no overall plan. However, the nearly completed Suva City Peninsula Plan of the Lands Department and Watling (1985, 1986) cover the important areas of urban mangroves.

Those in Fiji who subscribe to the "Wasteland" concept of mangroves are quick to see value in the idea of using mangrove ecosystems as places for waste/rubbish dumps. The wasteland philosophy has encouraged local governments to site rubbish dump in the mangroves-with a potential bonus where such dumps can be used as a basis for reclamation.

The proud and beautiful capital city of Suva is blighted by a poorly controlled dump in the mangroves close to its centre. Other major towns on the coastal zones (Lautoka, Nadi, Labasa, Sigatoka, Tavua and Savusavu) have their dumps in the mangroves.

iv) **Sewage Processing**

Mangrove areas are proving extremely important to Fiji's Sewerage and Sewage Treatment Programme. With the exception of Nausori, all of Fiji's municipal sewerage plants are associated with Mangroves either as sites for the processing plants using oxidation ponds or for disposal of the effluent which may be directly into the mangroves or in their vicinity.

Approximately 150 ha of mangroves is planned for use in the Programme but about 55 ha has been converted for pond construction to date. The use of mangrove areas in the Programme is principally a cost saving factor - $2.3m were saved in the 8 ha Lautoka plant by comparison with a conventional sewerage treatment plant (Green 1983). Refer Table V for various sewage disposal Programmes.

Eutrophication caused by waste products of man's activities, of which treated sewage disposal is a major source is likely to increase concurrently with population growth and development.

In some places it has lately come to be appreciated as a major problem. Sewage discharged near reefs has killed coral in the U.S. Virgin Islands and in Hawaii (Banner 1974; Salvat 1977).

Whilst the disposal of sewage effluent after secondary treatment in mangroves may be environmentally sound (but this has not been unequivocally demonstrated) there are dangers if domestic sewage is contaminated with industrial wastes and toxic bioaccumulation occurs. In addition, secondary sewage treatment does not remove most toxic wastes which are potentially harmful to both marine life and human consumers of contaminated seafood, nor does it remove most viruses which are potentially harmful to swimmers (Westman 1974, Millar 1978).

Government's sewage disposal programme is shown on Table V.

v) Tourism

The development of Tourist industry is a national priority and as such mangrove areas will be considered for conversion if associated with development sites.

Mangrove reclamation for tourism development (200 ha) is significant and given the expected planned growth of the tourist industry, is likely to place demands for conversion in the future.

The whole of south western coast of Viti Levu known as the coral coast, has been declared a tourism area. Major tourist development activities are located in this zone.

Obviously resort developments are preferred on the coastal zone for the attraction it offers; and often mangroves being placed in such situation are target for conversion.

One single such project has taken up 160 ha of mangrove at the Denarau Resort project development at Nadi.

There are however, some resorts who appreciate the environmental value of the mangrove and have planned to preserve the ecosystem to their advantage for the visitor attraction it offers-The Turtle Island Resort, Yasawas; Vulani Island Resort (proposed) at Lomolomo; and Vunaniu Resort (proposed) at Vunaniu.

Table VI: Shows areas converted for various uses.

1.6 SHORELINE CHANGES DUE TO ACCRETION AND EROSION

There is very little data available on the succession, accretion or erosion of Fijian mangroves. Geomorphological changes in mangrove areas are evident in estuarine areas but only those in the Rewa Delta have been studied (Roy and Richmond 1983).

Certain areas of south eastern Viti Levu bear the scars of damages sustained in mangrove areas from landslips and earth works in adjacent areas resulting in die back situation (Watling 1986).

Comparison of 1954 and 1978 aerial photographs reveal substantial changes to mangrove vegetation along the main river banks of the Ba river with considerable erosion and deposition. Comparison also reveals changes in the extent of hypersaline mudflats, whilst constant in location their size changes as a result of recession or invasion of Tiri. The trend at present points to a reduction in size.

Like other Islands in the Pacific, Fiji is invariably affected annually by tropical cyclones, many of which are very severe. Most cyclones originate from the northwest and affect the northern and western coasts. Observations following three severe cyclones in 1983-1985 revealed little structural wind damage except a narrow zone of wave damage in some locations resulting in limb fracture and uprooting. Total defoliation occurred over a narrow area of the cyclone paths. More damage was caused by heavy rain-induced flood damage on river banks. (Watling 1986).

Apart from above observations no regular monitoring has been carried out to the shoreline changes due to accretion and erosion.

2. SOCIO ECONOMIC VALUES AND PATTERNS OF USE

"*The traditional mangrove dweller appears to have learnt the particular order of his world in Nature's symphony and I dare guess that Huxley would have been proud of him, had he known the mangroves and the men who are part of them.*" Vannucci - 1989 "Mangroves and US".

A society values a mangrove ecosystem both for the extractable resources it supports, for its non-consumptive services it provides as well as the ecological values of the system. Mangrove support diverse communities of microscopic and macro terrestrial and aquatic flora and fauna (Saenger *et al.* 1977 and UNESCO/UNDP 1987). Some of the plan and animal species are of direct

Table V. Sewage treatment proposal for various towns and cities.

Treatment Plant	Type of Plant	Population Served	Ultimate Population Served	Future Extensions and Improvements	Disposal of Effluent	Area of Mangrove Taken ha	Total Area to be taken ha	Area of Adjacent Mangrove within 2km ha
Kinova Suva	Tricklig Filter (Secondary)	35.000	250.000	Plant to be developed in 30.000 population stages (Trickling filter)	PRESENT: Via 800m Long outfall FUTURE: Extend 1000m outfall and then triplicate	6	6	102
Raiwaqa	Trickling Filter	14.000	15.000	No extension planned. Many improvements to be made within 2yrs. Probably to be abandoned in say 15 yrs.	Into creek in mangrove	2	2	86
Nadi	Paaveer Ditch Secondary	6.000	60.000	Plant being duplicated to serve 12.000 population. Further stages oxidation ponds in mangrove.	PRESENT: into river FUTURE: Possibly into mangrove areas	-	40 (1500 P/ha)	1257
Lautoka	Oxidation Ponds (125 day only)	25.000	100.000	25,000 population stages	Via 2.0 km outfall to sea	16 (for 2 stages)	32	20
Labasa	Oxidation Ponds (Full Treatment)	2.000	15.000	5.000 population stages	Dispersal inside Mangrove	24	24	800
Sigatoka	Oxidation Ponds (Full)	Not yet constructed	12.000	2 - 6000 population stages	Into river	7	7	21
Ba	Oxidation Ponds (Full Treatment)	Not yet constructed	50.000	5.000 population stages	Into creek in mangrove	7	33	157
Nausori	Trickling Filter	Not yet constructed	20.000	5.000 population stages	Into river	-	-	-
Tavua	Oxidation Ponds	Not yet constructed	5.000	2.500 Population stages	Into creek in mangrove	7	7	37
					Total	69	151	2480

Table VI. Reclamations undertaken for various purposes 1896-1986 (Lal 1989) (ha).

	Govt.	Private	C.S.R.	TOTAL
Agriculture	1,159		2,390	3,549
Industrial	102	19		121
Sewage	55			55
Residential		31		31
Tourism		557		557
TOTAL	1,316	607	2,390	4,313

and indirect economic and social value to human societies throughout the world (Saenger *et al.* 1987). Mangrove ecosystem also provide a variety of non-consumptive services ranging from recreational and aesthetic benefits which are derived from their unusual flora and fauna populations, to protection from soil erosion, flood mitigation, filtering of nutrients and protection of interior lands from saline intrusion. (Saenger *et al.* 1983).

2.1 FORESTRY

Historical:

Historically, the demand for mangrove resources has mainly been for firewood.

Early records of commercial consumption is sketchy though a pattern of increasing consumption up until the mid 1950s can be observed. Post Deed of Cession, i.e., post 1874, Sugar company in the Central Division was regularly supplied with mangrove wood for fuelling their burners. Over a four year period during the 1880s, one of the mills was supplied with 10,900 "Punjabi tons" of mangrove wood from Dogo, tiri and sinu gaga (CSO 181/1881). [A punjabi "ton" is a stacked volume of 50 cubic feet (cu ft) which, gives an equivalent wood volume of 1.06 cu m]. On average, each of the three mills burned about 1,300 "tons" (about 1,380 cu m) of mangrove wood per year. The estimated annual harvest fuelling the sugar mills in the late 1870s was about 40 ha in the Rewa Province. However, in the late 1880s, the sugar mills switched to imported coal when various chiefs in the Rewa Province declared a tabu or ban on the cutting of firewood for commercial purposes. The resumption of the use of mangrove as firewood did not take place until the 1890s when the Colonial Sugar Refinery Company (CSR) was issued with a forestry licence to cut vast areas in the Northern Division. Over 1,600 ha (4,000 acres) of mangrove area were licensed for fuelwood, and most of these were subsequently reclaimed for sugarcane plantations (see Lal 1989 for details).

In the Central Division, commercial harvest of mangroves was resumed at the turn of the century after mangroves were declared Crown property (CSO 5162/1908).

Thus, in 1909, for example, at least 3,000 cu m of firewood from mangrove forest were supplied to various government institutions (CSO 2960/1909). With growing populations and secondary industries such as laundries, bakeries and soap factories, the demand for fuel increased. In 1927, the annual harvest was estimated to be 10,000 "tons" or about 10,612 cu. m (Sykes 1931a), of which Suva alone consumed about 6,000 "tons" (6,368 cu. m). Mangrove harvest for fuelwood peaked at about 50,000 cu. m in the early 1950s, when 75% of the area in the Rewa Delta deemed suitable for commercial harvest was licenced (Loweth 1955).

Later in the 1950s the C.S.R. Co. had switched to a more conveniently available fossil fuel. However, on the national front, consumption had increased. Some of the mangrove wood was also exported during the early 1920s when a Canadian firm exported more then 50% of about 700 cu m of felled dogo timber (CSO) 1483/1923). Today there is no known export, though recently some interest was shown by a Taiwanese company to take advantage of a 13-year tax haven under the new Trade Free Zone policies.

Present Uses:

The commercial consumption oi mangrove forest over the ten years (1982 - 1991) averaged about 2,699 cu. m, of which fuelwood accounts for about 96% or 2585 cu. m (Table VII).

Present day commercial uses of mangrove products for purpose other than fuel account for less than 1% of the total present consumption, though it was about 10% during the 1930s-1950s. Dogo also yields good quality charcoal.

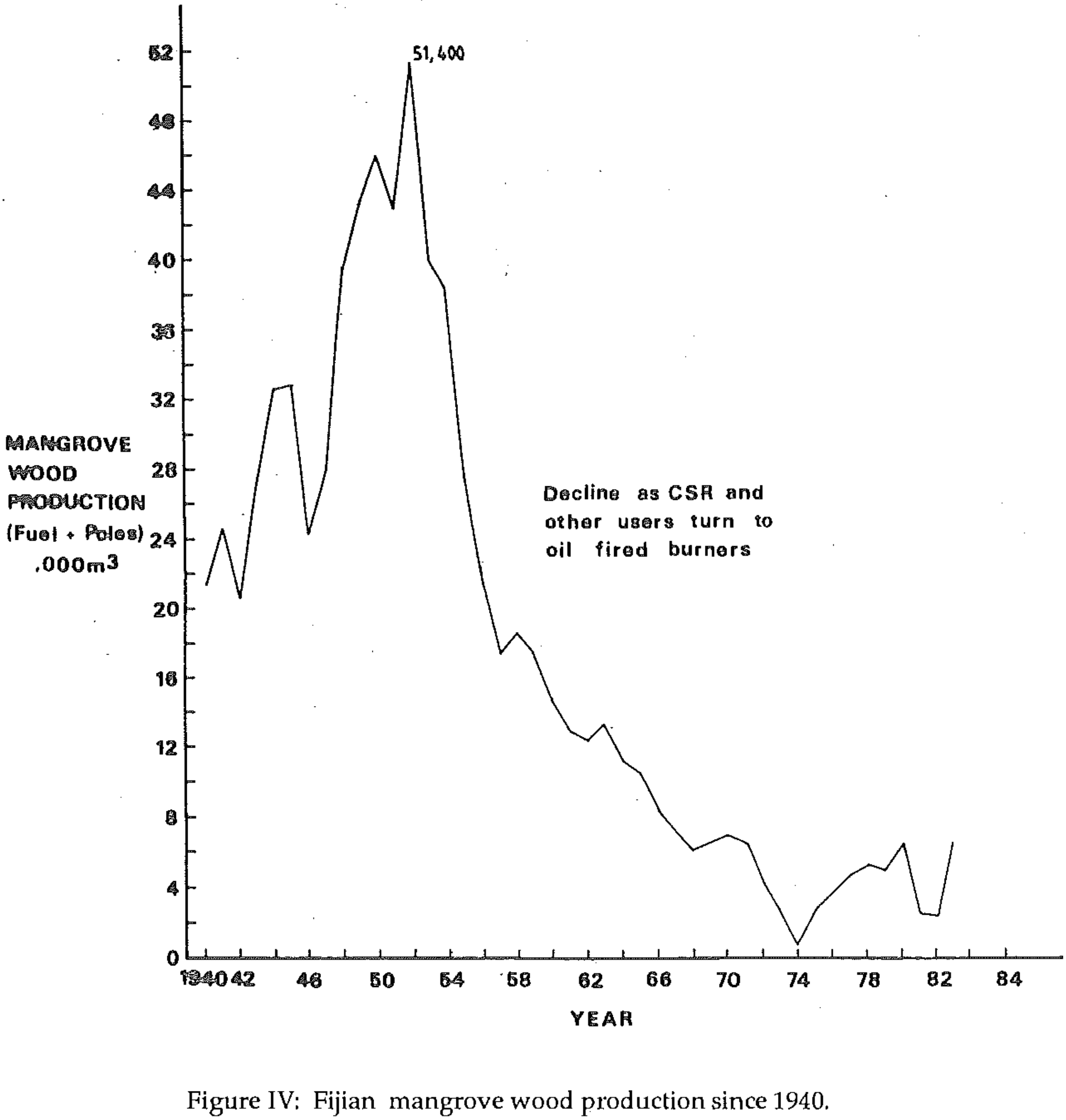

Figure IV: Fijian mangrove wood production since 1940.

[Forestry Department figures - approximate only]

Table VII. Commercial harvest of mangrove wood (UNITS cu. m of standing crop).

Year	Poles	Charcoal	Firewood	Total
1982	85	49	2,584	2,718
1983	90	44	2,776	2,910
1984	85	27	4,374	4,486
1985	37	34	1,526	1,597
1986	23	20	2,775	2,818
1987	312	30	2,378	2,720
1988	17	51	4,470	4,538
1989	16	84	2,502	2,602
1990	52	-	1,438	1,490
1991	69	11	1,027	1,107
	786	350	25,850	26,986

Source: Computed from the Forestry Department records.

During 1982-1986, the consumption of charcoal, which is a luxury item fueling barbecues in urban areas, had declined from 8,170 kgs to 3,280 kgs in weight. This is equivalent to a decline from 49 cu m of wood to 20 cu. m. Other species such as **dabi** is used for boat knees. During their mid-1930s; tannin was also produced from **dabi** and **dogo**. **Dabi** bark contains one of the highest proportions of tannin (84%) but **dogo** (containing 19%) was used because it was available in abundant quantities.

Another use of mangroves is the use of **dogo** for timber poles for building house, beams, etc. Because of its resistance to the teredo marine borer, **dogo** is also preferred for fishing stakes.

Subsistence Uses:

Mangrove firewood is used for subsistence purposes mainly by rural villages and urban and periurban low cost housing settlements.

Rural Village Consumption:

It is estimated that 33,953 cu m of mangrove trees were harvested annually in the three divisions (Table VIII). This figure is derived from a per household consumption of 4,596 kgs per annum and 8,865 Fijian households located in or near mangrove forests. The density of mangrove wood

Table VIII. Subsistence consumption of mangrove firewood by Division.

Division	No. of H/H	Wood (cu. m)
Central	3,117	11,938
Western	3,000	11,490
Northern	2,748	10,525
Total	8,865	33,953

Sources: Subsistence estimates based on Department of Energy Village Energy surveys, Siwatibau (1978) raw data, Lands Department maps and unpublished village population data from the 1986 Census Records.

is estimated to be 1.2 t/cu. m (see Lal 1989 for detail).

Urban and Periurban Consumption:

Like rural villages, urban and periurban households also use mangroves primarily for domestic cooking. It is estimated that urban and periurban households consume 4,707 cu m of mangrove wood per year of which 3,922 cu m or 88% is gathered while the rest is bought from the commercial concessionaires (See Lal 1989).

Total Subsistence Uses of Mangrove Forestry Products:

In total, the subsistence consumption of mangrove wood is 37,875 cu m which accounts for about 93% of all mangrove fuelwood consumed in Fiji (See Fig. V).

Total Fuelwood Consumption:

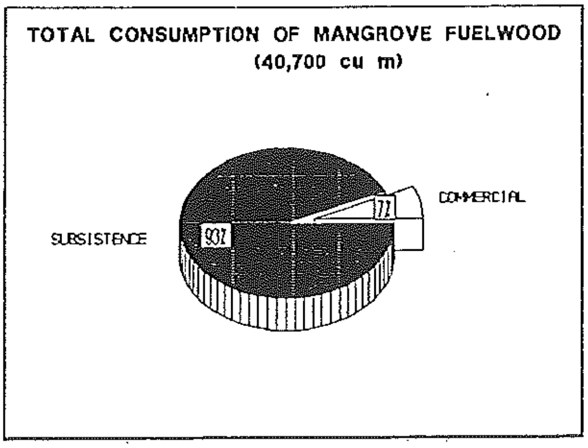

Figure V: Total fuelwood harvests for subsistence and commercial purpose.

The present total consumption of mangrove fuelwood is about 40,684 cu m or about a third of what 38,543 ha of forest could support on a 40 years rotation cycle.

Potential Yield of Firewood:

There is very little information available on the potential yield of firewood from a unit area of tiri and dogo. From limited research in Fiji in the 1950s and experiences form Malaysian managed mangrove, *Rhizophora* species forests, the Forestry Department estimated a total yield of about 135 "*Punjabi ton*" per acre or 353 cu. m per ha (Loweth 1955). This was based upon a managed dogo forest with a thinning time table of 5 feet at 15 years age, 8 feet at 25, 15 feet thinning at 35 and clear felling at 40 years (Loweth 1955). From an unmanaged forest, with an assumed growth of 5 cu. m/ha/year for the dogo species alone (Firth 1978), 200 cu. m/ha over a 40 year rotation period was projected (Swarup, pers. comm).

For tiri forests, based on a preliminary forest survey in the Rewa Delta in the Central Division and assuming a 40 year rotation, it was estimated that an average yield of 2.3 cu. m/ha/yr, or a total yield of about 92 cu. m/ha, could be harvested from a tiri alliance (Lal 1989). A dogo alliance, 88% of which comprised of dogo trees, was estimated to yield of 201 cu. m/ha or 5 cu. m/ha/yr. Dogo species alone gave an estimated yield of 4.7 cu m/ha/yr which compares closely with Firth's figure.

On the basis of the species composition of tiri and dogo alliance in the Central Division and on the assumption that the generic tiri and dogo alliances in the other divisions were similar in species composition, harvestable wood volume for the three deltas were estimated. The harvestable volume from the Ba and Labasa deltas are estimated to be 92 cu. m/ha and 186 cu. m/ha over a 40 year period (Table X).

Traditional Use:

The majority of the indigenous Fijian are coastal dwellers and a large proportion of these have access to and utilise mangrove areas. It is not surprising therefore that such communities have a profound utilitarian knowledge and dependence on mangroves. Research noted earlier has shown that 83% of fish species caught in mangrove area are recognised locally and consumed (Lal *et al.* 1983).

The direct and indirect products of mangroves are free continually supplied and self sustaining, as they are important determinants of the quality of life for coastal communities.

Market Price:

Mangrove wood is sold in bulk to squatter and low cost housing settlements, crematoriums, and secondary industries such as brick building and chicken processing. The price varies slightly depending upon how and where dogo is sold. Except in the case of dogo sold to secondary industry, fuelwood in Fiji is generally sold on the basis of the "*Punjabi ton.*"

According to the concessionaires interviewed, bulk sales of dogo at squatter settlements averaged $7 a "*Punjabi ton.*" This is equivalent to $6.6 per cu m. On the other hand, at crematorium, dogo is sold by the pyre loads. Each pyre requires about 12 logs each of 7 feet long, 21 logs of 4 feet in length and 40 blocks of about 2 feet long split into halves, which is equivalent to about 5

Table IX. Total consumption of mangrove fuelwood by Division (cu. m).

	Central	Western	Northern	Fiji
Commercial	1,041	1,156	612	2,809
Rural Villages	11,938	11,490	10,525	33,953
Urban & Periurban	3,922	N	NA	3,922
Total				40,684

Sources: Commercial Figures from the Forestry Department Records and Subsistence Figures from Table VIII.

Table X. Estimate of the harvestable wood from the three divisions.

Division	Delta	Volume cu. m/ha 40 year
Central	Rewa	201
Western	Ba	92
Northern	Labasa	186

Source: Lal 1989.

Table XI. Traditional Uses of Fiji's Main Mangrove Species.

Species	Uses
R. stylosa	
R. samoensis	
R. x *selala*	Firewood for cooking food, charcoal making, tannin for fishing net and line preservatiowoody middle layer of prop root and aerial roots for stinging fish to facilitate their transport; prop and aerial roots mud lobster, *T anomala* traps; bark to enclose crushed *Sesarma sp*. Bait for mangrove crab trap; stakes for husking coconut; aerial roots for plaited fish traps; timber for scaffolding buildings, tool handles, poles for fish traps, boats, fish fences and fence posts.
B. gymnorhiza	Firewood for cooking, smoking fish, cremation, timber for scaffolds, boat building, beams, rafters, furniture, tool handles poles for fence posts, fish traps, boats; tannin for fishing nets and line preservation; stakes for husking coconuts, dye made from bark for hair, clothes, tapa clothes; during periods of food scarcity radicle of dogo seedling was used as vegetable.
X. granatum	Firewood, timber, fence posts, beams, poles, boat knees, medicine.
L. littorea,	
B. littoralis	Firewood, timber, beams, poles for fish traps, canoe making, medicine.
E. agallocha	Medicine for curing leprosy (Seeman 1878), medicine sap was regarded as poison; scented heartwood and thus sought after for incense.

Sources: Sykes 1931a and Pillai 1987.

"*Punjabi tons*" average, dogo about $6 per cu m delivered to the crematorium. Small quantities of dogo are supplied directly to secondary industries in loads of 7 tons of actual weight for $27, which is equivalent to about $4.6 per cur cu.m.

Thus, the average price of dogo sold in bulk (excluding sales to secondary industries) is $6.3 per cu.m. On the other hand, the retail price of dogo sold in small bundles of about 8-9 kgs is 50 cents. This translates into a retail price of $70.8 per cu.m. A very small quantity is sold in bundles to a largely urban elite. According to one of the concessionaires, less than 5%-10% of commercially sold wood is retailed in this manner. The retail price of dogo wood as charcoal is higher than the shadow price of wood in terms of a kerosene equivalent of $52 per cu.m. The average price of commercially sold dogo, is used as the marginal benefit of consuming fuelwood.

Not included in this estimate and in the economic analysis are the tuna baitfish species and the tuna industry which relies on these baitfish for its pole and line fishing. These baitfish species are caught mainly in areas away from major mangrove deltas though still within the inside demarcated areas (IDA) waters (Lewis, *et al. 1983*).

The mangrove dependent species accounted for about 54% of all the recorded weight of fish and nonfish sold through municipal markets and other outlets during 1984-1987. While nationally, the sale of mangrove dependent fish and nonfish products has increased over the last 4 years, fish sales throughout the Central Division have levelled off, at about 1,600 tonnes.

During the 1984-1987 period on average, 2,207 t of mangrove dependent fish were sold, while other non-mangrove fish species totalled 1,754 t. On the other hand, 187 t of mangrove dependent nonfish products, such as crabs and prawns, and 268 *t* of non-mangrove products (but excluding *kai* - a freshwater bivalve) were recorded. Two-thirds of all fish and non-fish products sold nationally were marketed in the Central Division (Table XII).

Not all the recorded sales in the Central Division are caught from the Central Division waters, as fish caught in other areas are sold in Suva because of slightly relatively higher prices which can be obtained there. Based on the catches of those fishermen (at least 7) who are based in the Central

Table XII. Annual weighted average of fish and nonfish sales through municipal markets and other outlets (weights given in tonnes).

	Centr.	West	North	Fiji
Mangrove Dependent	1,643	481	270	2,394
Non-Mang Dependent	1,266	489	262	2,016

Sources: Complied from Fisheries Division Market Data and list of Mangrove Dependent fish and nonfish species given in Table I.

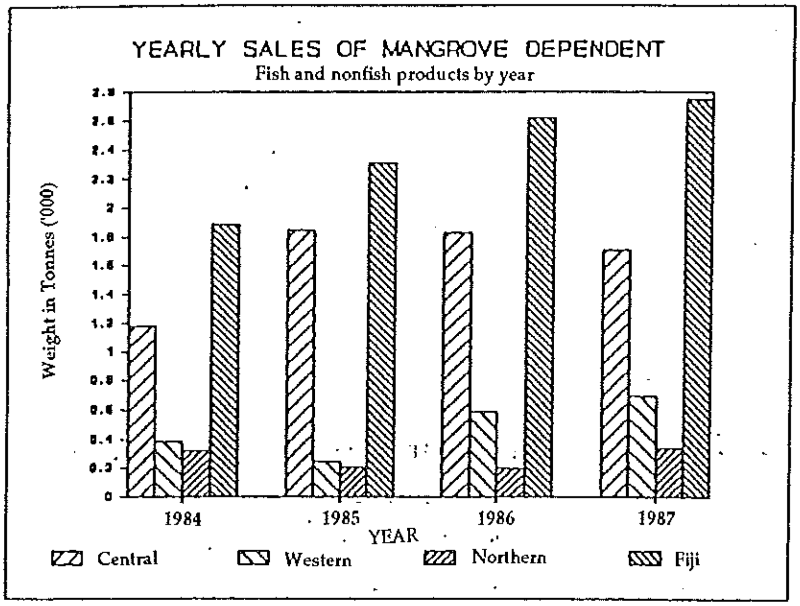

Figure VI: Yearly sales of the mangrove dependent fish and nonfish products by division.

Division but fish in the Northern Division and sell their fish in Suva, plus a limited quantity of fish marketed by the National Marketing Authority, the catch from Central Division is estimated to be about 300 *t* less than the recorded sales.

2.2 SUBSISTENCE

Subsistence consumptive uses of fisheries resource is extensive. The rural indigenous diet consists primarily of fish and non-fish mangrove products generally caught by women (Lal and Slatter 1982). The subsistence catches of fish and crustaceans vary considerably between households. Subsistence consumption of mangrove dependent fish products is estimated from data collected during survey of Fijian women's involvement in fisheries (Lal and Slatter 1982) and on 12 subsistence surveys conducted during 1985-1986 period for the Arbitration Hearings (MPI 34/2 file series). At least 30-50 % of the village households during each of the surveys were questioned regarding their average household subsistence catch/consumption per trip, and the number of trips taken per week, month and year. On the basis of the surveys of the villages actually situated in close proximity to the mangroves, it is estimated that an average household took 3 trips per week, 10 days a month obtaining 3 kg of fish per trip (range of 2-4 kg trip) and 5 days a month collecting 3 kgs of crustaceans, such as kuka, *Sesarma sp.* or mana, *Thalassina anomala*. As finfishing or crustacean fishing is not done at the same time, on average 540 kg (15 trips/month * 3kg/trip * 12 months) of fish and nonfish is consumed per year by each household. Based upon the number of villages actually situated in the mangroves (the same ones which were included in the subsistence forestry survey), the annual subsistence consumption of mangrove-dependent fish and nonfish products is

Table XIII. Estimates of subsistence fish consumption by villages located within the mangrove areas.

Division	No. of H/H	Volume (t)
Central	3,117	1,683
Western	2,748	1,484
Northern	3,000	1,620
Total	11,865	4,787

Sources: Estimated from Subsistence Catch Data in Lal and Slatter (1982), 12 Subsistence Surveys conducted for the Arbitration Hearings, since 1983; Lands Department Map showing Villages in the Mangrove areas, and the Unpublished village population data from the 1986 Census Statistics.

estimated to be 4,787 t by 8,865 households on the two main islands (Table VIII).

It should be noted that the above estimate does not include the amount consumed by those Fijians who live in urban or periurban coastal areas and fish occasionally to supplement their diet. Also not included are Indian households which fish on an occasional bases. The figure arrived at in this study is about 55% of Watling's computed value of 8,760 t (Watling 1985).

Watling arrived at his estimate by using the figure of 60%, a percentage of weight of 1983 commercial sales of all commercially important species found in the Wairiki Creek survey (Lal, *et al.* 1984), of 14,600 t of subsistence consumption recorded by the Fisheries Division figures were estimated derived from a survey of all coastal Fijian villages located throughout Fiji, including villages on atolls and outer islands. Coastal fisheries associated with mangroves is not unique to the system as the same species are also caught in coral and seagrass ecosystems. Thus, using total subsistence values would give an overestimation of the mangrove dependency.

Another limitation of that survey, as noted in the annual report, was that the estimates were based on "subjective opinions of one person" who usually happened to be the village chief (Fisheries Division 1979).

Total Fisheries Utilizaton

In Fiji, the annual harvest of mangrove-dependent fish and nonfish products for subsistence and commercial uses is estimated to be 7,181 t (Table XIV). This annual harvest is supported by a mangrove area of 38,543 ha. As discussed earlier, only the coastal fisheries in the Central Division are considered to be fully utilized. This is implied by the levelling off of the commercial catches and the maximum use of the existing technology by fishermen working within the institutional setting of permits issued by the Traditional Fishing Rights owners.

The commercial production of mangrove-dependent fish in the Central Division is estimated to be 1,343 t. This plus the subsistence harvest of 1,683 t would result in an estimated catch of 3,026 t of fish and nonfish products supported by 9,136 ha of mangrove area. Assuming a direct correlation between the area of mangroves and the fisheries yield, the average mangrove dependent fish yield at full utilization is 331 kgs per annum - that is, a commercial output of 147 kgs/ha plus a subsistence harvest of 184 kgs/ha.

Table XIV. Total harvest (t) of mangrove-dependent fish products by divisions.

	Central	Western	Northern	Fiji
Subsistence	1,683	1,484	1,620	4,787
Commercial	1,343	481	270	2,394
Total (t)	3,026	1,965	1,890	7,181
Mangrove area (ha)	9,136	11,822	17,586	38,543
Yield kg/ha	331			

Sources: Subsistence values from Table XIII, Commercial values from Table XII Central Division figure of 1,343 is equal to 1,643 (Table XII) minus 300 t estimated to be sold in the Division but caught elsewhere.

This is below the range of potential sustainable fish yields of 8,000-10,000 kgs/ha expected from estuaries and lagoons with a detritus input equivalent of an aquatic primary productivity of 100-1,000 gm/ha/yr (computed using the ratio of primary productivity to fish yield figure from Marten and Polovina 1982).

The gross value of mangrove associated fisheries products harvested commercially and for subsistence consumption in Fiji is estimated to be about $31 million per year.

2.3 AQUACULTURE

Aquaculture has not taken grounds in Fiji as yet. The only project initiated by Government and then taken over by a private company has ploughed in about $500,000, (Lal 1989) but the project did not prove to be viable.

With traials undertaken it is possible to achieve an yield of 1.8 tons/ha/year, if managed properly.

2.4 AGRICULTURE

Sugar is the backbone of the Fiji's economy. Exports of raw sugar and molasses were valued at US$146.5 m in 1989. Sugar production will remain the principal agricultural activity.

With growth of population and shortage of suitable land for farming Government initiated reclamation projects. However, that proved to be uneconomical. Government has therefore decided not to reclaim large areas of mangroves for agricultural purpose.

Lal, 1989 - carried out an economic analysis of Raviravi reclamation (refer section 1.5) observed that -

"With an annual harvest of 56 t/ha of sugar cane achievable within 30 years of the completion of the reclamation (1978) and a projected shrimp yield of 1.8 t/ha from the 24 ha pond area the Net Present Value of the net development benefits from Raviravi project as a whole are negative $3.3 million. Including the foregone net benefits stream of the fisheries and forestry products harvestable from the ecosystem the total net benefits are negative $4.3 million."

Using the multidisciplinary approach advocated in the study for project evaluation, it is found the agricultural use of reclaimed land without irrigation is not economically viable even without taking into account the in situ benefits of the mangrove foregone.

The Raviravi Sugarcane Reclamation which involved only drainage works began in 1971 while the Dreketi Rice Irrigation Scheme which had both drainage and Irrigation, an important factor in the desalination process.

The projects have not fulfilled the expectations of their planners.

Trials carried out at Raviravi by the Fiji Sugar Corporation gave an yield of 13-20 tonnes per ha using the four commercial varieties of cane. However, the yields on reclaimed areas carried out during the CSR days (60 years back) are very encouraging. In Tabucola, 120 ha of reclaimed land is giving an average yield of 90 tonnes per ha. (Sugrim 1983). Present price of cane is about $50 per tonnes.

Rice is being grown on reclaimed land (150 ha) at Dreketi. Acid sulphate soils and poor drainage have been major management problems. Yields have ranged from 1.13 to 2.63 tonnes per ha; using the salt tolerant variety "Deepak." Price $339/t (Lal 1989).

2.5 RESIDENTIAL AND INDUSTRIAL DEVELOPMENT

Most of the Towns and the Cities are located on the coastal zone and as such it is inevitable that foreshore areas have to be exploited for expansion to provide various services.

Of all the towns, the capital City of Suva has most mangroves within and around its environs. About 25 ha have been converted to residential development. However, major part has been claimed by industrial development for expansion of industries.

A further area of about 100 ha is planned for industrial development, mainly in and around the city of Lautoka and the Town of Tavua in the Western Division. Industrial development in Suva and Labasa in Vanualevu have both claimed over 40 ha each.

There has not been much reclamation for residential area as yet however there will be pressure for this in the future. Most of the reclamation (31 ha) has been in and around Suva environs.

Reclamations are either carried out by private developers or Government. Being State Land the lease is issued over subdivided plots by Government for period of 99 years at yearly rental. The rental is reassessed at 10 years interval at 6% of the Unimproved Capital Value (U.C.V.) of the land.

2.6 RESORT DEVELOPMENT

Tourism is one of the mainstays of Fiji's economy. It accounts for about 15 percent of GDP and 21 percent of foreign exchange earnings (Ministry of Information Publication, 1990). With a strong and growing international demand tourism provides a significant and expanding source of foreign exchange earnings for Fiji. In 1986 tourist arrivals reaching all time high of 257,824 fetched a foreign exchange earnings of F$186 million.

Tourism is being accorded special emphasis as an engine for Fiji's economic growth and the indications are that the sector is now poised for growth.

Several major resort development projects are being planned or in the process of development and expansion.

Most of the hotels being located on the coastal zone have put pressure in mangroves. Mangrove reclamation for tourism development (557 ha - Lal 1989) is significant and given the expected and planned growth of the industry, is likely to place increasing demands.

One such major project-the Denarau Island Resort has reclaimed 160 ha of mangroves for the development of various services. F$300 million is expected to be spent on the development.

Fiji is the largest vacation destination in the South Pacific with more than 100 hotels. The industry employs an estimated 24,000 people- about 11-12 percent of the labour force.

3. ECOLOGICAL AND ENVIRONMENTAL VALUES

The mangrove ecosystem is an ecologically complex system. It comprises of terrestrial and aquatic subsystems with the mangrove water providing the linkage between the two. Besides the ecological benefits, other benefits derived from the system can be categorised into direct consumptive and non consumptive uses.

Consumptive uses of products such as forests, fisheries or game animals result from actual harvest of resources that the system supports while indirect uses such as shore erosion protection, flood mitigation benefits and recreation benefits are based upon the maintenance of the ecosystems.

Environmental benefits of the mangrove ecosystem include those that are derived from its non-consumptive uses such as bird watching, wildlife photography and other recreational benefits which are assumed to be a function of the total mangrove area and forest volume. Environmental benefits are a function of the area under forest and the volume of forestry biomass.

3.1 COASTAL PROTECTION

Under natural conditions mangrove shores act as a seaward barrier against coastal erosion and at the same time aid in stabilizing the coastline. They do provide considerable protection to areas on their landward side by ameliorating the erosive action of waves and currents. They cannot prevent all flooding but do mitigate its effects. The coastal protection mangroves afford is roughly proportional to the width of the mangrove belt. Very narrow fringing mangrove margins offer minimal protection whilst extensive stands not only prevent wave damage but reduce much of the flooding damage by damping and holding flood waters (Odum *et al.* 1982). Indonesia has recommended 400m "green belt" to be maintained (Burbridge and Koesoebiano 1982) whilst a minimum of 50-100 m is recommended by Tang (1976) and Rabanal (1978) in Malaysia.

Despite the very frequent occurrences of cyclones in Fiji the current practice is to maintain belt of 9-30 m. (/Rabanal (1981) recommends a "Buffer Zone" of 50-100 mm along rivers and 100-200 m along the seacoast of Fiji.

3.2 FEEDING AND NURSERY GROUNDS FOR FISHERIES

Mangrove areas act as a habitat as well as spawning and nursery grounds for fish and non fish fauna. (Odum and Heald 1972, Lal *et al.* 1984. Robertson 1988).

Not all species caught in mangrove waters are permanent residents. Some species such as those belonging to the families Garridae, Sparidae, Engraulidae and Pomadasyidae are demersal coastal species but spawn in estuaries (Johannes 1978). On the other hand some *Lethrinus* sp., *Siganus* sp., and *Lutjanus* sp. inhabit mangroves and migrate to coastal reef slopes to spawn (Johannes 1980). Mangroves provide a habitat for greater refuge for smaller fishes (Robertson 1988).

In Fiji over 70% of the fishes landed in municipal markets are coastal or estuariae species mainly dominated my Mugilidae, Siganidae, Carangidae, Lutujanidae and Lethrinidae species (Fisheries Division 1979, 1980) of which over 60% of the species spend sometime in the mangroves.

General observations has been made by Lal (1983) in regards to the use of mangroves for feeding and as a nursery from studies carried out in Wairiki Creek. (Refer section 1.4).

Lal observed that a large number of fishes utilise mangrove as a habitat or nursery and feeding grounds. Juveniles of some of the commercially important fishes such as Lutjanidae (*L. argentimaculatus, L. fulrus*), Siganidae (*S. vermiculatus*), Sphyraenidae (*S. baracuda*), Mugilidae (*V. seheli*), Carangidae (*C. sexfasciatus, C. ignoblis, C. papuenuis*) were collected in gill nets or while seining around in shallow waters.

Ward (1976) also collected juveniles of Mugilidae, Mullidae, Siganidae, Lutjanidae and Sphyraenidae in box and brushtraps in studies carried out in the Veisari Creek mangroves.

3.3 FORAGING AND STOP-OVER SITE FOR MIGRATING BIRDS

Fiji's mangrove vegetation is not used directly by any migratory bird species, however the mud flats associated with mangrove in many parts of Fiji are important feeding sites for many species of migratory wader (Watling 1982).

Waders arriving annually in large numbers include the Bar-tailed Godwit *Limosa Lapponica*, Pacific Golden Plorer *Pluriatis fulva* and the Wandering Tattler *Actitis hypolencos*.

3.4 PRIMARY AND SECONDARY PRODUCTION

An understanding of primary and secondary production is important for proper allocation of mangrove resources for different purposes. Speaking simply, the production of plant material by mangrove plants with the assistance of energy from he sun and raw materials take from the mud in which they grow is called **Primary Production**. The growth of fish, crabs, shellfish, insect and other animals which feed on this primary material is termed secondary production.

Just as there is a continual flow of nutrients and other substances from land surfaces into mangrove areas, so there is a movement of fish food from mangroves into lagoons and among reefs.

Some of this important transfer of food is less easily seen being in the form of migrating fish or microscopic marine animals and plants. Thus it is important to recognize that the value of mangrove extends beyond the areas they occupy; they contribute also to the fisheries productivity of adjacent waters. (Baines 1979).

Organic detritus produced in the mangroves is exported at high rates into the coastal zone and support the productivity of these waters. The total amount of leaf litter, bark and flowers which all comprise the mangrove detritus is found to be only magically lower than the volume of the standing crop. (Bunt 1987).

Studies carried out in Fiji by Lal 1989 (unpublished data) on detrital production arrived at 1000 gm/sq.m or about 1t/ha per annum. This compares well with Australia which has similar production (Bunt 1982). In Malaysia production of up to 16t/ha is reported (Sasekumar and Loi 1983). The variation detrital productivity is a function of mangrove plant species as well as environmental factors (Duke *et al.* 1981).

The extent of detrital export is a function of the nature of the mangrove soil, types of fauna present in the mangrove soils, the degree of ebb and flow tidal fluctuations and the volume of water flow. (Montague *et al.* 1987, Camacho and Bagarinao 1987).

Using Marten and Polovina's ratio and taking into account the amount of detrital input into estuarine waters from mangroves (1t/ha), the potential fish yield directly due to mangroves could be in the range of 800kg/ha to 10,000 kg/ha/annum, depending upon the productivity of the coastal waters, technology and effort.

Biomass:

Mangrove forest does not represent any considerable plant biomass. Studies carried out by Lal (1989) in the Rewa Delta revealed that the volume of wood realised from Tiri (Rhizophorae sp.) averaged 2.3 cu. m/ha/annum and 5 cu. m/ha/annum from Dogo (*B. gymnorhiza*).

Therefore harvestable wood volume for the three deltas Rewa, Ba and Labasa over a 40 year period estimates to 201 cu. m/ha/40yr (Rewa) 92 cu.m (Ba) and 186 cu.m (Labasa).

4. MANAGEMENT AND CONSERVATION

4.1 FOREST POLICY AND LEGISLATION

Following the British Colonial tidal law, the Government recognises the Mean High Water Mark (MHWM) as the legal boundary between land and foreshore. All land above the MHWM belongs either to the State, Fijians as Native Land or private owners as Freehold land.

All foreshore below MHWM belongs to the State (unless alienated, in exceptional cases) and no ownership of resource therein is recognised. However, the right to use the fishery resources belong, where existence off traditional rights is recognised by the Native Lands and Fisheries Commission, to the Customary Fishing Right owners.

Thus the ownership of mangrove land and plants thereupon lies in the hands of the State. Mangrove being found on the land-water interface, their uses are not controlled by any one legislation or institution. Instead there are a number of piecemeal, use oriented legislations that separately govern the various resources, such as forestry, coastal fisheries or land.

Forestry licences are issued and regulated by the Forestry Department under the Forestry Act, while fishing activities are controlled under the Fisheries Act Cap 135. The Crown Lands Act (Cap 132) provides special provisions relating to foreshore land and soils beneath the waters and prohibits their use without a lease form the Government.

On 13th September, 1933, under the Forest Ordinance all mangroves were declared "Reserved Forest" to be maintained and controlled by the Conservator of Forests (Forestry Department).

Early in 1940s the licensing system was overhauled and Divisional Working Plans, based on Forest management on sustained yield basis were implemented (Swaroop 1983). Village mangrove reserves were established and these were kept outside licenced areas.

Towards the end of 1950 demands of mangroves for industrial fuel declined so markedly due largely to convenience of imported fuel that by early 1960s local market for mangrove as industrial fuel virtually disappeared.

In accordance with the Forestry Act the Conservator of Forest issued different types of licences ranging from permission for selective cutting to the occupation of the area for the purpose of reclamation.

The cutting of mangrove was permitted within the policies of the Forestry Division which took soil erosion and productivity (forest) as the major considerations.

Various types of developments were allowed under the Temporary Occupation Licence (TOL). Under the TOL the Conservator of Forest allowed reclamation of mangroves and after satisfactory completion of reclamation the Conservator of Forest advised the Director of Lands to issue appropriate lease.

A cabinet decision in 1974 deproclaimed all mangrove reserves, in order to allow free entry and fishing rights to the Native people. Through this decision all mangroves came under the jurisdiction of the Director of Lands as an intergral part of Foreshore, and are dealt in accordance with special provisions made in the Statelands Act (Cap 132) relating to Foreshore Land and soils beneath the waters.

Section 21 (1) specifically states that:

"No lease of any Crown foreshore land or of any soil under the waters of Fiji shall be made without the express approval of the Minister and such approval shall not be granted unless the Minister declares that such lease does not create a substantial infringement of public rights."

The Administrative and Institutional arrangement for use of mangrove ecosystem is shown diagrammatically in Fig. VII.

Recognizing the ownership of the Customary Fishing Rights over the Foreshore, Cabinet also decided that any loss to Fishing Rights should be compensated for and provided for an

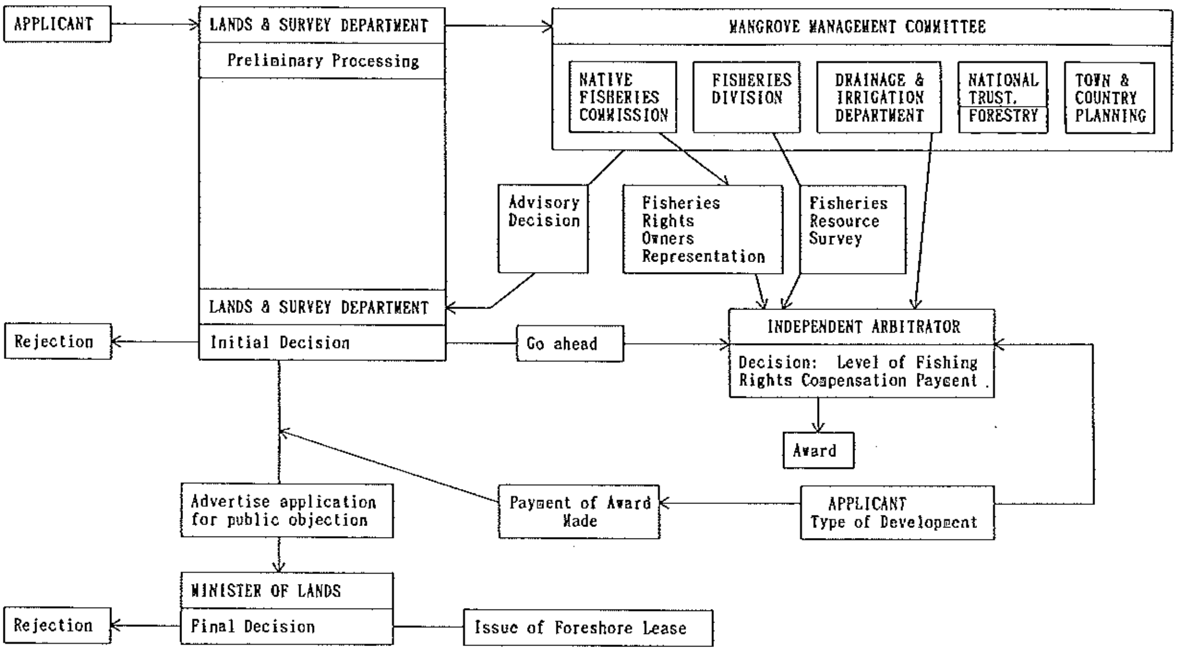

Figure VII: Administrative and Institutional Control of the mangrove ecosystem in Fiji.

appointment of an Independent Arbitrator to assess the compensation.

Customary Fishing Rights:

Traditional fishing rights existed before the Cession of Fiji to Britain in 1874. This right was recognised by the British and embodied in Article 7 of the Deed of Cession:

"That the right and interest of the said Tui Viti and other high chiefs the ceeding parties hereto shall be recognised by the British so far as is and shall be consistent with British Sovereignity and Colonial form of Government."

The fishing right is a right to fish in the Customary Fishing grounds as determined by the Native Fisheries Commission under the provisions of the Fisheries Act (Section 13 and 14 Cap 158). The Native Fisheries Commission was constituted in 1958 to determine the ownership and investigates the rights of each tribal unit and records it in the register kept by the Commission. These rights cover the reef and foreshore including mangroves and extending to inland waters as well.

Duty of the Independent Arbitrator and Guidelines to Method of assessment.

Duty: To assess the quantum of recompense to the owners of fishing right where the fishing rights are extinguished or diminished by reason of grant of foreshore leases or licences and the use of foreshore by the State by lessees and licences.

Guidelines: In assessing the quantum of recompense payable the Independent Arbitrator shall take into account the following:

i). The extent of the total resource of fish available before the rights are restricted.

ii). The extent of the total resource of fish remaining after the rights are restricted.

iii). The possible effect of the proposed development on remaining resources.

iv). The estimated annual rate of catch which is currently made by the claimants and the average estimated nett annual value of such catch to them.

v). The current degree of dependency of the claimants on their fishing rights before the proposed development.

vi). The possibility of a greater or lesser dependency on these rights by the holders within the foreseeable future.

vii). Any other matters which appear relevant to the arbitrator.

In arriving at the recompense the Independent Arbitrator will hear views of the owners of the fishing rights, the intending lessee/licensee and as may be necessary the officers of Native Land and Fisheries Commission, and experts from the Fisheries and Marine Departments.

4.2 ROLE OF FORESTRY AGENCIES

From 1933 (when mangroves were declared "Reserved Forest"), till the Cabinet decision of 1974, the Conservator of Forests still remains responsible for policing and control of exploitation: cutting rights are issued by the Forestry Department with prior consent of the Director of Lands (Lands Department).

At present exploitation is based on eight foot thinnings. Clear felling is permitted only in areas approved for reclamation.

4.3 MANGROVE MANAGEMENT PLAN

Arising from the recommendations of a mangrove workshop held in Suva, February 1983 (Lal 1983) the Cabinet endorsed the formation of Mangrove Management Committee and directed that a Mangrove Management Plan be drawn up. This was considered a matter of urgency and pending its preparation there were to be restraints of further mangrove reclamation.

The Mangrove Management Plan was thus prepared with the following terms of reference.

- To formulate a set of criteria which will form the basis a broad zonation philosophy in conjunction with the Mangrove Committee.

- To critically assess individual areas with the assistance and advice of government officers.

The primary objective behind the preparation of the plans was to allow for a degree of flexibility within mangrove and developed scheduled zones while affording maximum protection for the majority of the resource.

The mangrove areas of Viti Levu and Vannua Levu are divided into hierarchical zones of reserves, managed resource and development areas using land use zoning. (Watling 1985, 1986). The zoned plan takes into account the existing mangrove vegetation, the pattern of subsistence and commercial uses and the development carried out in the national interest.

The mangrove areas are thus zoned to allow for conservation of mangroves for sustainable harvest of forest and fisheries resources. Simultaneously some areas are zoned to allow conversion for other uses.

The seven principal uses are categorised as:

Traditional uses, sustenance of Capture fisheries, Fuelwood Production, Shoreline Protection, Sewerage Processing, Preservation for Science/education and aesthetics, conversion for alternative uses.

i) Primary Designation: Mangrove Reserves

(a) Resource Reserve

Mangrove areas identified as being of primary importance specifically in the sustenance of the capture fisheries, but for other reasons too which would become known on completion of detailed research. Areas selected on the basis of suspected high productivity or diversity, generally rather little used and with limited access. **The objective is to prevent any activities which might deleteriously affect the resource.** This should include appropriate zoning of adjacent land and coastal areas to ensure the integrity of the area.

(b) National Reserve

Areas of major scientific, educational or aesthetic interest. The objective is to provide full protection for the areas.

ii) Secondary Designation: Managed Resource Areas

(a) Traditional Use Zone

Table XV. Mangrove Zonation a Use-Compatibility Matrix

Designation			Major Uses						
			Fishing, Firewood, Building, Medicine etc.	Feeding grounds, Nurseries, Breeding sites	Fuelwood, Timber	Science, Education, Aesthetics	Erosion, Storm surge	Sewage, Pollution	Agriculture, Aquaculture, Urban
Primary Mangrove Reserve	Secondary Managed Resource	Tertiary Development Zone	Traditional Use	Capture Fisheries	Wood Production	Preservation	Shoreline Protection	Sewage Processing	Conversion
Resource Reserve			P	1	X	2	2	X	X
National Reserve			X	2	X	1	2	2	X
Wood Production (Potential) (in use)			P	2(1)	1	2	2	2	X
	Traditional Use		1	1	X	2	2	X	X
	Shoreline Protection		P	2	X	2	1	2	X
		Sewage Processing	X	2	2	2	2	1	X
		Urban Development	2	2	X	2	2	X	1
		Tourist Development	X	2	X	2	2	X	1
		Agriculture Development	X	X	X	X	X	X	1
Cabinet	Ministerial	Mangrove Management Committee	Decision Required for Designation Change						

Key 1-Primary function
2-Secondary function
P-Permitted
X-Incompatible

Mangrove areas which are subject to continual use and are required for the sustainable subsistence needs of rural communities. In some localities Traditional use zones will be effective 'Buffer Zones' around Resource Reserves.

(b) **Wood Production Zone**

Mangrove areas which have potential either through location on species composition, to be managed for commercial timber or firewood. Exploitation should be managed by the Forestry Department and based on specific Working/Management Plans.

Potential Wood Production/Zones should be regarded as Resource Reserve until they are managed for wood production.

(c) **Shoreline Production Zone**

Mangrove areas which are clearly required for the protection of adjacent land-roads, seawalls, agricultural land; or adjacent offshore reefs from inland erosion causing silt or pollutant dispersal.

Planning of Mangroves should be carried out in vulnerable areas which have lost their mangrove flora.

iii) **Tertiary Designation:** - Development Zones

(a) **Sewage Processing**

There are two components to the Mangrove areas required for sewage processing, a relatively small site converted during the construction of the oxidation ponds and a larger dispersed area which is likely to receive the effluent. Monitoring for possible health hazards in the latter area is essential.

(b) **Urban**

Areas primarily destined for conversion in peri-urban environs. Conversion should not be seen as the only development option. Designation of some mangrove areas as 'open space' - to enhance the waterfront, for local coastal protection or for aesthetic and educational purposes would be important. However, the zones should not be considered as essential to the national resource and their destiny should to a large part be controlled by the plans of urban authorities.

The latter should appreciate or be made aware of the aesthetic, conservation function in addition to the conversion option.

(c) **Tourism**

The development of the tourist industry is a national priority and as such mangrove areas will be considered for conversion if associated with development sites.

Tourist operators are increasingly aware of the value of mangroves as tourist attractions and this should be encouraged in the preliminary planning period.

(d) **Agriculture**

Areas which should be converted for agricultural use. Projects involving large scale clearance of mangroves will always be considered on their own merits and decisions made at the highest level. They cannot be zoned for in advance. At present only those areas cut off from salt water by sea wall construction are zoned for agriculture. Mangroves should not be clear-felled along the banks of creeks in such areas, as they will survive for many years in fresh water and will help prevent bank erosion.

The procedure for dealing with application over foreshore is documented at Supplement A.

4.4 SILVICULTURAL SYSTEMS

Both local and overseas experience shows that mangroves can be successfully regenerated naturally with some enrichment planting if necessary. Although mangroves are tolerant to shade to certain extent; in a mature stand dense overhead canopy has to be removed to allow light to penetrate if natural regeneration is to be encouraged.

In 1940 sustained yield management on a 40 year rotation was implemented on the basis of mean annual increment data available at that time. Compartment carrying mature stands was eight foot stick tinned and after five years clear felled when the area would be covered with seedlings from natural generation with very few blanks. Large blank areas were planted within three years from clear felling to get an even crop without loss of any volume increment (Swaroop 1983).

The plan was however abandoned when the demand for fuelwood diminished in the 1960s. Today exploitation is a eight foot thinning and on selective basis only. No clear felling is permitted.

4.5 REFORESTATION

There is no planned reforestation programmes. Natural regeneration within the felled areas have been very good. If reforestation programme is planned in the future, the first areas to be planted should be ; the bare mudflats within the mangrove areas.

4.6 FOREST CONSERVATION

The National Policy for mangroves as stated in the Mangrove Management Plan is that:

Mangroves are an important national asset. Primarily as a resource base for capture fisheries. Secondarily as a renewable source of products which contribute significantly to the quality of life of associated coastal communities.

Recognizing this:

The natural processes of the ecosystem should be preserved wherever possible thereby allowing the sustained harvesting of its renewable products and the preservation of future development options. Conversion activities should be minimised and permitted only in the national interest and after a detailed socio-economic comparison with the expected loss to the capture fisheries and other renewable uses.

The future of mangroves depends on human populations and "development" pressures. It is impossible and it would be self-defeating to recommend and insist on total conservation of the mangroves.

Total conservation of all the mangroves of the world for the sake of the mangroves themselves would be hopeless task to achieve because of so many vested and competing interests who all want to share the benefits and opportunities offered by the coastal zone. (Vannucci 1989).

The conversion of some mangroves to other uses is therefore inevitable. Keeping these in mind the fundamental objectives would be to:

(a) Exploit "Fiji" foreshore resources wisely in a manner which is consistent with the maintenance of a healthy environment and for the benefit of the country as a whole.

(b) Major reclamation of mangroves especially for agricultural purposes would be discouraged and the reclamation for specialised uses would be considered with careful evaluation and assessment against impact on environment.

The land use zonation plans of the three major deltas of Rewa, Ba and Labasa reflects the Government's aim for conservation of the resource. See Appendix B.

4.7 CASE STUDIES OF SUSTAINABLE MANAGEMENT PRACTICES

An example of sustainable management practices can be found in the Rewa Deltas wood production zone. The mangrove Management Plan identifies:

- Rewa Delta's mangrove as amongst the most productive mangroves in Fiji.

- Primary concern should be to preserve this productivity to sustain subsistence and economic needs.

The Mangrove cutting operation for fuel wood production is managed in a sustainable basis. The areas zoned for wood production are divided into compartments and plans are drawn for their management.

The concessioners issued with licences are given clear directives on methods of operations. No clear felling is allowed. Thinning with 8 feet stick is carried out. Trees to be cut are marked by the Forestry Department staff. The cutting operation is closely supervised and monitored. Upon completion of operation in a compartment the Forestry Department staff ensures that the felled area has been properly cleared of cut branches and twigs.

4.8 CASE STUDIES OF NON SUSTAINABLE USE

Mangrove utilisation is of two types:

(a) Non-sustainable yield utilisation and

(b) Sustainable yield utilisation.

The first type of activity is large scale modification or replacement of the ecosystem for some other purpose. Some of the more significant activities of this nature include reclamation of mangroves for agriculture, aquaculture, urban development etc.

These have been described earlier in section 1.5.

One example of non-sustainable use through which large areas of mangrove were lost was through disposal of dredged materials in the mangroves.

The Drainage and Irrigation Department has undertaken a massive project of dredging the Rewa River for flood mitigation. It is a project of national importance with approximately $20 million invested to-date.

The final 6 km of the main channel to the mouth of the river is an ecologically vulnerable area where some of Fiji's finest mangroves are found. These are identified as mangroves of national importance; primary designation being-'Resource Reserve' (with potential for fuelwood) in the Mangrove Management Plan.

These mangroves are almost exclusively fine stands of Dogo (*B. gymnorhiza*) a species particularly susceptible to sedimentation.

Consequently dredge disposal in the lower Rewa is ecologically hazardous and requires careful planning and implementation.

To date dredge disposal sites are thought to have been selected on a basis of convenience; with cost of acquiring and operation being the determining factors.

In view of the losses sustained to mangroves through dumping of dredged material and study was undertaken to identify suitable disposal sites.

The vegetation map and the proposed disposal sites are shown on Fig. VIII and IX.

4.9 GUIDELINE FOR SUSTAINABLE MANAGEMENT

The mangroves are essentially a forest formation and like other forests are a renewable natural resource. It is thus possible to manage the mangrove ecosystem on a sustainable use basis. The concept of sustainable use involves either sustainable harvest or sustainable economic returns while at the same time the system can be maintained in as natural or close to its original state as possible (e.g. the use for tourism). This sustainable use often does not mean sustaining the solely through preservation. Preservation can be part of sustainable use management plan.

A statement of the National Policy is given in section 4.6.

The fundamental objective therefore would be to exploit Fiji's foreshore resources wisely in a manner which is consistent with the maintenance of a healthy environment and for the benefit of the country as a whole.

The first phase of the National Mangrove Management Plan which focuses on the three major deltas, having majority of the mangroves; identifies specific management considerations. They are stated as follows:

BA DELTA:

- Mangroves of Ba Delta supports major natural fisheries. Therefore importance should be given to this function.

- Large scale conversion for agriculture should not be considered.

- No industrial development be considered on mangrove areas.

- Existing situation be maintained.

- Only selective cutting be allowed on wood production zone.

- Through Impact Assessment be undertaken before dredging Ba River.

LABASA DELTA:

- The mangroves in Labasa Delta is a major contributing factor toward rapid growth of fisheries in Labasa.

- Conversion of mangroves for Agriculture should be avoided.

- Controls needed on discharge of pollution from Sugar Mill and Industrial estates.

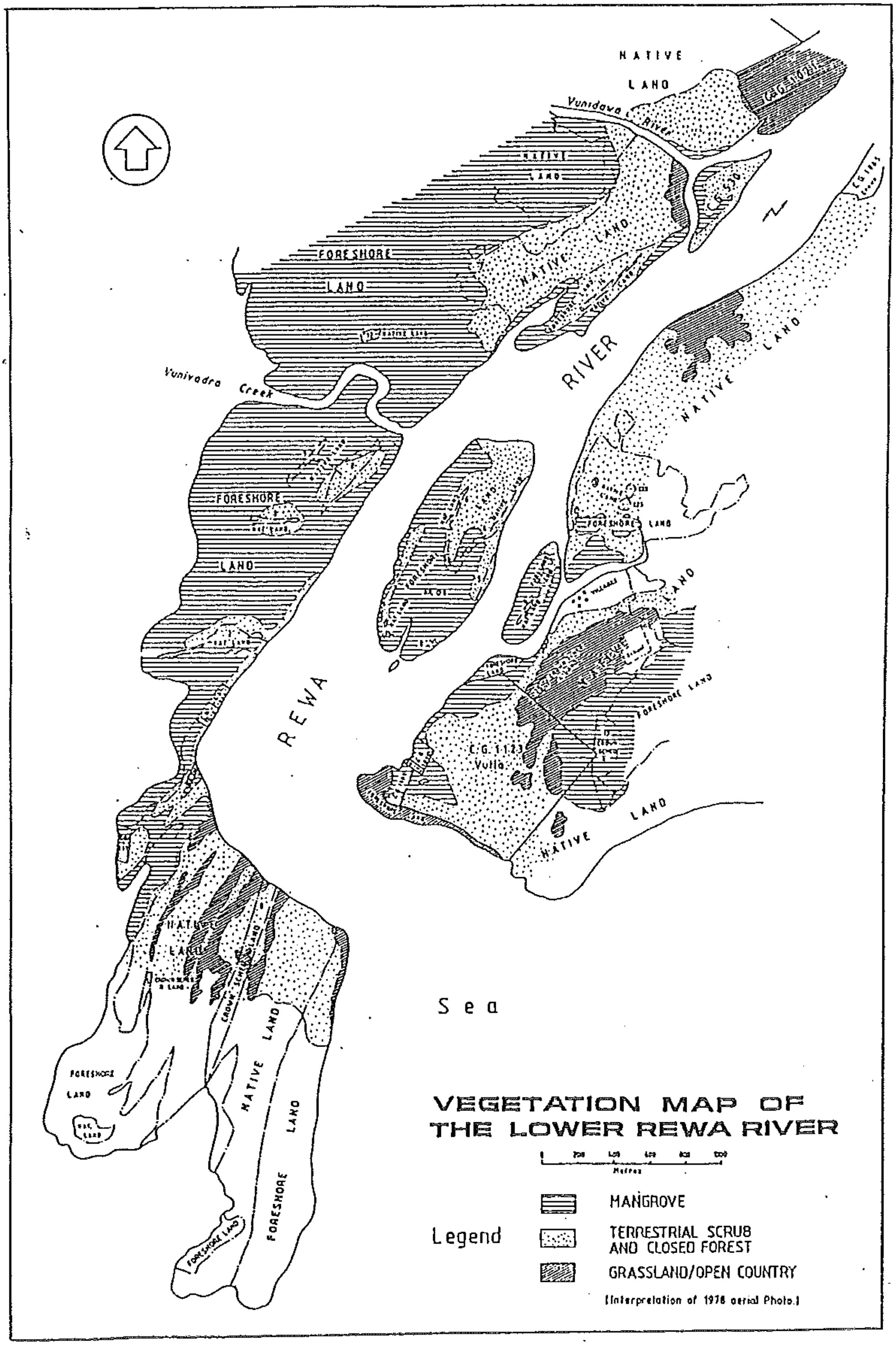

Figure VIII. Vegetation map of the lower Rewa river.

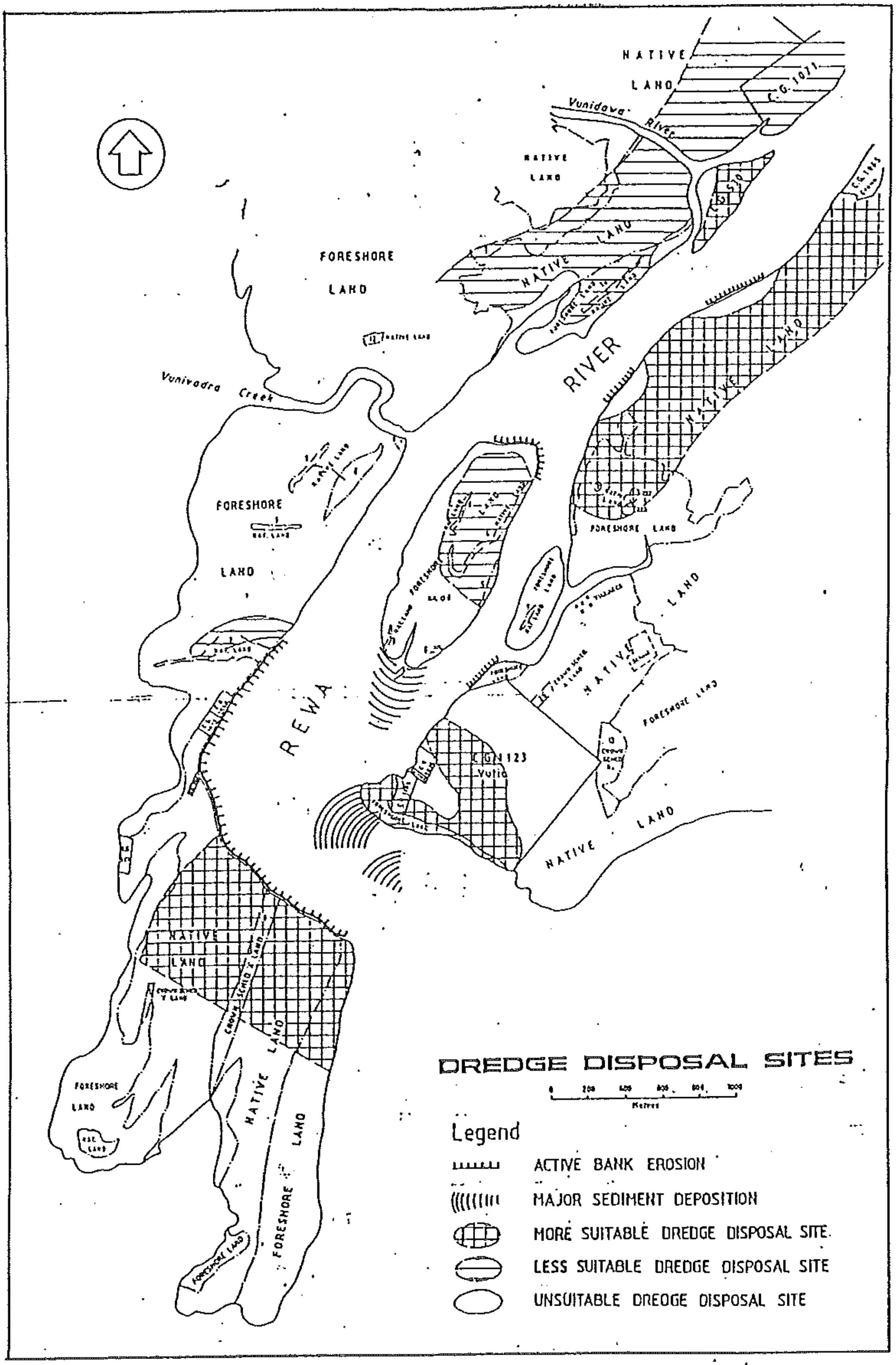

Figure IX: Dredge disposal sites.

- Town Councils rubbish dump needs better management.

-Through impact study be undertaken before carrying out the dredging of Labasa' River.

REWA DELTA:

- Rewa Deltas mangroves are amongst the most productive mangroves of Fiji.

-Primary concerns should be to preserve this productivity and sustain subsistence and economic needs.

- Impact on present dredging operation on mangroves should be evaluated.

- Increased agricultural development will increase risk of pollution through chemical use.

- Pollution should be monitored.

- Wood production zone identified, be harvested on a sustained yield basis.

- Concessions on commercial felling needs close supervision and monitoring.

- Prosecute offenders - for illegal cutting of mangroves.

- The high population density and anticipated community development will increase pressure on the Rewa Mangroves, with traditional uses evolving into more non-sustainable activities. Increased management will be required and an appropriate educational/awareness programme will be vital.

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SUPPLEMENT A

PROCEDURE FOR PROCESSING FORESHORE LEASE

Following procedure has been adopted for the processing of application of foreshore lease.

i) Application is made on an appropriate form available from the Department of Lands and Survey.

ii) The Lands & Survey Department upon receipt of the application will carry out preliminary processing of application by consulting relevant Ministries/Departments including other relevant agencies (e.g. Directorate of Town and Country Planning, Ministry of Works, Health, Rural Local Authorities, City/Town Councils if applicable, Marine Department and Commissioners of Divisions etc.)

iii) A copy of plan showing the area applied for is sent to Native Lands Commission to determine and advice precisely whether Fishing rights exist over the area concerned and what division of the people enjoy these rights.

iv) Once the comments are received, it is considered by the Mangrove Management Committee-only in areas where mangrove reclamation is involved.

v) Once it has been determined from the comments received at (ii) that the application could be processed further, then Fisheries Department is asked to survey and assess the quantity of marine resource in the area applied for.

vi) When the report is received from the Fisheries Department, it is forwarded to the Independent Arbitrator with details of application, requesting for a date of hearing to determine the amount of recompense for the loss of Fishing Rights.

vii) The Commissioner of the Division is advised at the same time to inform the Fishing Rights owners that the Independent Arbitrator in due course will hear their views on any claim for the loss of the right to fish in their fishing grounds.

viii) The Independent Arbitrator fixes the date of hearing and advises the parties concerned.

ix) The hearing is conducted by the Arbitrator and decision conveyed in writing later on.

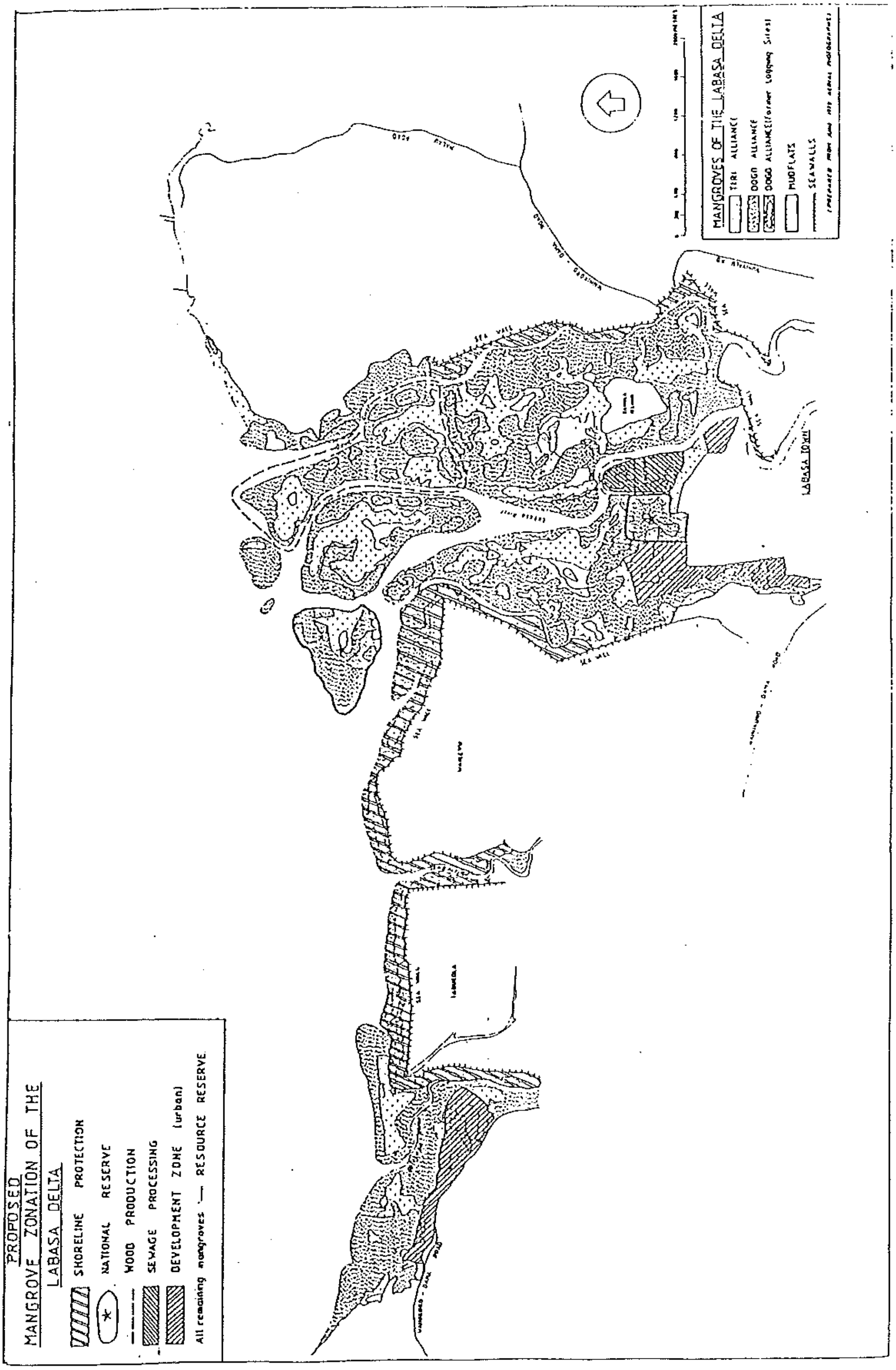
x) Upon receipt of the recompense award, the Director of Lands advises the applicant to deposit the sum with the Lands Department.

xi) The Director of Lands then informs the Applicant to advertise the application in terms of the Crown Lands Act called for Public objections.

xii) Objections received is considered by the Minister. If the Minister is satisfied that no substantial infringement of the Public Rights is created by the proposed development then an appropriate lease is granted.

If the development proposal is of such a nature that it will create adverse impact on the environment, the developer will be asked to provide an environmental impact assessment, normally undertaken by a qualified consultant in that field. Processing a foreshore lease normally takes at least 12 months.

SUPPLEMENT B



SUPPLEMENT B: Proposed mangrove zonation of the Labasa Delta.

SUPPLEMENT C

The Figures received with the original manuscript unfortunately cannot be reproduced adequately. They illustrate a recommended:

SUSTAINED YIELD MANAGEMENT PLAN

Fig. 1: Year 0 - Clear Felling

a) The contractor although given a license to remove ALL trees and ALL wood over three inches in diameter has left the less desirable trees and wood but is ordered under threat of the penalty clause in his license to remove.

b) This compartment has now been properly cleared. There is little slash left.

Year 1 and 2 - Do Nothing

The slash will rot and disappear. Seedlings bent and broken during fellings will sprout again. Tides will bring new seedlings.

Fig. 2: Year 3 - Planting

a) The forest Officer inspects the area and finds a few blanks. He arranges for them to be planted immediately.

b) The area is now completely covered with seedlings, some just planted and some several years old.

Years 4 to 14 - Do Nothing

Fig. 3: Year 15 - Three-Foot Stick Thinning

a) The average girth of the trees is 12 inches (four inches diameter). For clearness the stilt roots of the *tiri* have been omitted.

b) The remaining trees stand about 4 1/2 feet apart. The stumps of the trees are shown for clearness but would in fact be very short. Almost all *tiri* have been removed.

Year 16 to 24 - Do Nothing

Guard against pilfering.

Fig. 4: Year 25 - Five Foot Stick Thinning

a) The average girth of the trees is 18 inches. The removal of badly shaped trees in this thinning is very desirable as the increased volume of a bent knotty tree is of far less value than the same increment on a straight tree.

b) The trees are left at an average of seven feet apart. Young seedlings will appear in the area but will die off as the branches of the larger trees grow together.

Year 26 to 34 - Do Nothing

These fine poles will tempt people, and increased vigilance is necessary.

Fig. 5: Year 40 - Clear Felling

a) The contractor is required to remove all trees and all usable wood over three inches in diameter.

b) If the work has been done well, no usable wood will be left.

Start Again at Year 0.

Mangrove resource information system

Introduction

The choice of the best management option and the development of an appropriate management plan for a mangrove area requires at the outset a detailed inventory of its environmental, physical and biological characteristics, its present uses, and its environmental, ecological and socio-economic values. In addition, the assessment of benefits, costs and risks for various management options can be assisted by access to information on successful and unsuccessful management strategies in other localities, provided that differences in environmental, political, and socio-economic conditions between localities are recognized. Thus specific case studies of successful and unsuccessful management practices can provide useful guidelines for others to follow. Given the required inventory and other information it should be possible to choose a goal for management using a framework such as that outlined by Umali, R. *et al.* (1986), or the more specific ecological and economic benefit cost analyses described by Lal, P. N. (1990) and Aksornkoae, S. *et al.* (pp. 83-132 of this report).

Much of the information required for making management decisions already exists in the extensive literature on mangroves. However, it is scattered across many scientific journals and both published and unpublished reports, which are often unknown or unavailable to policy makers, resource users and coastal zone managers. Furthermore, this information is often not in a form that can be easily interpreted and utilized for allocating mangrove resources and developing appropriate management plans. It is also clear that some countries do not have adequate inventories for making rational decisions on the sustainable use and management of their mangrove ecosystems. It was for these reasons that the preliminary workshop of this project, held in Bangkok over the period November 1990, identified the need to develop a database for the acquisition and analysis of data relevant to the management of mangrove ecosystems and which, with further development, might provide a mangrove information and decision support system for policy makers, resource users and coastal zone managers.

From the outset it was recognized that it would not be possible to develop a working mangrove information database within the constraints of the present project. More realistically, however, it was considered feasible to develop a prototype database that could be evaluated using data provided by the three participating countries, and which could serve as the initial model for data to be collected in other countries.

Implementation

Information can be grouped broadly into two categories, quantitative alphanumeric data, and descriptive or inferential information which is usually of a textual nature. Both are important in decision making. Quantitative alphanumeric data can be further subdivided into two kinds: firstly, that which generally does not change with time (i.e. static) data, such as geographic information like latitude and longitude, or perhaps summary long-term averages of temperature and other climatic data; secondly, data that is collected or varies over time (temporal data) and which thus forms part of a time series. Ideally a database model should provide the capacity for storing, retrieving and linking all the information that is relevant to any given problem or decision. In practice it is much easier to design a database model to handle quantitative alphanumeric data (both static and those which change with time) than one which handles descriptive or inferential information.

Conceptually, the database is designed to hold information over a range of spatial scales. In general, the primary geographic scale envisaged is that of a contiguous area of mangrove of any size which can be identified as a complete ecosystem unit, and which has, or should logically have, its own overall management plan, ideally administered by a single agency.

It must be emphasised that the present database is not yet a programmed or fully implemented relational database model that provides a consistent user interface, data input validation and queries. To develop an integrated relational database with these features is beyond the scope of this project. Rather, it is a series of data tables that share one or more common fields to provide the necessary linkages in a fully relational database implementation. Where possible it shares common fields with a database that has been developed in the ASEAN-Australia Coastal Living Resources Project, in order that the two databases might be linked at some time in the future. However, the overlap between the two databases is minimal. The purpose of the ASEAN-Australia database is to hold site specific research and monitoring data on soil characteristics, forest structure, and fauna at selected sites in ASEAN countries. The present database, on the other hand, has been conceived to focus more on utilization and management at the local, regional and national levels.

The choice of the most suitable database management software to implement a fully relational database cannot be made until the full scope of the database is more fully known. The data tables in the present database are in the form of DBase III files, which are a *de facto* format for most other database management systems and geographic information systems software. Data held in the database should therefore be accessible across most hardware and software platforms, providing the greatest possible flexibility for the future development of a more broadly based mangrove information database.

The data tables have been designed initially to hold three types of alphanumeric information:

1. Meteorological data.
2. Inventory data on the area, and physical, chemical and biological characteristics of mangrove ecosystems.
3. Data on the utilization and socio-economic values of mangroves.

These three types of information are considered to be the minimum necessary to assess the status of conservation, use and management of mangrove ecosystems.

The structure and content of the various data tables presently in the database are given at the end of this section of the report. These tables have been set out to provide relatively simple data entry and ease of data checking without access to a fully relational database implementation. Thus there is some redundancy in the tables. In a full database implementation, for example, all meteorological data tables could, and should, be combined into a single table. There is also scope for reorganising other data tables to reduce redundancy, and for including additional fields or tables as the need arises. In a more complete relational database implementation, linkages between data tables will be chiefly through the common fields of Sample_ID, Locality_ID and Site_ID.

Copies of the sample database tables were sent to Indonesia, Malaysia and Thailand in May 1992, each country being requested to provide as much data as possible. Owing to the short time available to compile data only Malaysia and Thailand submitted limited data sets in the format requested. Furthermore, there are issues of data validation that need to be addressed before the data sets are more widely distributed.

Future implementation

It is clear from the data submitted by Malaysia and Thailand that the present database tables require modification to reduce ambiguity and make the task of entering data easier. Furthermore, given the amount of tabular data presented in the three country reports, there is also clearly scope for adding additional fields and tables. There remains, however, the question of what kinds of additional information should be included. In view of these issues, it is evident that substantially more effort needs to given to developing an appropriate mangrove resource information database. A full database implementation will require:

1. Identification of further information required by policy makers and coastal zone managers.
2. A more complete compilation and assessment of the available data on mangrove ecosystems.
3. The selection of appropriate personal computer software to implement a fully relational database.
4. The design of better data structures, and forms for data entry and queries.

These steps should be carried out with the longer-term objective of a full geographic information system (GIS) in mind. This is a significant task in which ISME should play a central role. For individual countries to derive maximum benefit from a database, each should be responsible for maintaining their own data. The role of ISME should be to define the framework and coordinate the database. It should also maintain a master database that holds the data from all countries in order to facilitate the transfer of information between countries, institutions and individuals.

There are two other issues that must be addressed in implementing a mangrove resource information database. The first concerns the integrity of data and its validation. Mechanisms will need to be put in place to ensure the reliability of data and that it has been entered correctly. Some cross-checks have already been included in the present data tables, but additional measures may be necessary.

The second issue that needs to be considered is the question of data security. A global database should hold as much of the available information as possible. Countries, institutions and individuals must be encouraged to provide all their relavant data, some of which might be unanalysed and unpublished. Some measures may need to be taken to ensure that such data is not made available to others without the permission of the provider. Again some measures to ensure this have been included in the present data tables, but others may need consideration.

Data tables

The content and structure of the present data tables are shown below. The tables are fully annotated and for the most part are self-explanatory. The first of the tables (MASTER.DBF) is the Master Table. This is the main table that holds the information that is common to all other tables. The key fields of Sample_ID, Site_ID and Locality_ID in this table provide the links between all tables in a relational database. The other tables in the database have at least one of these key fields in common with the Master Table. Each entry in the other tables must have a corresponding entry in the Master Table to maintain referential integrity. Each locality must have a unique Locality_ID that is not duplicated. All data relevant to a particular locality, which may be spread across many tables, are identified by the same Locality_ID.

Table 1. Partial listing of Species Codes to be used for exclusive mangrove species.

Species	Code	Species	Code
Acanthus ebracteatus	AE	*Excoecaria agallocha*	EA
Acanths ilicifolius	AI	*Heritiera littoralis*	HL
Acanthus volubilis	AV	*Heritiera formes*	HF
Aegialitis annulata	AA	*Kandelia candel*	KC
Aegialitis rotundifolia	AF	*Laguncularia racemosa*	LG
Aegiceras corniculatum	AC	*Lumnitzera littorea*	LL
Avicennia alba	AW	*Lumnitzera racemosa*	LR
Avicennia bicolor	AB	*Nypa fruticans*	NF
Avicennia eucalyptifolia	AY	*Osbornia octodonta*	OO
Avicennia germinans	AG	*Pelliciera rhizophorae*	PR
Avicennia intermedia	AN	*Phoenix paludosa*	PP
Avicennia lanata	AL	*Rhizophora apiculata*	RA
Avicennia marina	AM	*Rhizophora harrisonii*	RH
Avicennia officinalis	AO	*Rhizophora lamarckii*	RL
Avicennia rumphiana	AR	*Rhizophora mangle*	RG
Avicennia tomentosa	AT	*Rhizophora mucronata*	RM
Avicennia tonduzii	AZ	*Rhizophora racemosa*	RR
Bruguiera cylindrica	BC	*Rhizophora selala*	RX
Bruguiera exaristata	BE	*Rhizophora stylosa*	RS
Bruguiera gymnorhiza	BG	*Scyphiphora hydrophyllacea*	SH
Bruguiera hainesii	BH	*Sonneratia alba*	SA
Bruguiera parviflora	BP	*Sonneratia apetala*	SP
Bruguiera sexangula	BS	*Sonneratia caeseolaris*	SC
Camptostemon philippinesis	CP	*Sonneratia griffithii*	SG
Camptostemon schultzii	CS	*Sonneratia ovata*	SO
Ceriops australis	CA	*Xylocarpus australasicus* (*X. mekongensis*)	XA
Ceriops decandra	CD	*Xylocarpus gangeticus*	XX
Ceriops tagal	CT	*Xylocarpus granatum*	XG
Conocarpus erectus	CE	*Xylocarpus moluccensis*	XM
Cynometra iripa	CI	*Xylocarpus parvifolius*	XP
Cynometra ramiflora	CR		

Table 2. Partial listing of Species Codes to be used for non-exclusive (associate) mangrove species.

Species	Code	Species	Code
Acrostichum aureum	AH	*Hibiscus hamabo*	HH
Acrostichum danaefolium	AD	*Hibiscus tiliaceus*	HT
Acrostichum speciosum	AU	*Mauritia flexuosa*	MF
Barringtonia racemosa	BR	*Maytenus emarginata*	ME
Brownlowia argentata	BA	*Myristica hollrungii*	MH
Brownlowia tersa	BT	*Oncosperma filamentosa*	OF
Cerbera floribunda	CF	*Pemphis acidula*	PA
Cerbera manghas	CM	*Pterocarpus officinalis*	PT
Clerodendrum inerme	CI	*Thespesia acutiloba*	TA
Cynometra mannii	CN	*Thespesia populnea*	TP
Dimorphandra oleifera	DO	*Thespesia populneoides*	TU
Dolichandrone spathacea	DS		

Table 3. Partial listing of Telex Codes to be used for Country Codes in database tables.

Country	Code
Angola	AN
Australia	AA
Bahamas	NS
Bangladesh	BJ
Barbados	WB
Belize	BH
Benin	DY
Brazil	BR
Brimeo	BO
Brunei	BU
Cameroon	KN
Cambodia	CP
Chile	CL
China	CN
Colombia	CO
Comoro Islands	CI
Congo	KG
Costa Rca	CR
Cuba	CU
Dominican Republic	DR
Eauatorial Guinea	EG
Ecuador	ED
Egypt	UN
El Salvador	ES
Ethiopia	ET
Fiji	FJ
French Guiana	FG
Gabon	GO
Galapagos Islands	GI
Gambia	GV
Ghana	GH
Guadeloupe	GL
Guatemala	GU
Guinea	GE
Guinea-Bissau	GB
Guyana	GY
Haiti	HC
Hawaii	HR
Honduras	HT
Hong Kong	HX
India	IN
Indonesia	IA
Ivory Coast	IC
Jamaica W. I.	JA
Japan	JP
Kenya	KE
Malagasy	MY
Malaysia	MA

Country	Code
Mauritius	IW
Mexico	ME
Mozambique	MO
Myanmar (Burma)	BM
Namibia	WK
New Zealand	NZ
New Caledonia	NW
Nicaragua	NA
Nigeria	NG
Oman	MB
Palau	PU
Pakistan	PK
Panama	PA
Papua New Guinea	NE
Peru	PE
Philippines	PH
Puerto Rico	PT
Qatar	DH
Samoa (American)	AS
Samoa (Western)	SX
Sao Tome	ST
Saudi Arabia	SJ
Senegal	SG
Seychelles	SZ
Sierra Leone	SL
Singapore	RS
Somalia	SM
South Africa	SA
South Yemen	SY
Solomon Islands	HQ
Sri Lanka	CE
St Lucia W.I.	LC
Sudan	SD
Surinam	SN
Taiwan	TW
Tanzania	TZ
Thailand	TH
Togo	TO
Tonga	TA
Trinidad & Tobago	WG
United Arab Emirates	UA
USA	US
Vanuatu	NH
Venezuela	VE
Vietnam	VT
Virgin Islands (British)	VB
Virgin Islands (U.S.)	VN
Zaire	ZR

File Name: MASTER.DBF - Master Table that holds information common to all database entries.				
Field_Name	Field_Type	Field_Length	Decimals	Description
Sample_ID	C	10		Sample_ID - CCGGGnnnnn, where CC is two character country code, GGG is a three character group code, nnnnn is a 5 digit sequential number.
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Site_ID	C	20		CCSSSnnn, where CC is 2 character country code, SSS is a three
Data_Table	C	12		Name of Data Table holding the data
Data_Type	C	3		3 character code for the type of the data - see below
Data_Status	C	2		Either PD (public domain) or RA (restricted access) - this should be specified by the Provider (see next field)
Provider	C	20		Contact name for person who entered in the data
Owner	C	20		Name of the person or institution that owns the data.
Sample_Date	C	8		Date sample collected

Notes:
1. Data_Type: (GEO = geomorphological); (HYD = hydroglogical or hydrodynamic); (USE = use); (ECO = socio-economic); (MET = meteorological); (FOR = forest structure)
2. Sample_ID: Each research group in a country should have their own unique 3 character code. Duplicate group codes within any one country are not permitted.

LOCALITY.DBF - static locality information that does not change with time				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Loc_Name	C	30		Name of mangrove unit or estuary
Loc_longit	C	8		Longitude at centre of mouth of estuary or mangrove unit
Loc_latit	C	8		Latitude at centre of mouth of estuary or mangrove unit
Geom_set	C	15		Geomorphic setting - e.g. low island, river delta, estuarine, marine embayment, exposed foreshore
Main_influ	C	15	0	Main influence - e.g. river dominated, marine dominated
Tide_range	N	5	2	Tidal range at Mean HighWater Spring Tide (m)
Silt_rate	N	4	1	Rate of siltation or accretion rate (cm)
Sea_level	N	4	1	Annual rate of eustatic seal level rise (cm)

SITE.DBF - site information				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Site_ID	C	9		Site ID - A unique ID to distinguish between different sites at any one locality. Should consist of the Locality_ID, followed by a dash and 3 digit site code. e.g. IA001-001
Site_Name	C	30		Name of site
Site_longit	C	8		Longitude of site
Site_latit	C	8		Latitude of site
Geom_set	C	15		Geomorphic setting - e.g. low island, river delta, estuarine, marine embaymen, exposed foreshore
Main_infl	C	15	0	Main influence - e.g. river dominated, marine dominated
Tide_range	N	5	2	Tidal range at Mean Water High Spring Tide (m)
Silt_rate	N	4	1	Rate of siltation or accretiion rate (cm)
Sea_level	N	4	1	Annual rate of eustatic seal level rise (cm)

FORSTRUC.DBF - mangrove forest structure				
Field Name	Field Type	Field Size	Decimals	Description
Sample_ID	C	10		Sample_ID - CCGGGnnnnn, where CC is two character country code, GGG is a three character group code, nnnnn is a 5 digit sequential number.
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Site_ID	C	9		Site ID - A unique ID to distinguish between different sites at any one locality. Should consist of the Locality_ID, followed by a dash and 3 digit site code. e.g. IA001-001
For_type	C	20		Forest type - closed canopy, open canopy
For_descrip	C	20		Forest description -
Inund_freq	N	2	0	Frequency of tidal inundation (number of days per month) - enter 0 for tidal frequencies of less than one day per month
Dom_Spp	C	2		Dominant species - give species code (See Table of species codes)
Oth_Spp	C	30		List other species present (SeeTable of species codes), each separated by a space
Stem_ha	N	5	0	Number of stems per hectare (> 4 cm DBH)
Avg_DBH	N	5	1	Average DBH (cm) (> 4 cm DBH)
Bas_Area	N	5	1	Basal Area (m^2 ha^{-1})
Avg_height	N	3	0	Average height of canopy (m)
Can_cover	N	2	0	Percent canopy cover
Loge_Io_I	N	5	3	Average Log_e (I_o/I) - as calculated using the ASEAN-Aust productivity method
No_seedlings	N	6	0	Number of seedlings per hectare (< 1 cm DBH)
No_saplings	N	5	0	Number of saplings per hectare (1 - 4 cm DBH)
Avg_litter	N	4	1	Average annual litterfall (tonne ha^{-1})

SOILPROP.DBF - Soil properties				
Field Name	Field Type	Field Size	Decimals	Description
Sample_ID	C	10		Sample_ID - CCGGGnnnnn, where CC is two character country code, GGG is a three character group code, nnnnn is a 5 digit sequential number.
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Site_ID	C	9		Site ID - A unique ID to distinguish between different sites at any one locality. Should consist of the Locality_ID, followed by a dash and 3 digit site code. e.g. IA001-001
Soil_type	C	15		Soil type - e.g. sand, sandy loam, clay, clayey loam, silt, silty loam
Soil_salinity	N	4	1	Soil salinity (ppt)
Soil_pH	N	4	1	Soil pH

File Name: DEMOG.DBF - Dbase file structure for Demography table.				
Field_Name	Field_Type	Field_Length	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Pop_100k	N	8	0	Population within 100km radius
Near_city	C	15		Nearest city with a population greater than 100,000
City_dist	N	5	0	Distance between centre of city with population > 100,000 and centre of the mangrove unit
City_popln	N	6	0	Population of nearest city with a population > 100,000
City_long	C	8		Longitude of nearest city with a population > 100,000
City_lat	C	8		Latitude of nearest city with a population > 100,000

File Name: TOURIST.DBF - Dbase file structure for Tourist Development table.				
Field_Name	Field_Type	Field_Length	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Devel_type	C	20		Type of development - eg. resort, recreation park, golf course, or specify other
Dev_area	N	7	0	Area of tourist development (ha)
Yr_devel	C	4		Year develped as tourist development, or proposed to be developed
No_visitors	N	6	0	Annual number of visitors
Devel_fee	N	3	0	Fee charged per visitor (to nearest US$) - Enter zero (0) if no fee charged
Ann_income	N	8	0	Annual income for development (US$)
Op_cost	N	8	0	Annual operating cost (US$)
No_empl	N	7	0	Number of local employees
Av_income	N	7	0	Average annual income of local employees

File Name: FORESTRY.DBF - Dbase file structure for Forestry table.				
Field_Name	Field_Type	Field_Size	Decimals	Description
Locality_ID	C	5		Sample ID - a two character country code, followed by a 3 character group code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
For_prod	C	15		Forest product - e.g. one of charcoal, poles, woodchips, alcohol, etc.
Ann_area	N	7	0	Annual area harvested (ha)
Harv_age	N	3	0	Age at harvesting (years) - if applicable
Avg_DBH	N	4	1	Average DBH at harvest (cm) - if applicable
Thin_1	N	3	0	Age at first thinning (years) - if applicable
Thin_2	N	3	0	Age at second thinning (years) - if applicable
Thin_3	N	3	0	Age at third thinning (years) - if applicable
Regen	C	10		Method of regeneration - manual (hand planting) or natural
Spacing	N	4	1	For manual regeneration only, please specify distance between seedlings (m)
Ann_prod	N	7	0	Annual production (tonne)
Ann_val	N	8	0	Annual value (US$)
Perc_exp	N	5	1	% of product exported
Exp_val	N	8	0	Annual export value (US$)
Loc_emp	N	7	0	No. local people employed
Av_incom	N	7	0	Average annual income of local people employed (US$)
Fix_cost	N	7	0	Annual fixed cost (US$)
Op_cost	N	7	0	Annual operating costs (US$)

File Name: FISHERY.DBF - Dbase file structure for Fisheries table .				
Field_Name	Field_Type	Field_Length	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Fis_meth	C	15		Fishery method - capture, pond, raft/cage
Fis_type	C	15		Type of fisheries - e.g. (shrimp, fish, oyster, horse mussel, green mussel, blood cockles, others by name)
Fish_spp	C	30		Latin name for species
Fis_name	C	20		Common name for species
Min_size	N	4	1	Minimum legal size (cm) if applicable - enter zero (0) if no minimum legal size.
Ann_area	N	7	0	Annual area fished (ha)
Ann_prod	N	7	0	Annual production (tonne)
Ann_val	N	8	0	Annual value (US$)
Perc_exp	N	5	1	Percent of production exported
Exp_val	N	8	0	Annual export value (US$)
Loc_emp	N	7	0	No. of local people employed
Av_incom	N	7	0	Average annual income of local employees (US$)
Fix_cost	N	7	0	Annual fixed cost (US$)
Op_cost	N	7	0	Annual operating costs (US$)

File Name: CONSERVE.DBF - Dbase file structure for Conservation table.				
Field_Name	Field_Type	Field_Length	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Park_type	C	20		Type of conservation area - eg. national park, nature park, forest reserve, fisheries reserve, habitat reserve, wildlife sanctuary, world heritage area, or specify other
Park_area	N	7	0	Areal extent of conservation area (ha)
Yr_gazetted	C	4		Year gazetted as conservation area, or year proposed for gazetting
Park_agency	C	20		Controlling agency - eg. Parks & Wildlife, National or State Forestry Service, Fisheries Service, etc.
No_visitors	N	6	0	Annual number of visitors (if applicable)
Park_fee	N	3	0	Fee charged per visitor (to nearest US$) - Enter zero (0) if no fee charged
Ann_income	N	8	0	Annual income for Conservation area (US$)
Op_cost	N	8	0	Annual operating cost (US$)
No_empl	N	7	0	Number of local employees
Av_income	N	7	0	Average annual income of local employees

File Name: AGRIC.DBF - Dbase file structure for Conversion to Agriculture				
Field_Name	Field_Type	Field_Length	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Crop_type	C	20		Type of crop - eg. rice, oil palm, coconut palm, sago palm, or specify other
Conv_area	N	7	0	Area converted, or to be converted (ha)
Ann_prod	N	7	0	Annual production (tonne)
Ann_val	N	8	0	Annual value (US$)
Perc_exp	N	5	1	Percent of production exported
Exp_val	N	8	0	Annual export value (US$)
Loc_emp	N	7	0	No. of local people employed
Av_incom	N	7	0	Average annual income of local employees (US$)
Fix_cost	N	7	0	Annual fixed cost (US$)
Op_cost	N	7	0	Annual operating costs (US$)

File Name: MISCEL.DBF - Dbase file structure for Miscellaneous Table. Use this table for data relevant to mining, salt ponds, and other miscellaneous uses not covered by other files.				
Field_Name	Field_Type	Field_Length	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Use_type	C	20		Type of mine - eg. tin, salt pond, or specify other
Conv_area	N	7	0	Area mined, or to be mined (ha)
Ann_prod	N	7	0	Annual production (tonne)
Ann_val	N	8	0	Annual value (US$)
Perc_exp	N	5	1	Percent of production exported
Exp_val	N	8	0	Annual export value (US$)
Loc_emp	N	7	0	No. of local people employed
Av_incom	N	7	0	Average annual income of local employees (US$)
Fix_cost	N	7	0	Annual fixed cost (US$)
Op_cost	N	7	0	Annual operating costs (US$)

File Name: URBAN.DBF - Dbase file structure for Urban Development Table.				
Field_Name	Field_Type	Field_Length	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Dev_type	C	20		Type of urban development - eg. high density, medium density, low density, or specify other
Dev_area	N	7	0	Area converted, or to be converted (ha)
No_housed	N	7	0	Number of people housed
Const_val	N	8	0	Construction cost (US$)
Perc_exp	N	5	1	Percent of production exported
Exp_val	N	8	0	Annual export value (US$)
Loc_emp	N	7	0	No. of local people employed
Av_incom	N	7	0	Average annual income of local employees (US$)
Fix_cost	N	7	0	Annual fixed cost (US$)
Op_cost	N	7	0	Annual operating costs (US$)

File Name: INDUSTRY.DBF - Dbase file structure for Industrial Development Table				
Field_Name	Field_Type	Field_Length	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes should match international Telex codes (See Table of Country Codes).
Ind_type	C	20		Type of industry - eg. port, automotive, or specify other
Ind_area	N	7	0	Area converted, or to be converted (ha)
Ann_prod	N	7	0	Annual production (tonne)
Ann_val	N	8	0	Annual value (US$)
Perc_exp	N	5	1	Percent of production exported
Exp_val	N	8	0	Annual export value (US$)
Loc_emp	N	7	0	No. of local people employed
Av_incom	N	7	0	Average annual income of local employees (US$)
Fix_cost	N	7	0	Annual fixed cost (US$)
Op_cost	N	7	0	Annual operating costs (US$)

DAYLENG.DBF - Mean monthly day length (hrs)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	30		Name of instrument (eg. Kipp & Zonen radiometer)
Jan	N	5	2	
Feb	N	5	2	
Mar	N	5	2	
Apr	N	5	2	
May	N	5	2	
Jun	N	5	2	
Jul	N	5	2	
Aug	N	5	2	
Sep	N	5	2	
Oct	N	5	2	
Nov	N	5	2	
Dec	N	5	2	

SUNSHINE.DBF - Mean monthly sunshine hours (hr)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	20		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	20		Name of instrument (eg. Stokes sunchine recorder)
Jan	N	5	2	
Feb	N	5	2	
Mar	N	5	2	
Apr	N	5	2	
May	N	5	2	
Jun	N	5	2	
Jul	N	5	2	
Aug	N	5	2	
Sep	N	5	2	
Oct	N	5	2	
Nov	N	5	2	
Dec	N	5	2	

SOLRAD.DBF - Mean monthly solar radiation flux density (W m-2)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. Kipp & Zonen radiometer)
Jan	N	4	0	
Feb	N	4	0	
Mar	N	4	0	
Apr	N	4	0	
May	N	4	0	
Jun	N	4	0	
Jul	N	4	0	
Aug	N	4	0	
Sep	N	4	0	
Oct	N	4	0	
Nov	N	4	0	
Dec	N	4	0	

RADINT.DBF - Mean monthly solar radiation integral (MJ)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. Integrating Kipp & Zonen radiometer)
Jan	N	5	2	
Feb	N	5	2	
Mar	N	5	2	
Apr	N	5	2	
May	N	5	2	
Jun	N	5	2	
Jul	N	5	2	
Aug	N	5	2	
Sep	N	5	2	
Oct	N	5	2	
Nov	N	5	2	
Dec	N	5	2	

PHOTON.DBF - Mean monthly photon flux density (mmol m-2 s-1)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. Licor Quantum Sensor)
Jan	N	4	0	
Feb	N	4	0	
Mar	N	4	0	
Apr	N	4	0	
May	N	4	0	
Jun	N	4	0	
Jul	N	4	0	
Aug	N	4	0	
Sep	N	4	0	
Oct	N	4	0	
Nov	N	4	0	
Dec	N	4	0	

PHOTINT.DBF - Mean monthly photon flux integral (mol m^{-2})				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) <u>or</u> automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. Integrating Licor Quantum Sensor)
Jan	N	5	2	
Feb	N	5	2	
Mar	N	5	2	
Apr	N	5	2	
May	N	5	2	
Jun	N	5	2	
Jul	N	5	2	
Aug	N	5	2	
Sep	N	5	2	
Oct	N	5	2	
Nov	N	5	2	
Dec	N	5	2	

MINTEMP.DBF - Mean monthly minimum air temperature (°C)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. chart thermograph, maximum thermometer)
Jan	N	4	1	
Feb	N	4	1	
Mar	N	4	1	
Apr	N	4	1	
May	N	4	1	
Jun	N	4	1	
Jul	N	4	1	
Aug	N	4	1	
Sep	N	4	1	
Oct	N	4	1	
Nov	N	4	1	
Dec	N	4	1	

MAXTEMP.DBF - Mean monthly maximum temperature (°C)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. chart thermograph, minimum thermometer)
Jan	N	4	2	
Feb	N	4	1	
Mar	N	4	1	
Apr	N	4	1	
May	N	4	1	
Jun	N	4	1	
Jul	N	4	1	
Aug	N	4	1	
Sep	N	4	1	
Oct	N	4	1	
Nov	N	4	1	
Dec	N	4	1	

MINWATEM.DBF - Mean monthly minimum water temperature (°C)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. chart thermograph, minimum thermometer)
Jan	N	4	1	
Feb	N	4	1	
Mar	N	4	1	
Apr	N	4	1	
May	N	4	1	
Jun	N	4	1	
Jul	N	4	1	
Aug	N	4	1	
Sep	N	4	1	
Oct	N	4	1	
Nov	N	4	1	
Dec	N	4	1	

MAXWATEM.DBF - Mean monthly maximum water temperature (°C)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. chart thermograph, maximum thermometer)
Jan	N	4	1	
Feb	N	4	1	
Mar	N	4	1	
Apr	N	4	1	
May	N	4	1	
Jun	N	4	1	
Jul	N	4	1	
Aug	N	4	2	
Sep	N	4	1	
Oct	N	4	1	
Nov	N	4	1	
Dec	N	4	1	

RAINFALL.DBF - Mean monthly rainfall (mm)				
Field Name	**Field Type**	**Field Size**	**Decimals**	**Description**
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) <u>or</u> automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. tipping bucket rain gauge, manual rain gauge)
Jan	N	4	0	
Feb	N	4	0	
Mar	N	4	0	
Apr	N	4	0	
May	N	4	0	
Jun	N	4	0	
Jul	N	4	0	
Aug	N	4	0	
Sep	N	4	0	
Oct	N	4	0	
Nov	N	4	0	
Dec	N	4	0	

EVAPOTRN.DBF - Mean monthly evapotranspiration (mm)				
Field Name	**Field Type**	**Field Size**	**Decimals**	**Description**
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual recording) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. pan evaporimeter, Piche evaporimeter, etc.)
Jan	N	4	2	
Feb	N	4	0	
Mar	N	4	0	
Apr	N	4	0	
May	N	4	0	
Jun	N	4	0	
Jul	N	4	0	
Aug	N	4	0	
Sep	N	4	0	
Oct	N	4	0	
Nov	N	4	0	
Dec	N	4	0	

MINRH.DBF - Mean monthly minimum relative humidity (%)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual or spot reading) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. chart thermohygrograph, Vaisala humidity sensor, sling psychrometer, wet and dry bulb thermometer, etc.)
Time	C	4		If manual spot readings, indicate time of reading (normally 1500 hrs)
Jan	N	5	1	
Feb	N	5	1	
Mar	N	5	1	
Apr	N	5	1	
May	N	5	1	
Jun	N	5	1	
Jul	N	5	1	
Aug	N	5	1	
Sep	N	5	1	
Oct	N	5	1	
Nov	N	5	1	
Dec	N	5	1	

MAXRH.DBF - Mean monthly maximum relative humidity (%)				
Field Name	Field Type	Field Size	Decimals	Description
Locality_ID	C	5		Locality ID - a two character country code, followed by a 3 digit site code. Where possible Country codes have been selected to match international Telex codes (See Table of Country Codes).
Met_Statn	C	20		Name of meteorological station
Statn_long	C	8		Longitude of meteorological station (degrees, minutes)
Statn_lat	C	8		Latitude of meteorological station (degrees, minutes)
Rec_leng	N	3	0	Length of record for this data set (years)
Mode	C	10		Mode of data collection - manual (ie. manual or spot reading) or automatic (ie. automatic recording of data)
Instrument	C	40		Name of instrument (eg. chart thermohygrograph, Vaisala humidity sensor, sling psychrometer, wet and dry bulb thermometer, etc.)
Time	C	4		If manual spot reading, indicate the time of reading (normally 0900 hrs)
Jan	N	5	2	
Feb	N	5	1	
Mar	N	5	1	
Apr	N	5	1	
May	N	5	1	
Jun	N	5	1	
Jul	N	5	1	
Aug	N	5	1	
Sep	N	5	1	
Oct	N	5	1	
Nov	N	5	1	
Dec	N	5	1	

PROJECT DOCUMENT -

The Economic and Environmental Value of Mangrove Forests and Present State of Their Conservtation

Background and Justification

Much of the living biomass on Earth is in the form of forest, of which tropical forests represent a significant proportion. In recent years widespread concern has been expressed at the escalating rate of destruction of tropical forests throughout the world, and its consequences for the global environment.

Although mangrove ecosystems represent only about 1% of the tropical forest on Earth, they are nevertheless highly productive in terms of timber, fuel wood chemicals, as well as providing a source of food and nursery grounds for many commercially important fish and prawn species. In addition, mangrove ecosystems stabilize coastlines, in many cases promote coastal accretion, and provide a natural barrier against typhoon, cyclones, tidal bores and other potentially damaging natural forces. They thus play a major role in maintaining a balanced environment and in providing a variety of foods and other products for human use in the coastal zone where 60-70% of the human population of developing countries live.

In many parts of the world, mangroves, like other types of tropical forest, have been destroyed by over-exploitation for short-term economic development and by human population pressures, with little regard for their long-term benefits to humans, particularly those that dwell along the coast. Recognizing this, UNESCO, with support from UNDP and other agencies, has implemented over the last decade several regional mangrove projects in Asia, the Pacific, Africa and the Caribbean. Their objectives were to develop an awareness of the value of mangroves, to develop expertise in research and management, and to promote the exchange of knowledge and management experience for sustainable use of mangroves throughout the world.

Japan has supported these projects, notably in the area of research, and in the promotion and sponsorship of international conferences on mangroves. In 1989, it formed the Japanese International Association for Mangroves (JIAM) as an agency for international cooperation.

With support from UNESCO, UNDP and the Government of Japan, the Regional Mangrove Coordinating Committee (RMCC), an inter-governmental body comprised of the chairmen of the National Mangrove Committees of countries in Asia and the Pacific, took the decision to form the International Society for Mangrove Ecosystems (ISME). The decision to form this non-govenmental international association was taken to improve international collaboration amongst mangrove researchers and managers, to promote further research of a high international standard, and to further enhance recognition of the importance of mangroves amongst government agencies, scientists, coastal zone managers, and the general community.

In view of the continuing loss of significant areas of mangrove from over-exploitation in the Asian-Pacific region and worldwide, there is an ever-increasing need to further promote ecologically sustainable uses and management of mangrove ecosystems. The concept of ecological sustainability implies flexibility in utilisation and management, recognizing the important ecological role of mangrove ecosystems and varying socio-economic conditions and aspirations from place to place.

The International Tropical Timber Organization (ITTO) has therefore agreed to fund a project to re-assess the economic and environmental value of mangrove forests and their present state of conservation in Asia and the western Pacific.

Project Objectives

1. To critically evaluate, as quantitatively as possible, existing knowledge on the geographic distribution and extent of mangroves in Asia and the western Pacific, their conservation, utilization and management, and their socio-economic importance.

2. To identify major gaps in existing knowledge that need to be addressed in order to develop ecologically sound plans for sustainable management of mangroves.

3. To identify and publicize examples of policies and management strategies that are ecologically sound and of socio-economic benefit.

4. To suggest research proposals based on the outcome of this project.

Project Outline

The project will focus on the following aspects:

1. An overviews of the present state of mangrove forests in selected RMCC countries.

   This will include an analysis of the areal extent of mangroves in different regions of each country according to major forest types, their floristic composition, their climatic conditions, associated soil types, their geomorphological setting and riverine or marine influences, the way in which they are used, and anthropogenic influences.

2. An assessment of current patterns of use and socio-economic values of mangrove forests in selected RMCC countries.

   This will involve an analysis of socio-economic values associated with forestry; agriculture; capture fisheries; mariculture; pond culture; mining; salt conversion; sewage treatment; urban, recreational and industrial development; and marine resources in general.

3. An analysis of the ecological and environmental value of mangrove forests in selected RMCC countries, with special emphasis on coastal protection and fisheries.

4. A review of the present state of conservation and management of mangrove forests in selected RMCC countries.

   This will include laws, regulations, and governmental agencies pertaining to management and conservation. It will also include an analysis of forest management and silvicultural systems, re-afforestation methods, and of other types of use and management. Examples of sustainable management of mangrove forest will be identified and management practices documented, using appropriate case studies in Thailand, Malaysia and Indonesia.

5. A review of mangrove management systems and their relevance to sustaining the ecological balance of coastal marine environments, and the sustainability of economic resources. Based on the foregoing reviews and assessments, some proposals for sustainable management of mangrove forests will be presented.

Project Implementation and Timetable (Tentative)

The project will be implemented by ISME, and coordinated by Dr. Barry Clough, Chairman, RMCC, according to the following tentative timetable, subject to ratification by participants at the Project Workshop to be held in Bangkok on 19-20 November 1991.

19-20 November 1991 - Meeting in Bangkok for the finalisation of project programme. Attended by representatives from RMCC, ISME, ITTO, JIAM; Government of Japan. Following this meeting, Chairmen of NATMANCOMs in RMCC countries will be requested to provide a report on the present state of mangroves in their respective countries. Specific directions for the preparation of these reports are being prepared and will be distributed for discussion in Bangkok.

22 November to 6 December 1991 - Project Coordinator will visit Thailand, Malaysia and Indonesia for specific discussions concerning case studies of current management practices, their economics, and their environmental impact.

December 1991 to March 1992 - NATMANCOMs will prepare country reports.

March/April 1992 - Project Coordinator will visit Indonesia, Malaysia and Thailand to finalise reports from these countries.

April-September 1992 - Preparation of final report and synthesis.

Proposed Budget

Personnel	10,419,000
Travel	2,398,296
Research	625,000
Workshop	6,051,704
Administration	4,700,000
Publications	2,600,000
Incidentals	206,000
	27,000,000

Country Reports

Contents

1. Area and extent of mangroves
   - on a region by region, state by state, prefecture by prefecture, or province by province basis.
   - where possible identifying the relative areas of different types of forest (classification scheme has yet to be finalised).
   - associated soil types/characteristics, and climatic and geomorphic settings.
   - analysis of loss/removal of mangroves according to type of activity and forest classification.
   - availability of remote sensing imagery and analysis capability.
   - identification of gaps in existing information regarding the distribution, floristics and areal extent of different kinds of mangrove forest.
2. Current socio-economic value of mangrove forests and patterns of use

Particular emphasis should be given to social and economic benefits and costs, to the areal extent and type of mangrove systems involved in each of the following:

- forestry
- fisheries-capture fisheries, mariculture, pond culture, marine resources in general
- agriculture
- mining
- salt conversion
- sewage treatment
- urban, tourist resort and industrial development

3. Ecological and environmental value of mangrove forests, with special emphasis on:
   - coastal erosion/protection
   - coastal fisheries nurseries and food chains
4. Conservation and management

Particular attention should be paid to:

- laws and regulations pertaining to the management and conservation of mangrove systems
- government agencies with responsibility for management and conservation
- forest management strategies and techniques
- silvicultural systems
- reafforestation methods, successes and failures
- other types of use and management
- identification and description of successful management practices resulting in sustainable use of mangrove areas

Preparation

Text

Where possible, Country Reports should be prepared on a word-processor, and submitted both as hard copy and on floppy disk. The following word-processor/disk formats are acceptable:

IBM PC/MS DOS compatible (5.25" 360KB and 1.2MB diskettes, or 3.5" 720KB and 1.44 MB diskettes are all acceptable). Acceptable word-processor formats are: Wordstar, Wordstar 2000, Word Perfect 4.2, 5.0, 5.1; Multimate; Microsoft Word 4, 5, 5.1: Microsoft Word for Windows; Ami Professional; DCA; plain ASCII text.

Apple Macintosh (all disk formats compatible with the Macintosh). Acceptable word-processors: Microsoft Word; MacWrite; plain ASCII text.

Where computer word processing facilities are not available, reports should be typed with a good quality ribbon, double spaced on high quality white paper.

Graphics

Again where possible illustrations of a non-photographic nature should be send both as hard copy and on computer disk. Computer generated graphics should be in one of the following forms:

IBM PC/MS DOS compatible (360KB, 1.2MB, 720KB, 1.44MB) - as Hewlett Packard graphics files (HPGL), Computer Graphics Metafiles

(CGM) or Autocad (DXF) files. CGM files are preferred, but please ensure that the background is white, not coloured.

Authors should also provide a copy of numeric data for graphics in the form of Lotus 1-2-3, Quattro or Excel spreadsheets, Dbase III, IV database files, or comma delimited ASCII files, as it may be necessary to re-do some graphic images in order to ensure consistency throughout the report.

In the case of hand-drawn illustration please ensure that they are drawn clearly in black ink on good-quality A4 (297 x 210 mm) paper. All lettering should be of a size that will allow 50% reduction in size without loss of readability.

Photographs

Please send either slides, or negatives and their corresponding prints. Mark prints clearly on back with matching negative.

International Society for Mangrove Ecosystems

Workshop on ISME/ITTO/JIAM Project

Assessment of Present State of Conservation and Use of Mangroves in the South-East Asia/Pacific Region.

Report on the Preliminary Workshop

Bangkok, 18-21 November 1991

1. **Opening of the Workshop**

The working sessions were formally opened at 0900 hrs on Tuesday, 19 November 1992 with Prof. Shizuo Saito in the Chair. Prof. Saito welcomed participants, briefly explained the importance of the project, and indicated that the scope and nature of the project would be outlined by the Discussion Leader, Dr. Barry Clough.

Mr. Emmanuel Ze Meka , representing ITTO, gave a brief introduction to the background for the project and outlined ITTO's expectations for the project. In particular he emphasised the importance of identifying both good and poor management practices, and the need to produce a set of guidelines for mangrove ecosystem management.

2. **Administrative Matters**

The Tentative Programme shown in Annexe I was adopted.

Dr. Chan Hung Tuck of Malaysia was appointed as Rapporteur for the workshop.

3. **Preliminary Country Reports**

Preliminary Country Reports were received from China, New Zealand, Philippines, Thailand, Vietnam.

4. **Project Outline**

Dr. Clough outlined the project proposal as described in Annexe II, indicating that two related projects were expected, one for West Pacific Island countries (implemented by JIAM) and one for Latin America (implemented by ISME).

It was pointed out that the last comprehensive analysis of regional mangrove resources was completed in 1985 as part of the UNESCO/UNDP Regional Project, *Research and Training Pilot Programme on Mangrove Ecosystems in Asia and the Pacific (RAS/79/002)*. Since that time there have been changes in the areal extent of mangroves within the region, as well as changes in management strategies or the implementation of new management plans in some countries.

It was emphasised that the present project would build on the information base already available from the UNESCO/UNDP Regional Project by including new information and in particular by quantification of available information where possible. It was pointed out that some kinds of information may not be amenable to quantification.

The Project Coordinator emphasised the need to identify gaps in information that are crucial to developing management options and detailed management plans, and the need to generate new project proposals to address these gaps in information. The need for close liaison with similar projects in other regions was also emphasised.

It was pointed out that the present project was subject to tight fiscal and time contraints, which necessitated that it be restricted chiefly to a few countries that had already invested considerable effort in managing substantial areas of mangrove on a sustainable basis. For this reason, the project would focus on Indonesia, Malaysia and Thailand, although information from other countries would be incorporated where possible.

5. Discussion themes

During discussion by participants, a number of key issues were highlighted. These included:

- The need to critically review information gaps in order to formulate new study proposals.
- The need to quantify data, particularly that relating to ecological and economic value, and that relating to management.
- The importance of studies of the socio-economic and environmental implications of various forms of utilisation and management.
- The need for a manual of procedures and methodologies for management that can be applied in participating countries.
- Much discussion focussed on the need for a database on the mangrove ecosystems of the region, and on the use of a geographic information system (GIS) to access and interpret this database. There was agreement that a full GIS was not feasible within the fiscal and time constraints of the present project. There was strong support, however, for the idea that data provided by the three main participating countries should be used to develop a model for data acquisition and storage by other countries in the region, with the longer term objective of interfacing the database to a GIS for analysis and interpretation.

6. Action Plan

It was agreed that the project as described in Annexe I should proceed, with particular emphasis placed on:

- Quantification where possible of
    - the total area of mangroves
    - the area set aside for conservation, forestry, fisheries, etc.
    - ecological and economic value of mangroves managed for different uses.
    - climatic, soil and structural characteristics of mangrove forests managed for different uses.
- Identification and evaluation of successful and unsuccessful management policies and techniques.
- Preparation of a manual of management techniques and methodologies.
- The development of a model database for the acquisition and storage of data on mangrove ecosystems in the region, in a form that is amenable to incorporation into a GIS at a later time.

- Identification of gaps in information that need to be filled in order to improve management of mangrove ecosystems.
- Development of further proposals to fill information gaps.

It was agreed that three countries, Indonesia, Malaysia and Thailand, should prepare comprehensive country reports according to a prescribed format, which will form the basis of a model database which can be used as a guide by other countries in acquiring and storing data on their own mangrove systems. It is expected that the three main participating countries will complete draft reports by the end of April 1992.

7. Closing of the Workshop

The workshop was formally closed by Prof. Saito at 1530 on Tuesday, 19 November.

Further comprehensive but informal discussions on the content and presentation of country reports were held between the Project Coordinator and individual participants on the morning of Wednesday, 20 November. It was agreed that where possible data should be presented in both tabular and graphical form to facilitate its incorporation into a database for later incorporation into a GIS.

Barry Clough

28 February 1992

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1. Reports and Manuals:

Nov.'86 Mangroves of Asia and the Pacific: Status and Management. Technical Report UNDP/UNESCO Research and Training Pilot Programme on Mangrove Ecosystems in Asia and the Pacific (RAS/79/002) 538 pp.

Nov.'87 Manual on Mangrove Palynology (Published jointly with the French Institute, Pondicherry)

June '88 Role of Microorganisms in Nutrient Cycling of Mangrove Soils, and Waters - Agate, A.D.; C.V. Subramanian and M. Vannucci (eds)

Sept.'88 Report on the Regional Symposium on New Perspectives in Research and Management of Mangrove Ecosystems, Colombo, Sri Lanka, November 11-14, 1986

Sept.'89 Report on the Training Course on Life Histories of Mangrove Species, Bangkok, Thailand, October 2-16, 1985, Appendix to Report on the Training Course on Life Histories of Mangrove Species, Bangkok, Thailand, October 2-16, 1985

Apr. '90 Manual for Investigation of Hydrological Processes in Mangrove Ecosystems, by B. Kjerfve, U.S.A.

Jan. '90 Special Working Group Meeting for Planning the Pilot Research Programme of Phase Two, Ranong, Thailand, September 1-7, 1986

2. Mangrove Ecosystems Occasional Papers:

No. 1 Jan. 1987 - Traditional Uses of the Mangrove Ecosystems in Malaysia - Chan, H. T. and Salleh Mohammad. Nor

No. 2 May 1988 - Timber Volume Inventory, 1987 - Mohd. Jinnahtul Islam and Faruq A. Khan

No. 3 Sept. 1988 - Socio-economic Status of the Human Communities of Selected Mangrove Areas on the West Coast of Sri Lanka, 1987 - Amarasinghe, M. D.

No. 4 June 1990 - Experimental Plantation for Rehabilitation of Mangrove Forests in Pakistan - Mohammad Tahir Qureshi - August 1986 - June 1988.

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No. 8 Nov. 1990 - Mangrove Plantation in Bangladesh - Neaz Ahmad Siddiqi and M.A.S. Khan; Neaz Ahmad Siddiqi

No. 9 Dec. 1990 - Timber Volume Inventory in the Sunderbans Using Aerial Photography and other Remote Sensing Techniques - Faruq Aziz Khan, A.M. Choudhury and Md. Jinnahtul Islam

3. Project (RAS/86/120) Related Publication:

M. Vannucci, 1989, The Mangroves and Us - A Synthesis of Insights, XVII + 203 pp. Published by Indian Association for the Advancement of Science, 55, Kaka Nagar, New Delhi-110003, India.: Rs/150/-

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No. 2 Proceedings of a Workshop on Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions, ITTO/ISME Project PD114/90(F), Dakar, Senegal, 20-22 January 1993

ISME Mangrove Ecosystems Technical Reports:

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