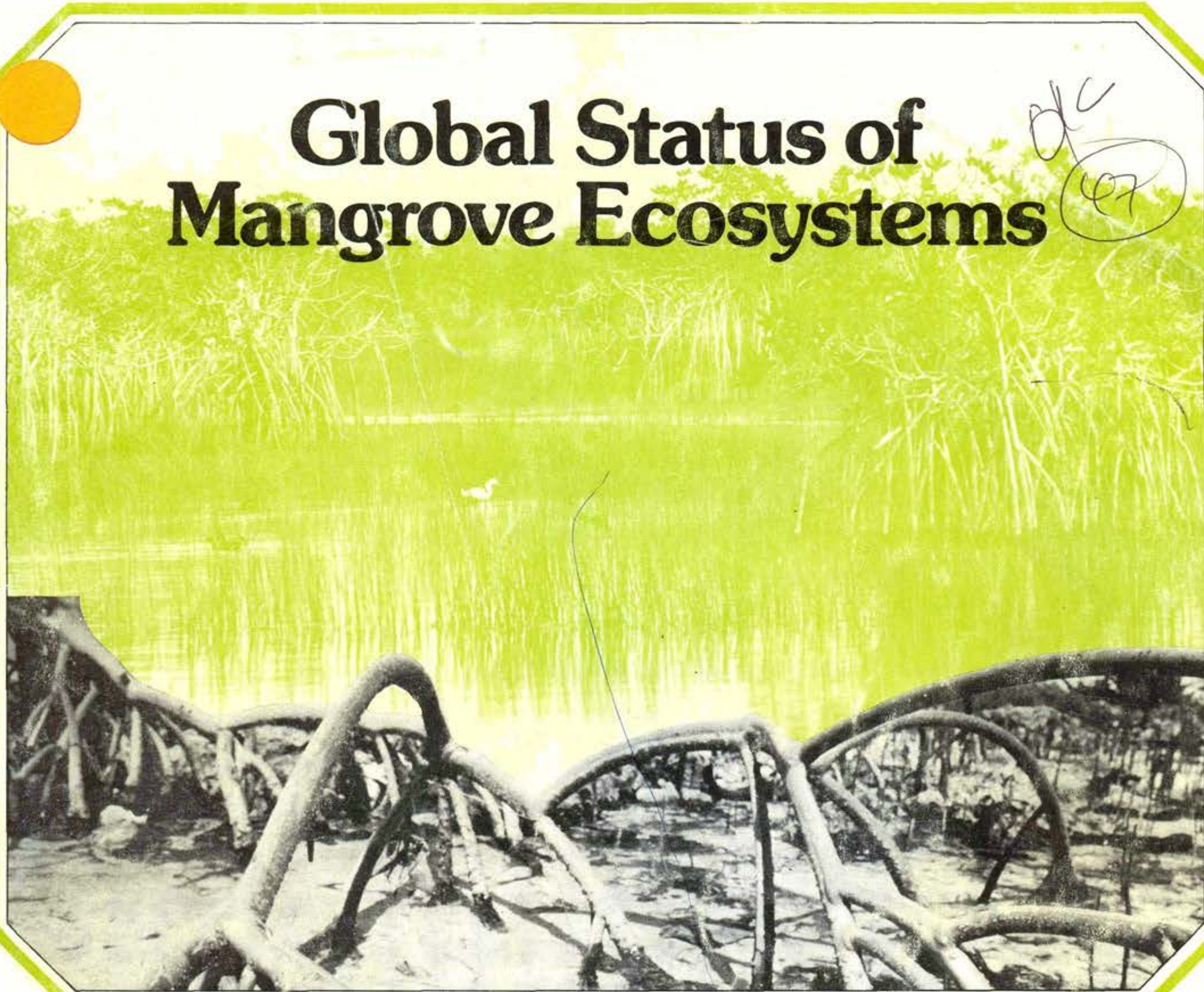
Global Status of Mangrove Ecosystems



By the Working Group on Mangrove Ecosystems of the IUCN Commission on Ecology in cooperation with the United Nations Environment Programme and the World Wildlife Fund

Commission on Ecology Papers Number 3

International Union for Conservation of Nature and Natural Resources

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For further information please contact: Executive Officer, IUCN Commission on Ecology, Av. du Mont Blanc, 1196 Gland, Switzerland.

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Edited by
P. Saenger, E.J. Hegerl and J.D.S. Davie

With the support of
the Netherlands Government
the Australian National Parks and Wildlife Service
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PREFACE

In 1978, the Scientific Committee on Oceanic Research (SCOR), in collaboration with Unesco's Division of Marine Sciences, created SCOR Working Group 60 on Mangrove Ecology. At the first meeting in San José, Costa Rica, Working Group 60 elected to undertake a biosphere inventory of mangrove lands and to determine their current status, managing institutions and research directions. Funds to initiate the inventory were provided by the US Man and Biosphere Program through the US Forest Service. Over the next two years, SCOR Working Group members searched the literature, distributed questionnaires and canvassed the international scientific community for relevant data and information. The SCOR Working Group members who participated in this project were François Blasco (France), Hansa Chansang (Thailand), Valentine J. Chapman (deceased, New Zealand), Gilberto Cintron (Puerto Rico), Antonio Lot-Helgueras (Mexico), Federico Pannier (Venezuela), A. Sasekumar (Malaysia), Samuel Snedaker (Chairman, United States), and Bruce G.Thom (Australia).

In 1980, the Commission on Ecology (COE) of the International Union for Conservation of Nature and Natural Resources (IUCN) created the Working Group on Mangrove Ecosystems to collate existing information on the global status of mangroves for international use in guiding the management and conservation of this natural resource. To ensure collaboration between the two independent working groups, François Blasco, Federico Pannier and Samuel Snedaker were invited to join the IUCN Working Group, chaired by Eddie Hegerl. The IUCN/COE Working Group met in Singapore in 1981 for the purpose of drafting a global status report on mangroves and graciously accepted the summarised data and information previously assembled by the SCOR Working Group. At the Singapore meeting — made possible through the support of the World Wildlife Fund (WWF) and the United Nations Environment Programme (UNEP)—a strategy was developed whereby the IUCN/COE Working Group would prepare and distribute a global status report to be followed by a scientifically detailed report prepared by the SCOR Group. It was agreed that two reports, differing only in style and detail, would reach a larger world audience and thus, be a more meaningful contribution.

With the publication of the Global Status Report on Mangrove Ecosystems, a first step has been taken. When the SCOR Working Group has released its Biosphere Inventory Report, the two working groups will collaborate on other projects designed to assist governmental leaders and scientists to fulfill their missions in the conservation of the tropical mangrove coastal zone.

◀ Fig. 1. Virgin mangrove forest in Indonesia. Courtesy: WWF/Nicholas V.C. Polunin.

Contents

1. Introduction

Mangroves are the characteristic littoral plant formations of tropical and subtropical sheltered coastlines. They have been variously described as 'coastal woodland', 'tidal forest', and 'mangrove forest'. The species which are known as mangroves are derived from a variety of plant families and they vary in their dependence upon littoral habitats. Where conditions are suitable the mangroves may form very extensive and productive forests.

Given suitable conditions for growth, propagules of these species colonise, and establishment begins. With the passage of time communities of species are assembled which interact among themselves and with the physical environment as an ecosystem.

Mangroves not only dominate the habitat and characterise the ecosystem, but also define an economic resource. This resource has been widely and variously used by coastal people of the tropics for thousands of years.

In recent years the rate and variety of human-induced influences have increased to the point where a large proportion of the global mangrove resource is threatened with destruction. Unlike natural disturbance due to storm-wind damage or tsunami ('tidal waves') for example, the effect of human influences is often to change the intertidal environment so that subsequent recolonisation and re-establishment of the vegetation is prevented. In South East Asia severe pressure on land for the conversion of mangroves to agriculture and fish-pond culture exists. In South Asia and Africa water diversions are severely disturbing mangrove ecosystems by diminishing freshwater inflows, increasing soil salinities, and interfering with nutrient supply. In the developed world the coastal zone is also the scene of intense activity. Conversion of intertidal land for marinas, ports and adjacent industrial developments, and 'canal type' housing estates results in the destruction of very significant areas of mangroves.

These conversion uses are in several ways in direct conflict with the objectives of conservation of the mangrove ecosystem. They eliminate the protection provided by these systems to the coast and the inland coastal zone ecosystems; they eliminate the protection provided to the adjacent estuarine and nearshore marine ecosystems; they eliminate the habitat for many forms of wildlife, especially birds, which have important cultural, tourist or scientific values; they eliminate the renewable timber, fuel and food resources; and they eliminate the biological species' richness and diversity. Of these five, the first four are readily recognizable as offering significant social and economic benefits to the human condition. The fifth is less readily perceived in the same pragmatic terms, and is perhaps best not done so. Mangrove ecosystems are reservoirs of species of plants and animals, bound together over a long evolutionary time, and still imperfectly known and understood. Their intrinsic interest has led them to be incorporated into the legends of many cultures.

It is the objective of this report to discuss the uses made of mangrove ecosystems and to try to resolve the conflicts arising from these uses. In doing so, we begin by stating the assumptions that:

- the conservation of mangroves will be inevitably bound to human attitudes and behaviour because we have a long historic and biological dependence on the coastal fringe;
- the properties of the mangrove systems which enhance their value for marine fisheries production, coastal protection, forest production and biological conservation will often be different, although not always exclusively so;
- management practices mindful of the need to maintain these properties are needed and these may differ depending on the objectives.

Thus, the philosophy we expound is one of conservation management which first seeks to prevent further destruction of existing mangrove forests. Most importantly, however, it recognises the need to devise management practices which optimise the conservation of the mangrove resource in such a way as to provide for traditional and contemporary human needs, while ensuring adequate provision of reserves suitable for the protection of the diversity of plant and animal life found in them.

The derivation of management procedures requires a knowledge of the dynamics of ecosystems, and specifically those processes which regulate them. The impact of environmental change can then be evaluated and controlled within the framework of scientific, as well as social and economic constraints. This approach has determined the structure of this report. Following an assessment of the global resource (§§ 2 and 3), existing knowledge of the critical processes which control the dynamics of the mangrove ecosystem is reviewed (§ 4). The ecological impacts of human uses on these processes are evaluated (§ 5), and management options for the resource are determined (§ 6). The potential for implementation of conservation management strategies is evaluated in terms of existing patterns of legislation and government organisation (§ 7). Finally, recommendations for better management and protection of mangrove ecosystems are made (§ 8), and research needs are identified which will help provide a clearer definition and, hopefully, some solutions to these problems (§ 9).

2. The Resource

2.1 Introduction and Definition

The biological components of the ecosystem—the plants and the animals — and the physical area of coastal land in which they live, are subject to a wide and increasingly intense set of uses. They therefore constitute a resource exploited because of socio-economic demands.

No hard and fast definition exists of mangroves — but they are usually defined as those plants associated with and more or less exclusive to the

TABLE 1. *Trees and shrubs of the World's mangroves*

Key: S = Shrub, i.e. less than 3 m
T = Tree, i.e. greater than 3 m
P = Palm
F = Fern

A—Exclusive species	Life-form	Distribution	Comments
Acanthus ebracteatus Vahl.	S	1 2	
Acanthus ilicifolius L.	S	1 2	
Acanthus volubilis Wall.	S	1	
Aegialitis annulata R. Br.	S	2	
Aegialitis rotundifolia Roxb.	S	1	
Aegiceras corniculatum (L.) Blanco	S	1 2	
Avicennia alba Blume	T	1 2	
Avicennia bicolor Standl.	T	3	
Avicennia eucalyptifolia Zipp. ex Miq.	T	2	
Avicennia germinans L.	T	3 4 5	
Avicennia intermedia Griff.	T	1	
Avicennia lanata Ridley	T	1	
Avicennia marina (Forsk.) Vierh.	T	1 2 6	
Avicennia officinalis L.	T	1 2	
Avicennia rumphiana Hall. f.	T	2	
Avicennia tomentosa Willd.	T	4	
Avicennia tonduzii Moldenke	T	3	
Bruguiera cylindrica (L.) Blume	T	1 2	
Bruguiera exaristata Ding Hou	T	2	
Bruguiera gymnorhiza (L.) Lam.	T	1 2 6	
Bruguiera hainesii C.G. Rogers	T	1 2	
Bruguiera parviflora (Roxb.) Wight & Arn.	T	1 2	Introduced to Hawaii
Bruguiera sexangula (Lour.) Poiret	T	1 2	Introduced to Hawaii
Camptostemon philippinensis Becc.	T	1	
Camptostemon schultzii Mast.	T	1 2	
Ceriops decandra (Griff.) Ding Hou	T	1 2	
Ceriops tagal (Perrottet) C.B. Robinson	T	1 2 6	
Conocarpus erectus L.	T	4 5	
Cynometra iripa Kostel	T	1 2	
Cynometra ramiflora L.	T	1	
Excoecaria agallocha L.	T	1 2	
Heritiera littoralis Aiton ex Dryander	T	1 2 6	
Heritiera fomes Buch.-Ham.	T	1	
Kandelia candel (L.) Druce	T	1	
Laguncularia racemosa Gaertn. f.	T	3 4 5	
Lumnitzera littorea (Jack) Voigt	S/T	1 2	
Lumnitzera racemosa Willd.	S/T	1 2 6	
Nypa fruticans van Wurmb.	P	1 2 5	Introduced to region 5 in 1906
Osbornia octodonta F. Muell.	S	1 2	
Pelliciera rhizophorae Planchon & Triana	T	3	
Phoenix paludosa Roxb.	P	1	
Rhizophora apiculata Blume	T	1 2	

(continued overleaf)

TABLE 1 (continued)

A—Exclusive species	Life-form	Distribution	Comments
Rhizophora harrisonii Leechman	T	3 4 5	
Rhizophora x *lamarckii* Montrouz	T	2	
Rhizophora mangle L.	T	2 3 4 5	In region 2 only at Fiji, New Caledonia, Samoa and Tonga; introduced to region 1 (Hawaii)
Rhizophora mucronata Lam.	T	1 2 6	Introduced to Hawaii
Rhizophora racemosa G. Meyer	T	4 5	
Rhizophora x *selala* (Salvoza) Tomlinson	T	2	Only at Fiji, Tonga and New Caledonia
Rhizophora stylosa Griff.	T	1 2	
Scyphiphora hydrophyllacea Gaertn.	S	1 2	
Sonneratia alba J. Smith	T	1 2 6	
Sonneratia apetala Buch.-Ham.	T	1	
Sonneratia caeseolaris (L.) Engl.	T	1 2	
Sonneratia griffithii Kurz	T	1	
Sonneratia ovata Backer	T	1 2	
Xylocarpus australasicus Ridley	T	1 2	
Xylocarpus gangeticus Parkison	T	1	
Xylocarpus granatum Koenig	T	1 2 6	
Xylocarpus moluccensis (Lam.) Roem.	T	1 2 6	
Xylocarpus parvifolius Ridley	T	1	Only in Thailand

B—Some important, non-exclusive species	Life-form	Distribution	Comments
Acrostichum aureum L.	F	1 2 3 4 5 6	
Acrostichum danaefolium Langsd. & Fisch	F	3 4	
Acrostichum speciosum Willd.	F	1 2 6	
Barringtonia racemosa Roxb.	T	1 2 6	
Brownlowia argentata Kurz.	T	1 2	
Brownlowia tersa (L.) Kosterm.	S/T	1	
Cerbera floribunda K. Schum.	T	1 2	
Cerbera manghas L.	T	1 2	
Clerodendrum inerme (L.) Gaertn.	S	1 2	
Cynometra mannii Oliver	T	5	
Dimorphandra oleifera (Triana ex Hemsl.)	T	4	
Dolichandrone spathacea (L.F.) K. Schum.	T	1 2	
Hibiscus hamabo Sieb & Zucc.	T	1	
Hibiscus tiliaceus L.	T	1 2 3 4 5 6	
Mauritia flexuosa (Linn. f.)	P	3 4	
Maytenus emarginata (Willd.) Ding Hou	S	2	
Myristica hollrungii Warb.	T	2	
Oncosperma filamentosa Bl.	P	1	
Pemphis acidula Forster	S/T	1 2 6	
Pterocarpus officinalis Jacq.	T	4	
Thespesia acutiloba (E.G. Backer) Excell & Mendonca	T	6	
Thespesia populnea (L.) Soland. ex Corr.	T	1 2 4 5 6	
Thespesia populneoides (Roxb.) Kostel	T	2	

mangrove habitat. While this definition has tautological overtones, the actual species usually listed are derived by wide consensus, and consequently allow ready recognition. These species can be subdivided into two groups: the exclusive species which are restricted to the mangrove habitat; and the non-exclusive species, which may be important in the mangrove habitat, but which are not restricted to it. Table 1 lists those species widely held to be mangroves and gives their geographical distribution (see Fig. 2). The exclusive mangroves listed in Table 1 are accepted as the operational definition of mangroves, while the important non-exclusive species listed are used in a merely supportive way. Throughout the World's tropics there are about sixty species of trees and shrubs that are exclusive to the mangrove habitat, some of which are shown in Figs. 3–6.

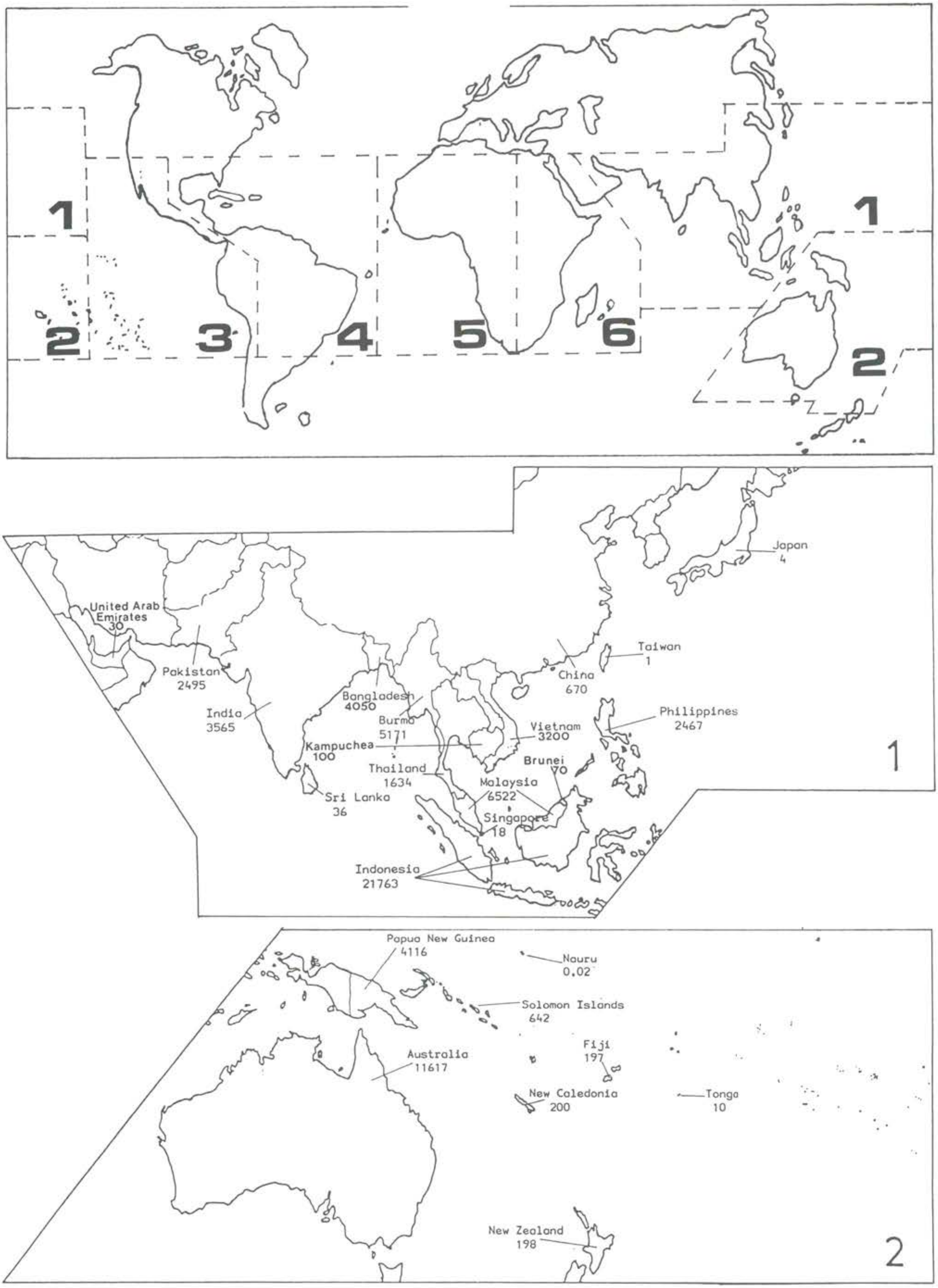


Fig. 2. *(For legend please see overleaf.)*

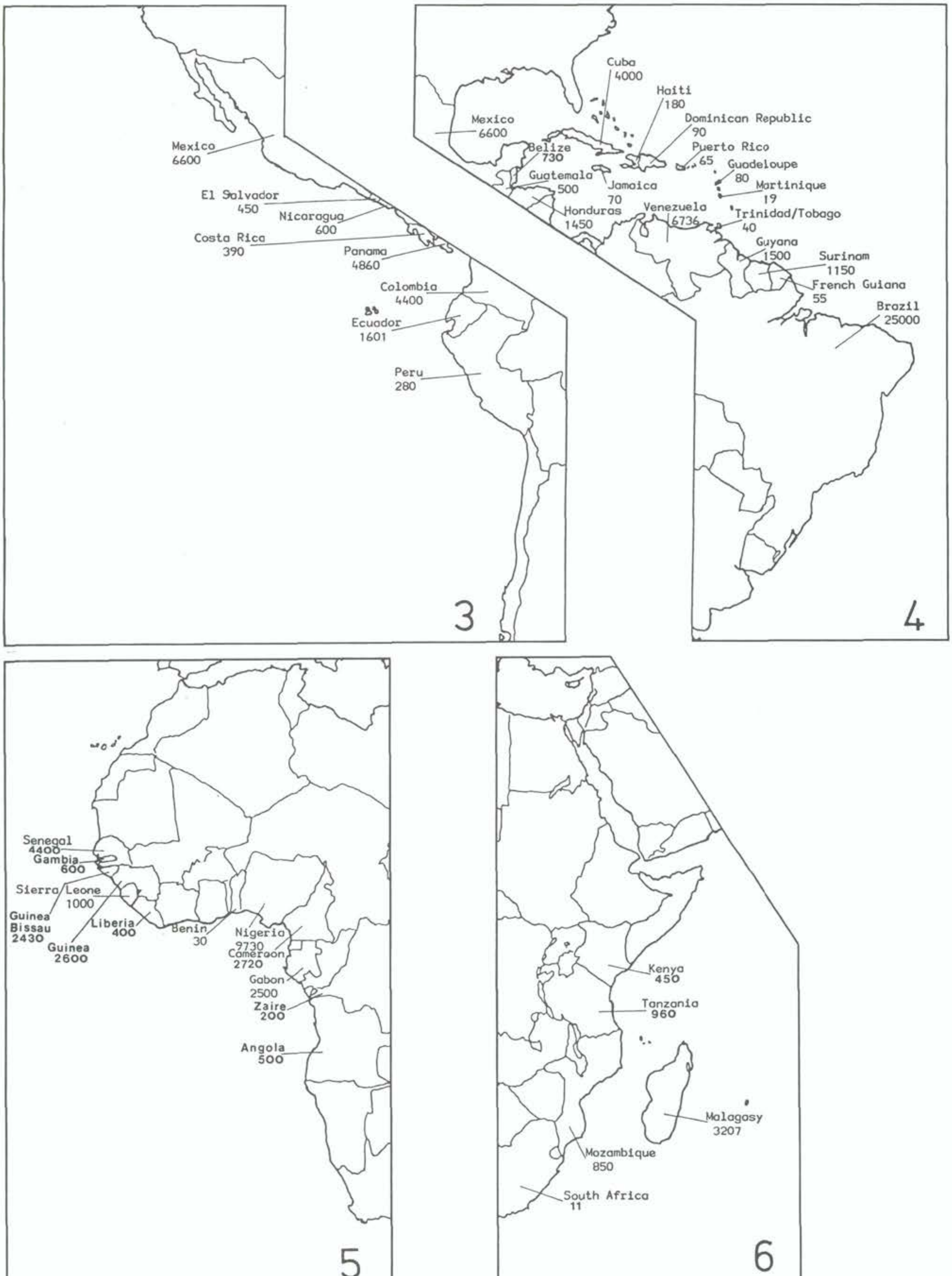


Fig. 2. Geographical zones used to describe distribution of mangrove forests (areal extent is given in km^2): **1**, Asia; **2**, Oceania; **3**, West Coast of the Americas; **4**, East Coast of the Americas; **5**, West Coast of Africa; **6**, East Coast of Africa and the Middle East.

Fig. 3. *Rhizophora stylosa*. This Figure and Figs. 4–6, courtesy: Australian Littoral Society/Andrew Elliott.

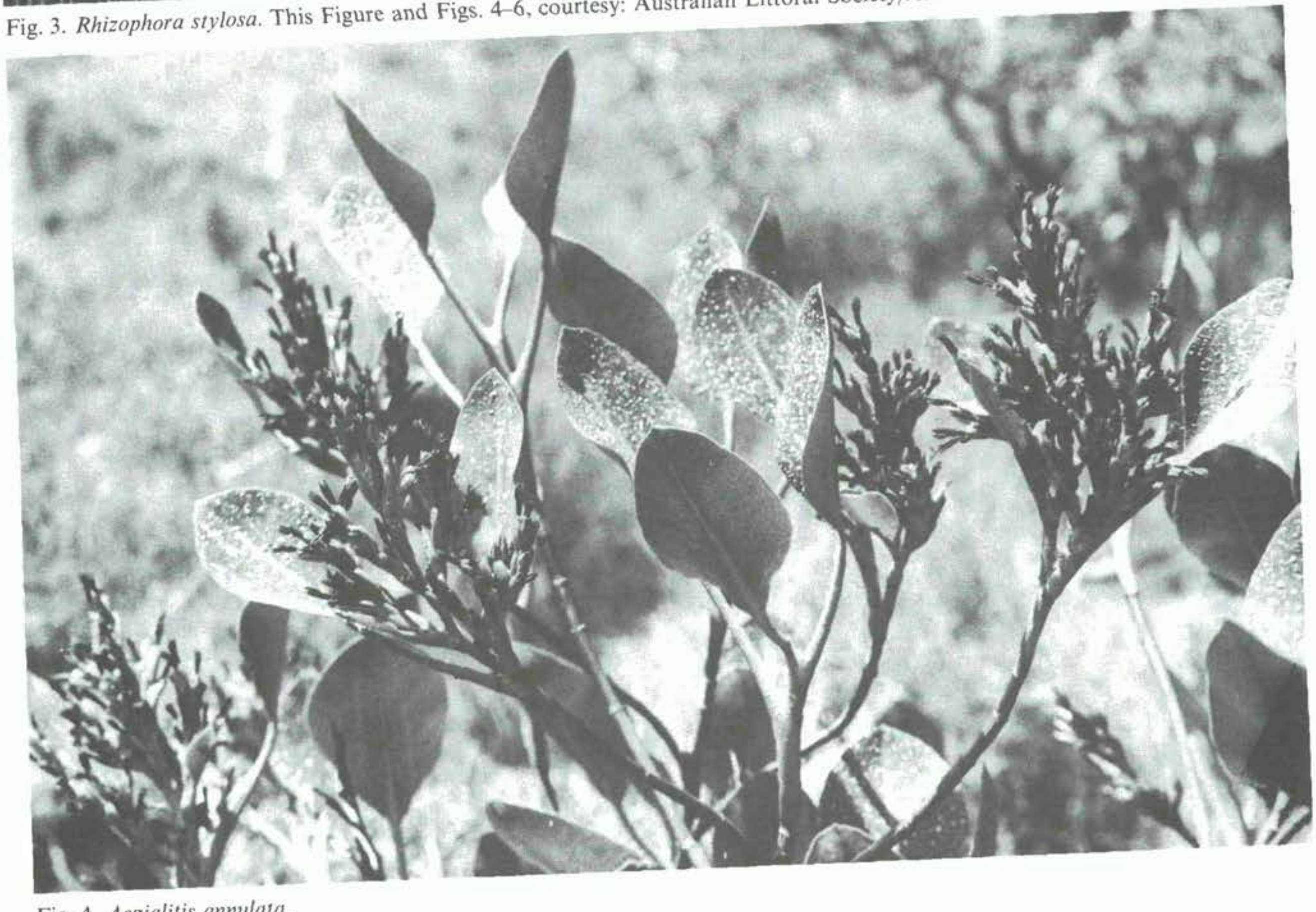


Fig. 4. *Aegialitis annulata*.

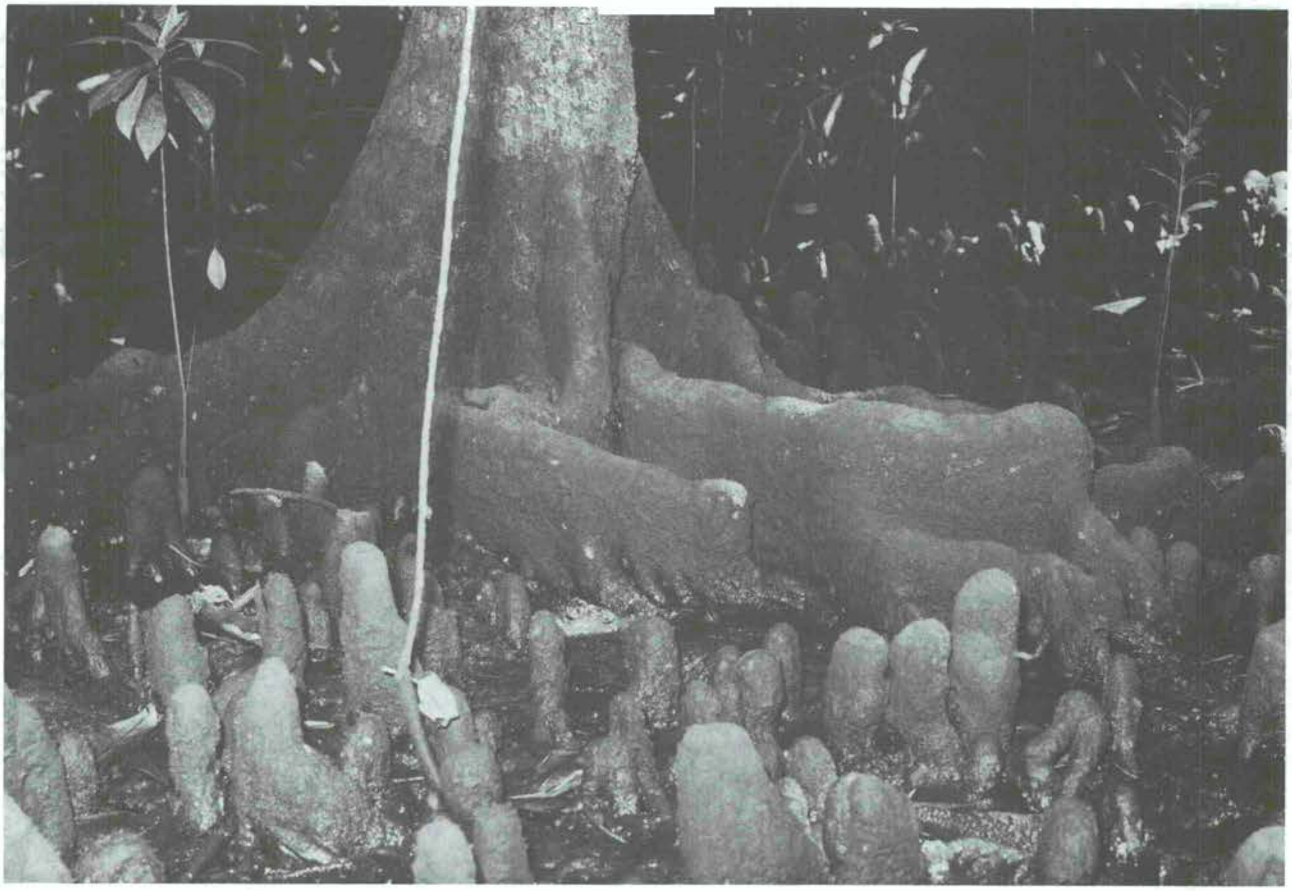


Fig. 5. *Bruguiera gymnorhiza.*

The mangrove resource of a region can thus be defined as consisting of:

(1) one or more of the exclusive mangrove shrub and tree species occurring in the region (Table 1); and

(2) any non-exclusive species of plants while growing in the area with (1); and

(3) the associated and/or correlated biota—the terrestrial and marine animals, the lichens, fungi, algae, bacteria, etc., whether temporary, permanent, casual, incidental, or exclusive, while in the area of (1); and

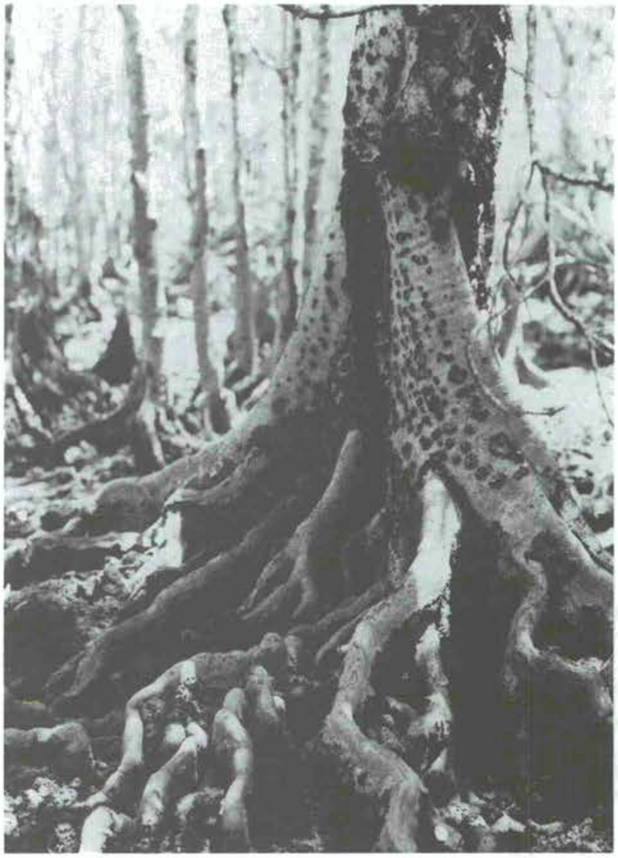
(4) the processes essential for its maintenance whether within the area of (1) or not.

2.2 Distribution and Area

While the distributions of the individual mangrove species constituting the resource are given in Table 1, the distribution and areal extent of the resource are shown in Fig. 2. The data on mangrove area are derived from a variety of published sources and from data collected by questionnaire by the Scientific Committee on Oceanic Research (SCOR) Working Group 60.

The reliability of these data is variable depending on the techniques used and the date of determina-

Fig. 6. *Ceriops tagal.*



tion. In some instances the areas are defined as mangroves only, in others areas of watercourses, etc., are included. However, it should be noted that for some countries the estimates given by foresters are lower than the figures given in this report. This is due to the fact that foresters generally take into account only the areas under forest cover, which may exclude substantial areas where the mangroves are low, open and bushy.

In Fig. 2 some determinations are based on air photo/planimetry methods while others are based on satellite imagery. The data presented in this Figure are the latest, the best available and, where applicable, the lowest estimate.

In Table 2, the relationship between mangrove areas, length of mangrove and total coastline is given for those countries where data are available.

2.3 Associated Biota

The mangroves are the only major members of the community which belong permanently to the resource, are generally exclusive to it, and lead to its general recognition. By contrast, other associated organisms sometimes occur in other intertidal habitats, often adjacent to mangroves. Some of these organisms depend upon the mangroves for only part of their life cycles, or alternatively the mangroves provide a suitable permanent habitat

TABLE 2. *Relationship between mangrove area, length of mangrove coastline and total coastline for those countries where data are available*

Country	Mangrove area, A (km²)	Mangrove coastline, B (km)	% total coastline	Ratio A/B
Australia	11,617	6,064	22	1.92
Mexico	6,600	9,900	–	0.66
Venezuela	6,736	1,102	33.4	6.11
Peninsular Malaysia	1,136	381	20	2.98
Peninsular India	3,565	380	8	9.38

but it is one which is non-obligatory. Over and above these species, the mangroves may support the existence of occasional species whose presence is almost incidental and of no critical significance to the mangrove community. Nevertheless, where mangroves are established, the presence of many other plants and animals is predictable and these form a significant part of the mangrove resource.

Table 3 contains a list of the number of species which have been found at various locations within each of the six geographical regions defined in Fig. 2. No attempt has been made to define the total number of species known from each taxa for each region, as this was considered to be beyond the scope of this report.

Table 3 is included to provide some perspective of the richness of species which have so far been collected in the more thoroughly studied mangrove localities throughout the World. There is no doubt that many additional species remain to be recorded.

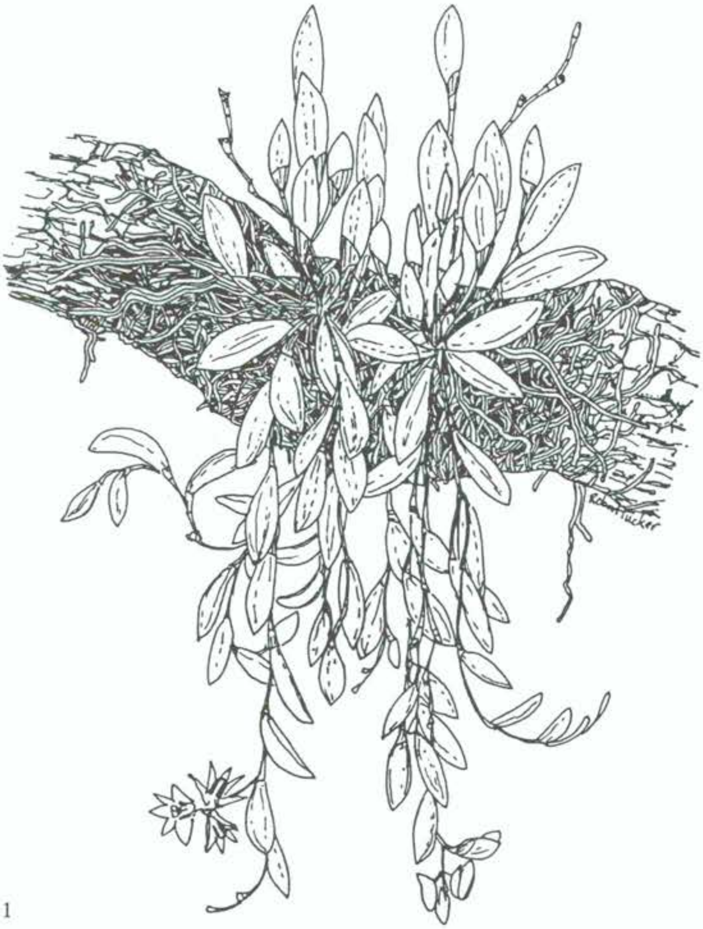
TABLE 3. *Number of species of associated biota recorded from mangroves in various localities in the geographic regions defined in Fig. 2*
Based on latest available sources.

Taxonomic group	Region					
	1	2	3	4	5	6
Bacteria	10					
Fungi	25	14				
Algae	65	93		105		12
Bryophytes/Ferns	35	5		2		2
Lichens		105				
Monocotyledons	73	42		20		8
Dicotyledons	110	80		28		20
Protozoa	18			3		
Sponges/Bryozoa	5	7		36		1
Coelenterata/Ctenophora	3	6		42		12
Non-polychaete worms	13	74		13		3
Polychaetes	11	35		33		72
Crustaceans	229	128		87		163
Insects/Arachnids	500	72				
Molluscs	211	145	32	124		117
Echinoderms	1	10		29		23
Ascidians	0	8		30		13
Fish	283	156		212		114
Reptiles	22	3		3		
Amphibians	2			2		
Birds	177	244		138		
Mammals	36	7		5		

The monocotyledons and dicotyledons in this Table are those plant species which, in addition to the mangroves listed in Table 1, can be found associated with the mangroves. They include epiphytes, parasites, climbers and other occasional herbaceous species (Fig. 7).

For some fauna (Figs. 8–11), particularly crustaceans, molluscs, fish and birds, the numbers of associated species are high, indicating the importance of the mangrove habitat to the diversity of these particular groups.

In many areas humans also belong to the mangrove community, in that at least at the subsistence level, man uses the mangrove resource as a source of food and materials, and as an area for habitation.



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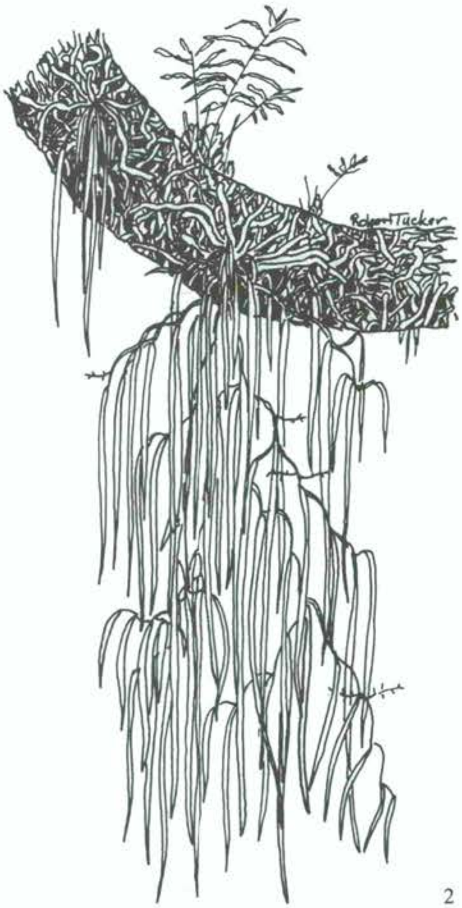

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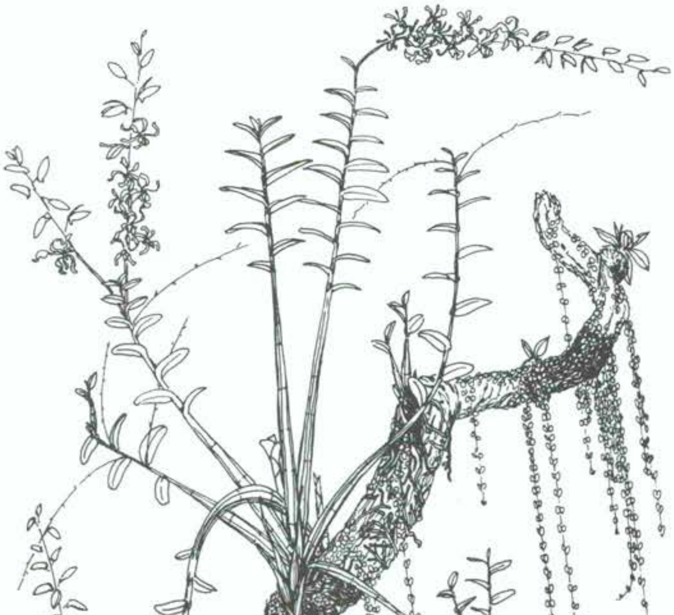

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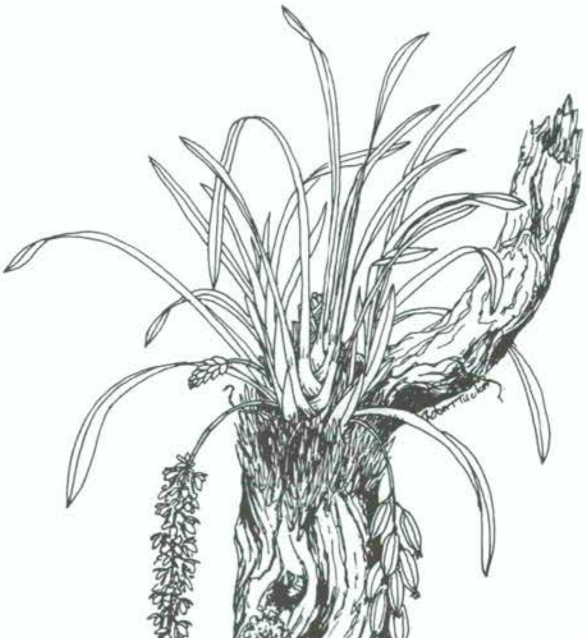

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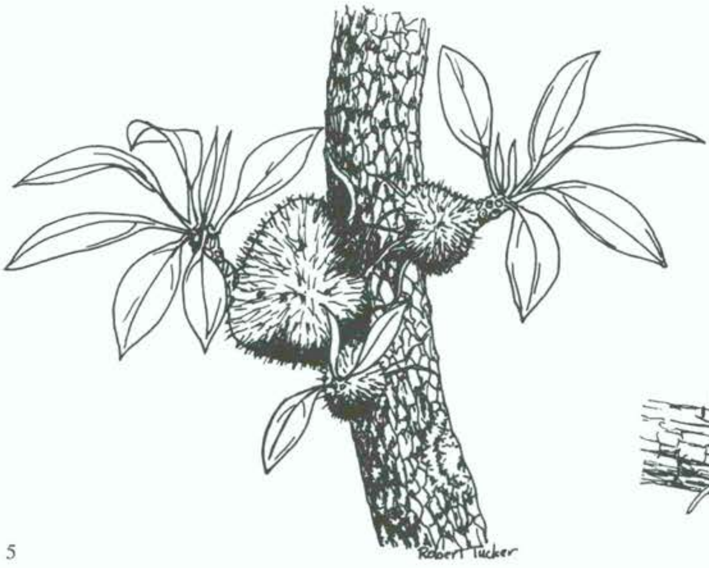

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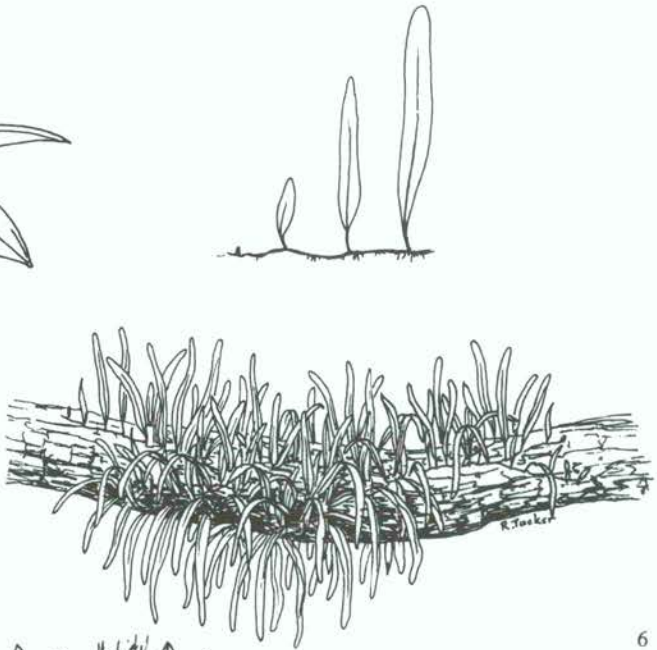

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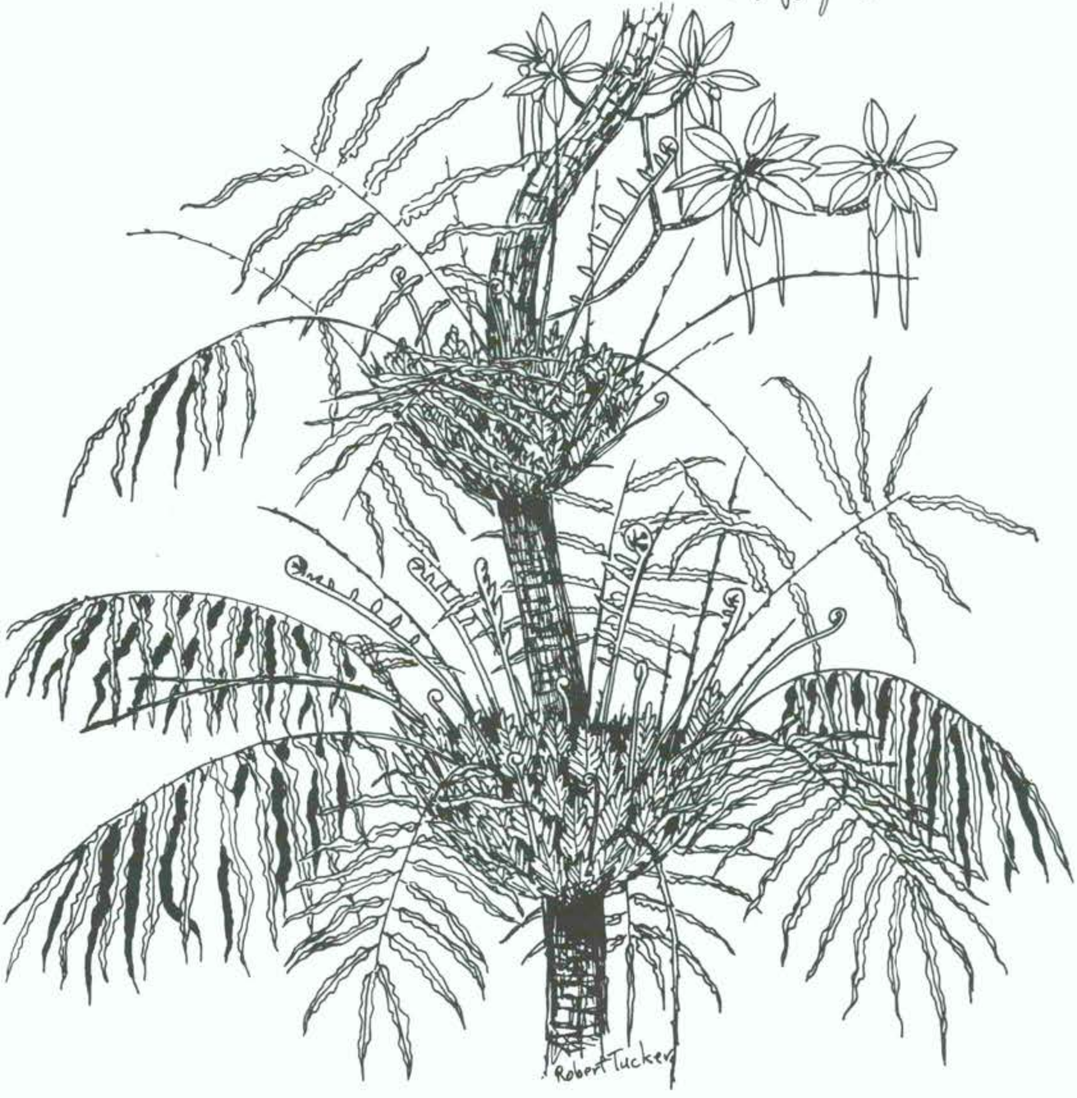

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Fig. 7. Plant species which can be found associated with the mangroves. 1, *Dendrobium rigidum* R. Br.; 2, *Dendrobium teretifolium* var. *fasciculatum* Rupp.; 3, *Dendrobium discolor* Ldl. and *Dischidia nummularia*; 4, *Cymbidium madidum* var. *leroyi* (St. Cloud) Menninger; 5, *Myrmecodia antoinii*; 6, *Polypodium confluens*; 7, *Polypodium rigidulum* S.W.

Figs. 8–10. Large numbers of birds, crabs and molluscs are often conspicuous in the mangrove forests. Courtesy: Australian Littoral Society/Andrew Elliott.

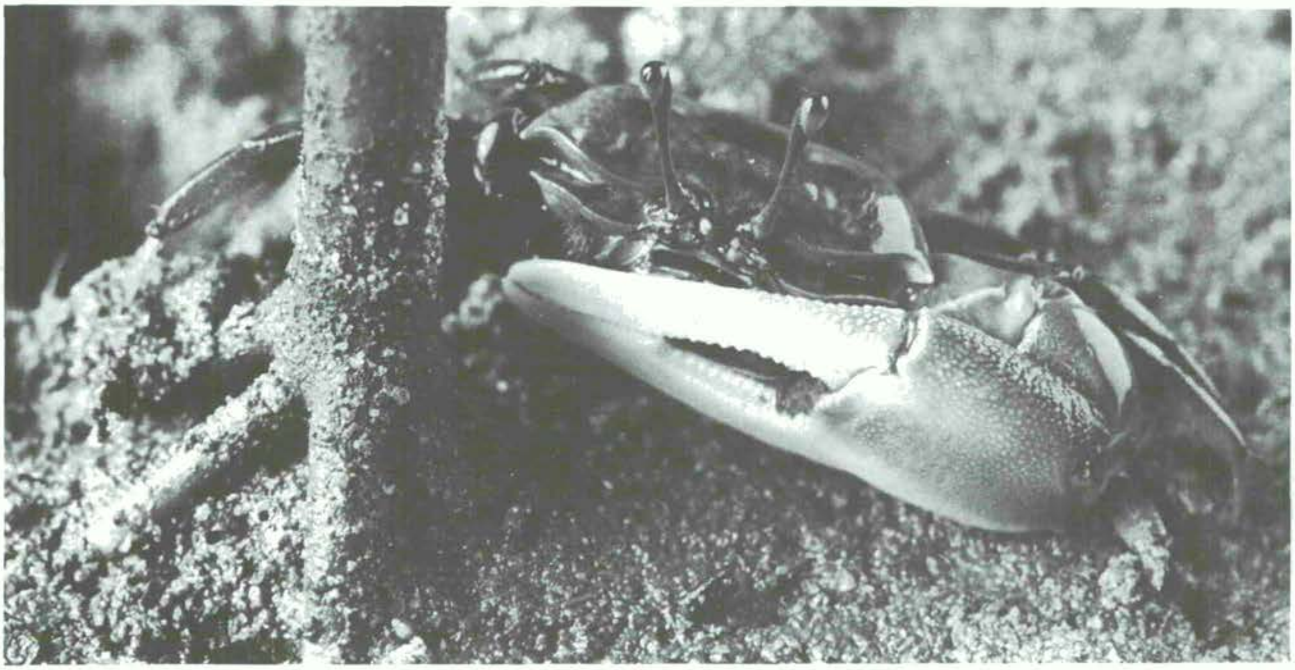


Fig. 11. In Australia, the Lesser Noddy *(Anous tenuirostris)* only nests in the mangroves on the Abrolhos Islands.

3. Value of the Resource

While many people are concerned about the accelerating pace of mangrove destruction, many others regard this resource as wasteland which ought to be converted to other forms of land use as rapidly as possible. This divergence of opinion arises because the uses and values of the mangrove system are many and extremely important, but are relatively little appreciated by decision makers, developers and many citizens, especially urban dwellers.

The importance of the resource derives both from the products taken directly from the mangrove systems, and from the amenities provided by the resource from within and beyond its boundaries.

3.1 Products

Products taken from the mangrove ecosystem range from construction materials (Fig. 12) to reptile skins and honey (Fig. 13). A partial list of products in their processed form is given in Table 4. Currently, mangroves in developing countries are being harvested and chipped for pulp and particle board on a very large scale by companies from developed countries. In addition, mangroves are used as an important and potentially sustainable source of fuelwood and charcoal to meet the increasing needs of developing countries for domestic fuel. Interest also has arisen in species such as *Nypa* palm, which produces alcohol that can be turned into transport fuel. Even though incomplete, Table 4 shows the substantial number of direct tree and shrub products.

Some grazing occurs in mangrove areas. For instance, cattle, camels and goats in India graze in the mangroves, camels are put onto mangrove islands in Pakistan, and caged sheep are grazed in Indonesian mangroves. Feral water buffalo in substantial numbers graze mangroves in northern Australia.

Other natural products are harvested from mangroves as indicated in the latter section of Table 4. Crabs are very common on the mud flats in most mangrove ecosystems and are often a very important subsistence of even commercial food source. In some systems, edible shellfish are supported on the roots and trunks of mangroves.

These direct uses often sustain communities whose economy is based on harvesting the fish, shellfish, crustaceans, wood and other minor products which may be gathered. The continued viability of these ecosystems and the well-being of these people depend on managing the resource in a sustainable fashion. Locally important industries, providing rural employment, are also based on the mangrove resource.

3.2 Amenities Provided

Mangroves reduce coastal erosion. They serve to dampen storm surges and to a minor extent high winds, both of which are associated with many tropical and subtropical storms. While the mangrove coastal barrier may be battered and damaged in severe storms, it will grow back naturally, without cost to man. No man-made coastal protection barrier is capable of self-repair.

The mangrove resource, where it occupies estuarine flood plains, performs a flood reduction function which may be lost if the area is filled and converted to other uses. Mangroves lining the banks of rivers also help prevent erosion of the river banks, which in turn helps protect adjacent property.

The mangrove area is a spawning and nursery area for many marine species of fish. Moreover, the particles of vegetation (detritus) and nutrients exported out of the mangrove ecosystem form the food base of a complex of marine organisms which, in turn, support valuable estuarine and near-shore fisheries (finfish, shellfish and crustaceans). Those whose livelihood depends on fishing (Fig. 14) have long recognised the interconnection between mangroves and fisheries, but these values have only slowly been considered in planning processes where decisions on allocations of intertidal land are being made.

The interesting and unusual fauna and flora of the mangrove community, particularly the bird life which feeds or shelters there, provides valuable opportunities for education, scientific study and tourism. For instance, thousands of visitors per year go to Trinidad's Caroni Swamp mangrove area specifically to see the very great numbers (as many as 20,000 birds) of scarlet ibis (*Eudocimus ruber*), and other birds which are rare or endangered. The endangered Bengal tiger (*Panthera tigris tigris*) is dependent on the Sundarbans mangrove area in India and Bangladesh. In Borneo, the proboscis monkey (*Nasalis larvatus*) is a mangrove inhabitant. These are but a few examples. While it is difficult to put monetary value on these wildlife-based activities, they are nonetheless significant uses which add to the importance of mangroves.

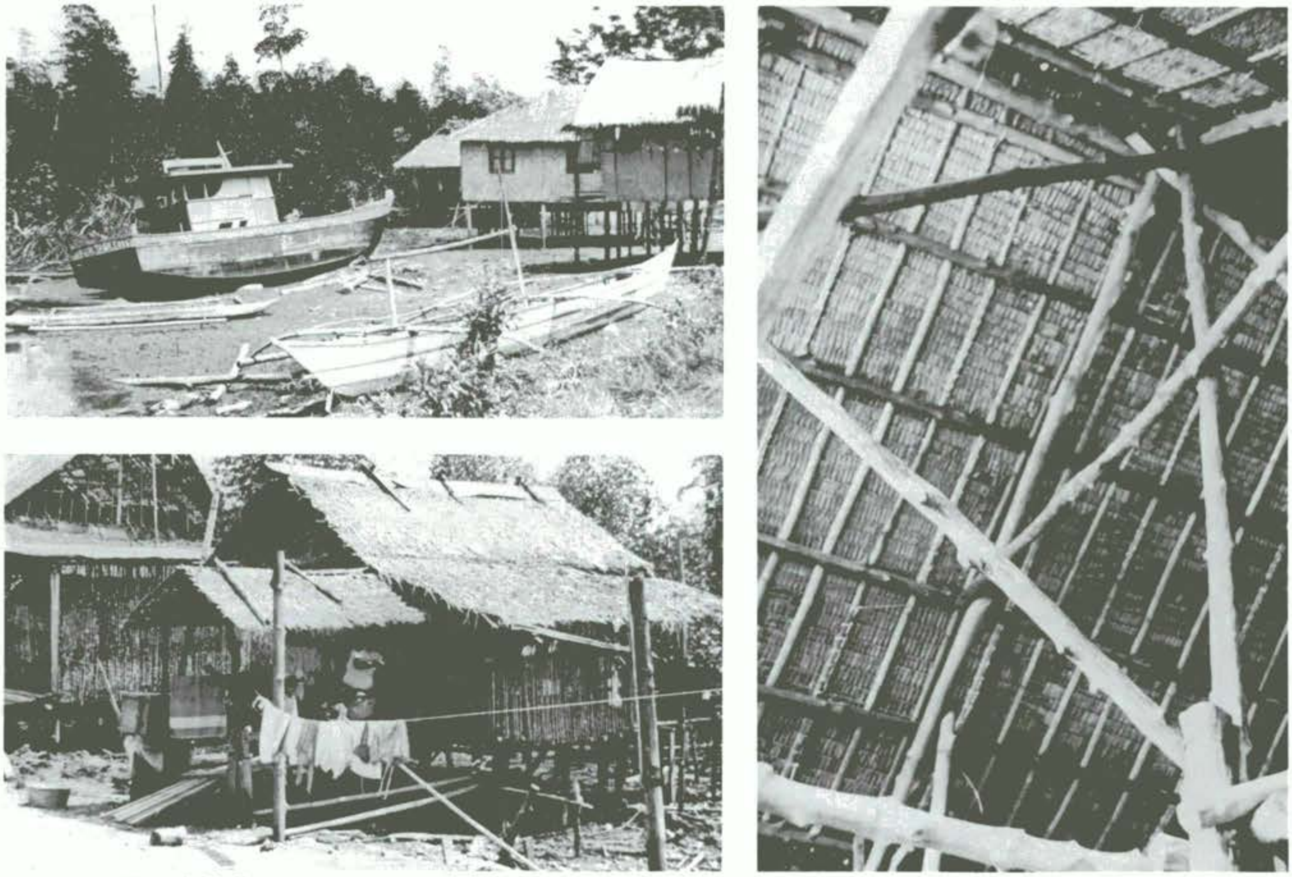


Fig. 12. A village built from mangrove materials on Palawan Island, Philippines. The *Nypa* palm provides thatch for roofing and walls and *Rhizophora* and *Bruguiera* provide the frames. Courtesy: Eddie Hegerl.

Fig. 13. The flowers of the mangrove shrub *Aegiceras corniculatum* provide a major source of honey for commercial beekeepers in Queensland, Australia. Courtesy: Australian Littoral Society/Andrew Elliott.

TABLE 4. *Products of mangrove ecosystem*

A. Mangrove forest products	
Fuel	Firewood (cooking, heating)
	Charcoal
	Alcohol
Construction	Timber, scaffolds
	Heavy construction (e.g. bridges)
	Railroad ties
	Mining pit props
	Boat building
	Dock pilings
	Beams and poles for buildings
	Flooring, panelling
	Thatch or matting
	Fence posts, water pipes, chipboards, glues
Fishing	Poles for fish traps
	Fishing floats
	Wood for smoking fish
	Fish poison
	Tannins for net and line preservation
	Fish attracting shelters
Textiles, leather	Synthetic fibres (e.g. rayon)
	Dye for cloth
	Tannins for leather preservation
Food, drugs and beverages	Sugar
	Alcohol
	Cooking oil
	Vinegar
	Tea substitute
	Fermented drinks
	Dessert topping
	Condiments from bark
	Sweetmeats from propagules
	Vegetables from propagules, fruit or leaves
	Cigar substitute
Household items	Furniture
	Glue
	Hairdressing oil
	Tool handles
	Rice mortar
	Toys
	Matchsticks
	Incense
Agriculture	Fodder, green manure
Paper products	Paper of various kinds
Other products	Packing boxes
	Wood for smoking sheet rubber
	Wood for burning bricks
	Medicines from bark, leaves and fruits
B. Other Natural Products	
Fish	
Crustaceans	
Shellfish	
Honey	
Wax	
Birds	
Mammals	
Reptiles and reptile skins	
Other fauna (amphibians, insects)	

Fig. 14. Mangrove-dependent fish provide an important source of food in this Papua New Guinea estuary. Courtesy: Peter Saenger.

3.3 User Perceptions

Mangrove systems are complex and diverse and are important to many human populations. The complexity exists not only in the conventionally defined biosphere, but in the broader sphere of human–mangrove interaction.

The mangrove system serves a multitude of functions and there are many other competing demands for these resources. Foresters believe that if mangrove areas are properly managed economic benefits from mangroves can be maintained. Fish farmers convert them into fishponds and environmentalists want to conserve the area for the protection of the many dependent organisms. The increasing pressures of population growth will force further the direct and indirect use of mangrove products, and the encroachment of man into mangrove areas (Fig. 15).

Mangrove forests have been depleted and subjected to various stresses originating from human activities. Man influences the growth and development as well as death and extinction of mangroves. With such a dynamic and useful resource as the mangrove, conflicts among the forestry and fishery sectors, and the mangrove dwellers are almost inevitable.

Decisions on the development, management and control of mangrove systems require an understanding of the perceptions of the many users and managers of the resource.

For example, in many mangrove areas, particularly in South-east Asia and India, many of the people inhabiting them, or at least living near them, and collecting mangrove products are those who may be called 'living below the poverty threshold'. For these people, the basic thing is survival and they would do anything just to survive. Most of these people do not have alternative sources of income other than the direct monetary gain derived from the mangroves. Many of them are ignorant of the other values of mangrove ecosystems and of the consequences of increased exploitation.

Fishpond operators, on the other hand, look at the profits derived from converting the mangrove into fishponds.

Policy makers contribute to the exploitation as well as conservation of mangroves; for example, in line with the need and the government's desire to increase fish production, some governments have offered financial assistance to clear mangrove swamps for fishpond culture. At the same time, however, they may promulgate policies that can prevent unwarranted destruction.

Fig. 15. In some countries the mangrove ecosystem provides an important recreational source. Courtesy: Australian Littoral Society/Andrew Elliott.

3.4 Global Distribution of Uses

While extremely little quantitative information exists on the distribution, intensity and magnitude of uses of mangrove ecosystems, a generalized picture is given in Table 5. Unfortunately, this is not complete for each country having mangroves. It proved very difficult to obtain even this level of information. It is thought that the greatest amount of use is occurring in South-east Asia, where perhaps half the total mangrove area is presently being commercially exploited. Large forest clearfelling operations are being conducted in Malaysia (Sabah and Sarawak), Indonesia (Sumatra, Kalimantan, Sulawesi), and Bangladesh for either paper pulp or cellulose derivatives such as rayon.

TABLE 5. *Major uses of the mangrove ecosystem*

Key. The following letters and numbers describe the distribution and importance of a particular use in a country:

- L = use is localised (i.e. only a use in some areas)
- W = use is widespread in a country's mangroves
- 1 = a minor use
- 2 = a moderate use
- 3 = a major use
- X = a use, but inadequate information to define distribution and importance of use

The following provides clarification of some of the 'use' categories:

- + Flood runoff engineering—riverine mangroves cleared to improve flow rates during flooding.
- ++ Flood assimilation—mangroves protected in order to retain natural floodplains.
- +++ Shoreline protection—existing mangrove fringes protected in order to safeguard shorelines from erosion and storm damage.
- * Shoreline protective planting—new mangroves planted in order to protect shorelines from erosion and storm damage.
- ** Riverbank protection—existing mangrove fringes protected in order to safeguard riverbanks from erosion and property damage.
- *** Riverbank protective planting—new mangroves protected in order to safeguard riverbanks from erosion and property damage.

TABLE 5a. *Potentially sustainable uses*

	Firewood	Charcoal	Construction purposes	Paper	Woodchip	Tannins	Food & drinks	Medicine	Stock grazing	Honey	Fish	Crustaceans	Shellfish	Utilization of other animal species	Recreation	Education	Preservation	Flood assimilation^{++}	Shoreline protection^{+++}	Shoreline protective planting*	Riverbank protection**	Riverbank protective planting***
OCEANIA																						
Australia	L1		L1				L1		L1	L3	W3	W3	L1		W3	W1	L2				L1	L1
Papua New Guinea	W2 L3		W2 L3			X	W1 L3				W3	W2	W2	W1	L1	L2			L1	L2		
Solomon Islands	L1		L1			W1	L1	W1			W1	X	X	X								
Fiji	W2		X			X	X	X			W3	W3	X			X			X			
New Caledonia																						
Other Pacific Islands	X	X	X			X	X	X			X	X	X				X					
New Zealand									X		X				W3	W3	L1		W3	W3	L3	L3
ASIA																						
Pakistan	W3		X				X	X	X		X											
India	W3		X			L2	X	X	W3	W2	W3	W3	W3				X		X		X	
Sri Lanka	X		X			X	X				X	X								X		
Bangladesh	W3		W3	L3		X	X			W3	W3	X					W3		X	W3		
Burma	W3	W3	W3			X				X	X	X		X								
Thailand	W3	W3	W3				X	X			X	X	X									

(continued overleaf)

TABLE 5a (continued)

	Firewood	Charcoal	Construction purposes	Paper	Woodchip	Tannins	Food & drinks	Medicine	Stock grazing	Honey	Fish	Crustaceans	Shellfish	Utilization of other animal species	Recreation	Education	Preservation	Flood assimilation[++]	Shoreline protection[+++]	Shoreline protective planting*	Riverbank protection**	Riverbank protective planting***
Malaysia	L1	W3	W3		L3	L1	L1	L?			W3	W3	L3	L1	?1	L2	L2		L?		L2	
Singapore	X		X								X									L1		
Indonesia	W3	X	W2?	L3	L3	X	X				X	X					X		X	X	X	
Brunei	X																					
Kampuchea	X	X																				
Vietnam	X	X	X			X																
Taiwan	L1						L1				L2	L2	L1	L1		L2	L1		L3	L2	L3	L2
Hong Kong																						
China						X														W3		
Japan	L1		L1			L1			X						X		X					
Philippines	W3	W3	W2			X	X				X	X							X	X	X	
AFRICA & MIDDLE EAST																						
Mauritania																						
Senegal	W3	L2	L3			W2	L2	L3			W3	W3	W2	W3			W3		X		W3	
Gambia	X		X																			
Guinea Bissau																						
Guinea	X																					
Sierra Leone	X		X																			
Liberia																						
Ivory Coast	W2	W2	W1			W2	W2		W1													
Ghana	X					X																
Togo																						
Benin	W3		L1						L2		W3	W3	L2	L1		W2				L1		L1
Nigeria	X		X								X	X	X									
Cameroon	W2										W2	L2	L3						X		X	
Sao Tome																						
Equatorial Guinea																						
Gabon	L2	L1	L1			L1	L1	L1			X			X								
Congo																						
Zaire																						
Angola																						
Namibia																						
South Africa	L1		L1					L1			L2	L2	L1		W1	L3	L2				L2	L1
Mozambique	W1	X				X					W1	W1	L1				L1					
Seychelles			X																			
Comoro Islands																						
Malagasy	X	X	X			X		X				X										
Mauritius																						
Tanzania			X									X										
Kenya	X		X			X					X	X										
Somalia																						

TABLE 5a (continued)

	Firewood	Charcoal	Construction purposes	Paper	Woodchip	Tannins	Food & drinks	Medicine	Stock grazing	Honey	Fish	Crustaceans	Shellfish	Utilization of other animal species	Recreation	Education	Preservation	Flood assimilation^{++}	Shoreline protection^{+++}	Shoreline protective planting*	Riverbank protection**	Riverbank protective planting***
Ethiopia																						
Sudan																						
Egypt																						
Israel	X														X		X					
Saudi Arabia	X								X													
Yemen																						
South Yemen																						
Oman									W3													
THE AMERICAS & THE CARIBBEAN																						
United States										X	X				X	X	X			X		
Mexico	X	X	X			X		X			X											
Guatemala	W2	W1	W3																			
Belize	X	X				X																
El Salvador	W3	W3	X								W3	W3		W3								
Honduras			L3			W2																
Nicaragua													L3									
Costa Rica	X	X				X		X														
Panama						X																
Colombia	X	X	X	X		X		X			X											
Ecuador		X	X			X																
Galapagos Islands																						
Peru			X								X	X	X		X							
Brazil	X		X			X		X			X											
French Guiana																						
Surinam						X																
Guyana						X																
Venezuela	W1	W1	W2					W1			W2	L3	W2		L3							
Trinidad & Tobago	W1	X	X				X				X	X	L2	L3	L3	L3	L3					
Cuba																						
Jamaica			X										X									
Haiti	X		X																			
Dominican Republic	X	L3																				
Bahamas																						
Puerto Rico		X	X				X				X											
Virgin Islands											X						X					
Guadeloupe	W2		L1								W2	W2						X			X	
Martinique	W2		L1								W2	W2			W1			X			X	
Other Antilles			X																			
Barbados			X																			
Bermuda																						

(continued overleaf)

TABLE 5b. *Elimination uses*

	Aquaculture ponds for: Fish	Crabs	Prawns	Ricefields	Sugarcane	Palm plantations	Other agriculture	Pasture	Solar salt	Industrial development	Urban development (excl. canal estates)	Canal estate housing development	Ports	Airports	Recreation areas	Mining	Waste assimilation	Flood runoff engineering[+]
OCEANIA																		
Australia					L2			L1	L3	W3	W3	W3	W3	W1	W1	L1	W2	L1
Papua New Guinea													L1		L1			
Solomon Islands																		
Fiji	X		X	X	X		X		X	X	X						X	
New Caledonia																		
Other Pacific Islands	X																	
New Zealand								L1		X	X							
ASIA																		
Pakistan																		
India	X		W2	W3	X	X		X	L3		W3		X					
Sri Lanka						W3												
Bangladesh			X	W3					X									
Burma			X															
Thailand	X		X	X		X	X		X	X	X					X		
Malaysia	L2	L1	L?	L2		L2	L1		L1	L2	L2		L2	L1		L?	L2	
Singapore	X									X	X				X		X	
Indonesia	X	X	X	W3		X			X	X							X	
Brunei																		
Kampuchea																		
Vietnam				X														
Taiwan	L1	L1															L1	
Hong Kong	X									X								
China																		
Japan																	X	
Philippines	W3		X	X					X	X	X		X				X	
AFRICA & MIDDLE EAST																		
Mauritania																		
Senegal	W3	W2	W2	W3		L2			L3	L1	L1	L2	L1				L1	W3
Gambia				X					X									X
Guinea Bissau				W3														
Guinea																		
Sierra Leone				X														
Liberia																		
Ivory Coast				L1	L1	L2	L1	L1		W3	W3						L2	L2?
Ghana																		
Togo																		
Benin	L2							L2	W3									
Nigeria	X																	

TABLE 5b (continued)

	Aquaculture ponds for: Fish	Aquaculture ponds for: Crabs	Aquaculture ponds for: Prawns	Ricefields	Sugarcane	Palm plantations	Other agriculture	Pasture	Solar salt	Industrial development	Urban development (excl. canal estates)	Canal estate housing development	Ports	Airports	Recreation areas	Mining	Waste assimilation	Flood runoff engineering+
Cameroon											L1		L1				L1	
Sao Tome																		
Equatorial Guinea																		
Gabon																		
Congo																		
Zaire																		
Angola																		
Namibia																		
South Africa					W2					L1	L2		L3				L1	L2
Mozambique						L1			L3		L1		L1				L1	
Seychelles																		
Comoro Islands																		
Malagasy																		
Mauritius																		
Tanzania									X									
Kenya																		
Somalia																		
Ethiopia																		
Sudan																		
Egypt																		
Israel																		
Saudi Arabia											X		X					
Yemen																		
South Yemen																		
Oman																		
THE AMERICAS & THE CARIBBEAN																		
United States										X	X	W3	X					
Mexico								X										
Guatemala							L2											
Belize																		
El Salvador						X	X		W3		X							
Honduras			L3						L1									
Nicaragua																		
Costa Rica	X								X									
Panama																		
Colombia																		
Ecuador	L1		L3						L1	X	X		L2					
Galapagos Islands																		
Peru																		
Brazil	L1								X	X	L3		L3				X	

(continued overleaf)

TABLE 5b (continued)

	Aquaculture ponds for:																	
	Fish	Crabs	Prawns	Ricefields	Sugarcane	Palm plantations	Other agriculture	Pasture	Solar salt	Industrial development	Urban development (excl. canal estates)	Canal estate housing development	Ports	Airports	Recreation areas	Mining	Waste assimilation	Flood runoff engineering^{+}
French Guiana																		
Surinam																		
Guyana																		
Venezuela									L2		L3	L3	W1		L1		L3	
Trinidad & Tobago				X						L1						L3		
Cuba																		
Jamaica																		
Haiti																		
Dominican Republic																		
Bahamas									X									
Puerto Rico										X	X		X	X				
Virgin Islands													X					
Guadeloupe																	X	
Martinique											X						X	X
Other Antilles																		
Barbados																		
Bermuda																		

4. Factors which Maintain Ecological Processes in Mangroves

4.1 Introduction

At suitable places along the coastlines of tropical and subtropical countries, particular groups of plants and animals have come together to form mangrove ecosystems.

Within these ecosystems, the individual plants and animals, the soil microbial populations, and the physical environment are linked by processes by which a continuous exchange and assimilation of energy occurs. These 'internal' processes of energy fixation, accumulation of biomass, decomposition of dead organic material and mineral cycling, are most strongly influenced by a small set of critical 'external' processes. This set of processes, governing available water, the pool of available nutrients and the stability of the habitat, is beyond the control of the ecosystem.

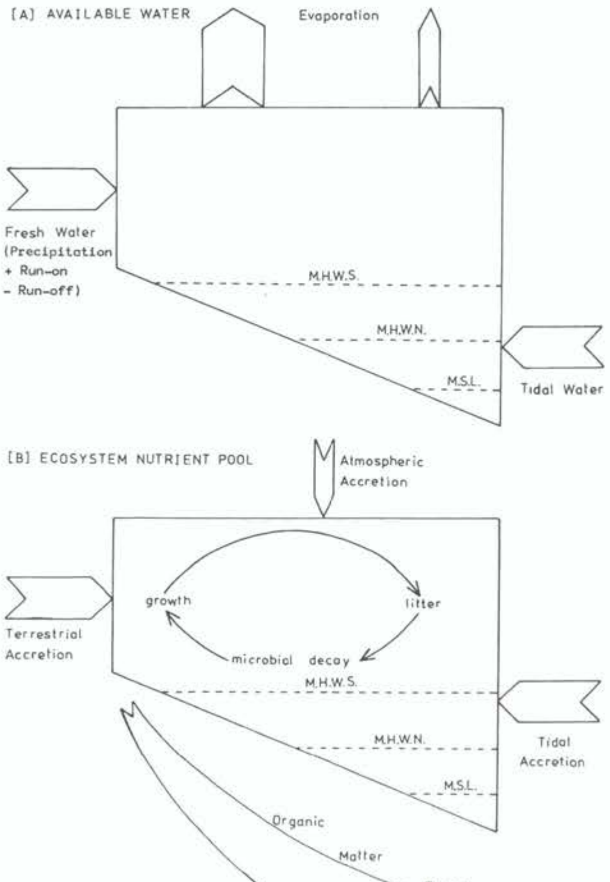


Fig. 16. Processes regulating the water and nutrient regimes in the intertidal environment. M.H.W.S. = mean high-water spring; M.H.W.N. = mean high-water neap; M.S.L. = mean sea level.

These 'internal' and the 'external' processes govern the biological diversity of the ecosystem, and its functional nature; and are often significant in determining its sensitivity to the various forms of exploitation to which it may be subjected. Providing these processes are maintained, the ecosystem will persist. Disturbance of any one may lead ultimately to the destruction of the system.

The most critical processes involved in the perpetuation of mangrove ecosystems depend upon:

(1) an adequate supply of water;

(2) an adequate supply of nutrients (which are illustrated in Fig. 16); and

(3) stability of the substrate.

Some of the activities most destructive of mangroves are those which take place outside the system, yet interfere severely with these processes.

Provided the system continues intact, an appreciable quantity of organic litter produced by the plants as they grow (leaves, fruits, twigs) makes its way into estuaries. Here biological degradation by bacteria, fungi and larger animals results in detrital complexes which appear to be the primary energy source for tropical marine coastal ecosystems. Consequently, mangroves are thought to play a vitally important role in maintaining estuarine fisheries.

4.2 Water

The availability of water to mangrove plants and animals depends upon the:

(1) frequency and volume of tidal exchange;

(2) frequency and volume of freshwater supply; and

(3) evaporative demand of the atmosphere.

Where tides occur no less than once per day and there are no other modifying influences, the salinity of the surface soils will, in most cases, equilibrate to approximately that of the adjacent water body (estuary or ocean). Mangrove plants and animals are physiologically capable of making use of water of this salinity. However, reduced root aeration or temperature stress may inhibit water uptake.

Where there are no diluting factors (rainfall, groundwater discharge, runoff), and the frequency of tidal influence is less than once per day, the effect of atmospheric evaporation and transpiration of water by the plants causes soil salinities to rise very rapidly. As salinities rise, there is a corresponding increase in the osmotic potential of the interstitial soil water, which makes water uptake by the plant roots more difficult. Under these conditions the exclusion, storage or excretion of excess salt increases the expenditure of energy by the plant. The efficiency with which each species deals with high soil salinities largely determines its position in the intertidal zone.

In the absence of any freshwater addition to the upper intertidal sites by rainfall or seepage, the concentrations of salts in the soil solution may exceed the physiological tolerances of all the plant species. In these arid conditions mangrove communities are restricted to a narrow band on the coastline, and much of the tidally affected zone is bare of vegetation.

Intertidal animals face similar problems of water and salt balance. Microhabitats such as water holes in tree trunks and decomposing logs provide opportunities for the landward extension of the ranges of many estuarine species. Behavioural adaptations regulating movement patterns provide other methods of escaping these rigorous stresses.

The best development of mangrove ecosystems occurs where upper tidal areas are exposed to a continuous supply of freshwater. This occurs either:

(1) where rainfall exceeds evaporation through the year;

(2) where hinterland swamps provide a continual seepage of freshwater;

(3) where large freshwater catchments allow strong dilution of estuarine waters, reducing salt additions to the soil;

(4) where large freshwater catchments and heavy seasonal rains provide regular and prolonged freshwater flooding of the tidal zone.

In each of these cases the effect of the freshwater is to remove salt from the soil by leaching, and to maintain soil water content above the permanent wilting point. The efficiency with which this regulation occurs depends upon:

(1) soil type; and

(2) internal drainage.

Leaching of salts will be rapid in sandy soils and become increasingly difficult as the clay content of the soil increases. Where internal drainage is good, the rate of leaching will be rapid. Both soil texture and internal drainage can be negatively influenced by poor management.

Because the availability of water and its salinity concentration control the metabolic efficiency of the whole ecosystem, any change in the rate of freshwater entering the ecosystem will have a significant impact.

4.3 Nutrients

An adequate supply of plant nutrients is necessary to maintain the growth of mangrove ecosystems. The nutrient pool of the ecosystem is regulated by five interacting processes, so that, in general, additions and depletions from the pool are balanced. These processes are:

(1) inorganic mineral ions are transported in solution to the root zone by freshwater or tidal flooding, thus adding to the nutrient pool;

(2) inorganic mineral ions are transported on the clay fraction of sediments deposited on the intertidal zone after freshwater flooding, thus adding to the nutrient pool;

(3) inorganic mineral ions are blown in across the coast by wind thus adding to the nutrient pool;

(4) flooding by freshwater and especially by the regular action of the tide, depletes the nutrient pool by exporting organic matter to the adjacent water body;

(5) microbial decay of organic material, assisted by the activities of larger benthic fauna (particularly crabs) results in the release of nutrients in soluble inorganic form, providing for 'internal' cycling of mineral ions within the nutrient pool.

Of these five processes, only the last, concerned with internal cycling of nutrients back to the living organisms, contributes to the conservation of the nutrient pool. In comparison with a terrestrial rainforest, for example, mangrove ecosystems are relatively open. This is one of the reasons well-managed mangrove forests can sustain the level of exploitation for timber products to which they are subjected, while also losing a high percentage of their litter to the adjacent estuarine ecosystem.

The ability of plant roots to assimilate nutrients depends upon the relative concentrations of the nutrients. If one element is lower than optimal in its ratio with the other elements, primary production is restricted, as if all nutrients were limiting. Most of the nutrients are delivered to the mangrove ecosystem in ample concentrations in the seawater, and by the atmosphere. However, some of the most important are derived in greatest abundance from the land. The unimpeded flow of freshwater into the mangrove ecosystem is of paramount importance.

4.4 Nutrient Export and Cycling in the Estuary

In tropical and subtropical countries mangrove ecosystems are often extensive in area and occur on the margins of oceans and estuaries. Here they receive enrichment from land and sea, and in turn, enrich the coastal waters.

The major process by which coastal waters are enriched is the export of decomposable organic material, mostly in the form of plant litter, into the adjacent aquatic system. The amount of organic material produced by the plant communities as they grow is very significant. In the lower intertidal levels and in the shallow portions of the estuarine waters, decomposition of this organic material by

Fig. 17. Detritus is the primary energy source in a tropical estuary, and mangroves generally are the primary source of the raw materials which produce it. Courtesy: Australian Littoral Society/Andrew Elliott.

fungi and bacteria results in protein-enriched fragments of detritus. In suspension in the water column or amongst the bottom sediments, the detrital complex is a source of food for the largest component of the estuarine biomass. In fact, detritus is the primary energy source in a tropical estuary, and mangroves generally are the primary source of the raw materials which produce it (Fig. 17).

While details will vary from one estuary to another, the general pattern of energy cycling within mangrove estuaries is known and is summarized in Fig. 18. From this diagram it can be seen that the marine animals which humans value as a source of food are either those organisms which feed directly on the detritus (e.g., shrimps, grey mullets) or those which feed on detritus-feeders (e.g., many other fish and crabs). In the absence of mangrove and other coastal fringing ecosystems, neither the habitat nor adequate food to support these organisms would be available, and these populations would be expected to decline.

4.5 Stability of the Substrate

The intertidal estuarine environment is subjected to continual change. Erosion, deposition and consolidation of sediments is regulated by seasonal and episodic activity related to freshwater runoff, tidal action, and wind and wave action.

In general, mangrove plant communities follow the movement of the shoreline. Erosive forces lead to the loss of seaward plants; depositional processes permit the seaward expansion of the

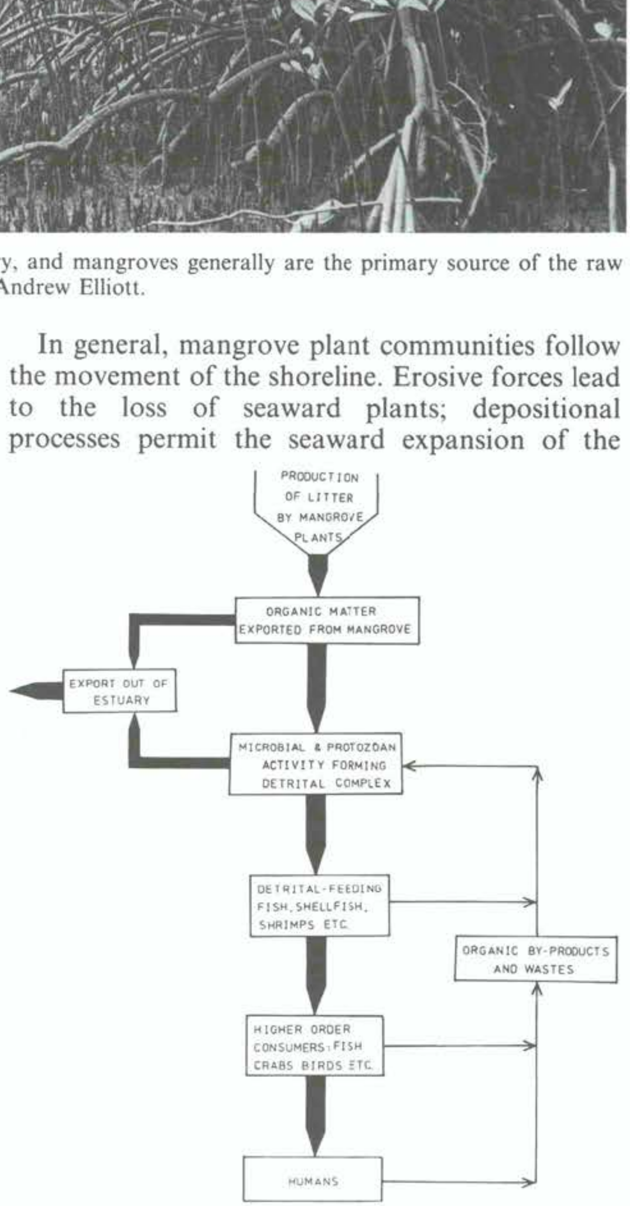


Fig. 18. Important pathways of energy flow in tropical estuaries.

community. Any activity in the catchment of the estuary which increases the flooding intensity or increases the sediment load will have an effect on these downstream mangrove ecosystems.

The effect of erosion is readily understood. However, the processes associated with deposition are more complex.

The rate of deposition of sediments in the intertidal zone depends upon:

(1) current velocity of the water body;
(2) the sediment load; and
(3) salinity and temperature of the water.

Each of these factors is subjected to seasonal change. Current velocity is dependent upon tidal amplitude and freshwater runoff from the catchment. This will vary with rainfall. The intensity of rainfall and the pattern of land-use in the catchment, will influence the quantity of sediment carried in the runoff. At the interface between saline water and freshwater, flocculation of sediment occurs, leading to increased deposition. The position in the estuary where this begins will depend upon the distance of tidal penetration. In seasonally varying climates this will vary through the year and be greatest when freshwater flows are at a minimum.

Sedimentation has several effects. The most direct positive effect is the accumulation of substrate to a topographical level at which colonisation by mangroves can occur. Providing this process continues, the shoreline will expand. New sites will become available for colonisation and the subsequent development of the plant community.

Negative effects can also occur. As the substrate height increases established plants may suffer pronounced root oxygen deficits as the blanket of sediment occludes aeration of the roots.

Root oxygen deficits also occur where sedimentation impedes drainage. Impoundment of water and consequent anaerobic soil conditions will follow. The result of both of these changes is the death of mature trees. Examples exist where extensive areas of forest have been killed by either natural or man-made impoundments.

Depending upon the circumstances, deposition can be highly favourable to mangroves, or a cause of increased mortality. Many human activities within a catchment have the potential to alter existing patterns of freshwater runoff and sedimentation to the detriment of the mangrove ecosystem.

5. The Causes and Consequences of Mangrove Destruction

5.1 Introduction

This survey of the global status of mangrove forests has found that vast areas are being destroyed either intentionally or as a secondary result of other activities. Each example of destruction has, as a common basis, policy decisions relating to economic development by both government and private sectors. In each case, it appears that a decision was made which either ignored the value of the mangrove resource, or which placed a significantly higher value on the alternative land or resource use. In essence, short-term exploitation for immediate economic benefits has taken precedence over the long-term generation of benefits which have both economic and natural values. It is believed that, in the majority of the cases, had the full value of the mangrove resource been taken into account, the subsequent action would have been modified or altered so as to protect those values for sustainable use.

Some of the dominant reasons for the destruction of the mangrove ecosystem are described in this section. The causes of mangrove destruction as currently underway in the World can broadly be distinguished as:

(1) over-exploitation by traditional users; and

(2) destructive action resulting from activities generally unrelated to sustained uses of mangroves.

These causes can be further subdivided by the scale of impact likely to result from a single decision. The scale of impacts commonly encountered with destructive uses is listed in Table 6.

It is apparent in this classification that repeated or simultaneous actions in a region increase the total impact. For example, one traditional exploiter is insignificant, however 10,000 exploiters focusing on one area would have a significant impact. Also, a combination of actions imposed in a local area would have a cumulative impact on the total system.

TABLE 6. *Scale of impacts*

Activity	Scale of Impact ha
Clearfelling	10,000 – 500,000
Diversion of freshwater	1,000 – 500,000
Conversion to agriculture	100 – 100,000
Conversion to aquaculture	100 – 10,000
Conversion to salt ponds	100 – 1,000
Conversion to urban development	100 – 1,000
Construction of harbours and channels	100 – 1,000
Mining/mineral extraction	10 – 100
Liquid waste disposal	1 – 10
Solid waste/garbage disposal	1 – 10
Spillage of oil and other hazardous chemicals	1 – 10
Exploitive traditional uses	1

5.2 Mining/Mineral Extraction

As the scarcity of industrial minerals increases, there is a corresponding increase in the mining of alluvial mineral deposits in the tropical coastal zone. Indeed, in many areas of the World there are rich alluvial deposits of tin (Fig. 19) and chromium, as well as other minerals associated with them such as titanium.

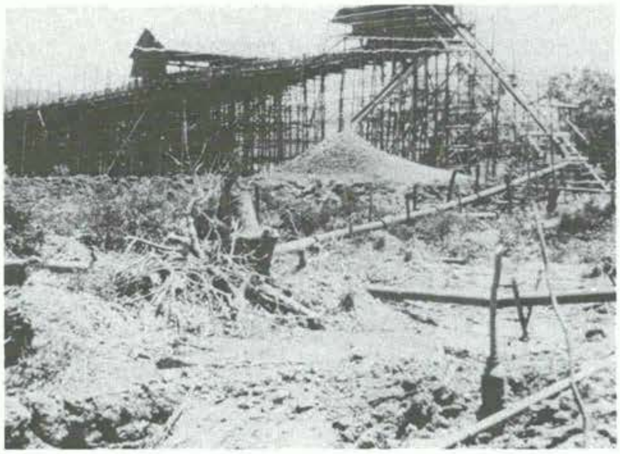


Fig. 19. Tin mining in the mangroves of Thailand. Courtesy: Twesukdi/Piya Karncharna.

The exploitation of ore bodies in the coastal zone takes place upstream, downstream and within the mangrove ecosystem. Mining within the system results in its complete destruction, whereas mining in adjacent areas causes variable destructive effects. The dominant effect is the deposition of overburden materials which are transported to and within the mangroves by surface water. Excessive sedimentation is detrimental to mangroves through its blocking role in the exchanges of water, nutrients and gases within the substrate and between the substrate and overlying water. When this exchange is totally blocked, the death of mangroves occurs within a period measured in days. Partial cessation of exchange imposes a stress on mangroves which is manifested in reduced productivity and reduced survival as a result of being made significantly more susceptible to any further stress.

The turbidity and increased siltation caused by dredging and overburden disposal also results in destruction of local corals and sea-grass meadows, and their associated faunas. Further, mangrove detrital-based food webs are disrupted and overall there may be a reduction in fishery yield.

Mining activities also are frequently associated with various refining processes to further concentrate the ore for economical shipment. Such procedures usually involve such steps as crushing, washing, chemical flotation, screening and dewatering. As partial refining takes place close to the mine area, wastes are often disposed of in the coastal zone subject to local sedimentation and/or transport to adjacent areas.

In some countries drilling for and production of oil occurs in mangroves, as on the Mahakam River in the Handil Dua area of East Kalimantan. The individual wells are not so much a destructive impact as are the associated pipelines and roads which alter drainage, and the almost invariable oil leaks which accompany the activity. Storage areas and shipping facilities may add to the impact.

As would be expected, the potential short-term economic gains from the ore generally far exceed the short-term economic or natural value of the mangrove forest, and there are few examples of mining being deferred, or mining procedures altered, in deference to the mangroves. However, in contrast to several of the examples presented here, mining could be viewed as a temporary land use if efforts were made to stimulate recovery and regeneration. Such efforts, though, are rarely being made in spite of the increased mining activities in the coastal zone.

Some specific cases

Puerto Rico

Mining for sand and the removal of most of a coastal dune for the construction of a large airport led to eventual destruction of a mangrove tract in northern Puerto Rico. Winter storm waves breached the residual dune on repeated occasions and large amounts of sand were washed into the adjacent mangrove swamp. Defoliation rapidly ensued and trees died where sand deposition was in excess of 30 cm. Mining of sand from coastal dunes or from offshore structures which shelter coastal mangrove swamps can be very damaging.

Australia

Several areas of oil shales are known to occur adjacent to, or in mangroves in north-eastern Australia. The Rundle oil shale deposits just north of Gladstone, Queensland, are situated mostly in upland sites but will require major diversion of freshwater flow to the adjacent mangroves. The largest oil shale deposit is located 400 kilometres further north in Repulse Bay and lies 100–300 m below a mangrove system. Mining of this deposit will require the destruction of considerable mangrove areas (approximately 1,000 ha), and a major diversion of freshwater which is likely to affect the mangrove systems within the entire Repulse Bay area. In addition, suspended solids from the spent shale dumps could conceivably enter the estuarine areas. On present data, these will have some toxic properties derived from their organic and heavy metal content, and will induce some stress in the mangrove ecosystem over and above those induced by turbidity.

5.3 Diversion of Freshwater

It is a popular misconception that mangroves are salt-demanding plants when, in fact, mangrove development is best in areas which have significant inputs of freshwater runoff. Accordingly, mangroves in arid, semi-arid, and/or seasonally arid environments are highly dependent on periodic inputs of freshwater. However, it is also in these types of environments, many of which are heavily populated, that the dry-season demand for freshwater for human use is highest. To decision makers who view freshwater runoff into the ocean as a waste of a valuable resource, it is almost inevitable that decisions are made to capture and use this resource in the terrestrial environment rather than see it 'wasted'. In considering the major rivers which have been dammed (e.g. Nile, Indus, Ganges, etc.), the downstream effects on both coastal vegetation and nearshore fisheries, will become readily apparent.

Freshwater inflows into mangroves may be altered by various upstream activities in the catchment area. Changes in agricultural and forest land use (e.g. logging) may change the amount, timing and quality of water entering the system. Minor changes will cause adjustments which may not be severe. Roads, if located perpendicular to the surface flow patterns, and not adequately provided with culverts, can severely disrupt the mangrove system.

Of major destructive effect, however, are large-scale reductions of freshwater inputs caused by human water uses such as irrigation or large water supply diversions out of the catchment. Moreover, large changes in volume and constancy of streamflow through such activities as flood control or power generation can also have destructive impacts. These problems usually result from major engineering works such as dams and barrages.

The diversion of freshwater (Fig. 20) from the mangrove ecosystem affects mangroves and associated fauna in a variety of ways. The actual mechanisms for these effects are not fully understood.

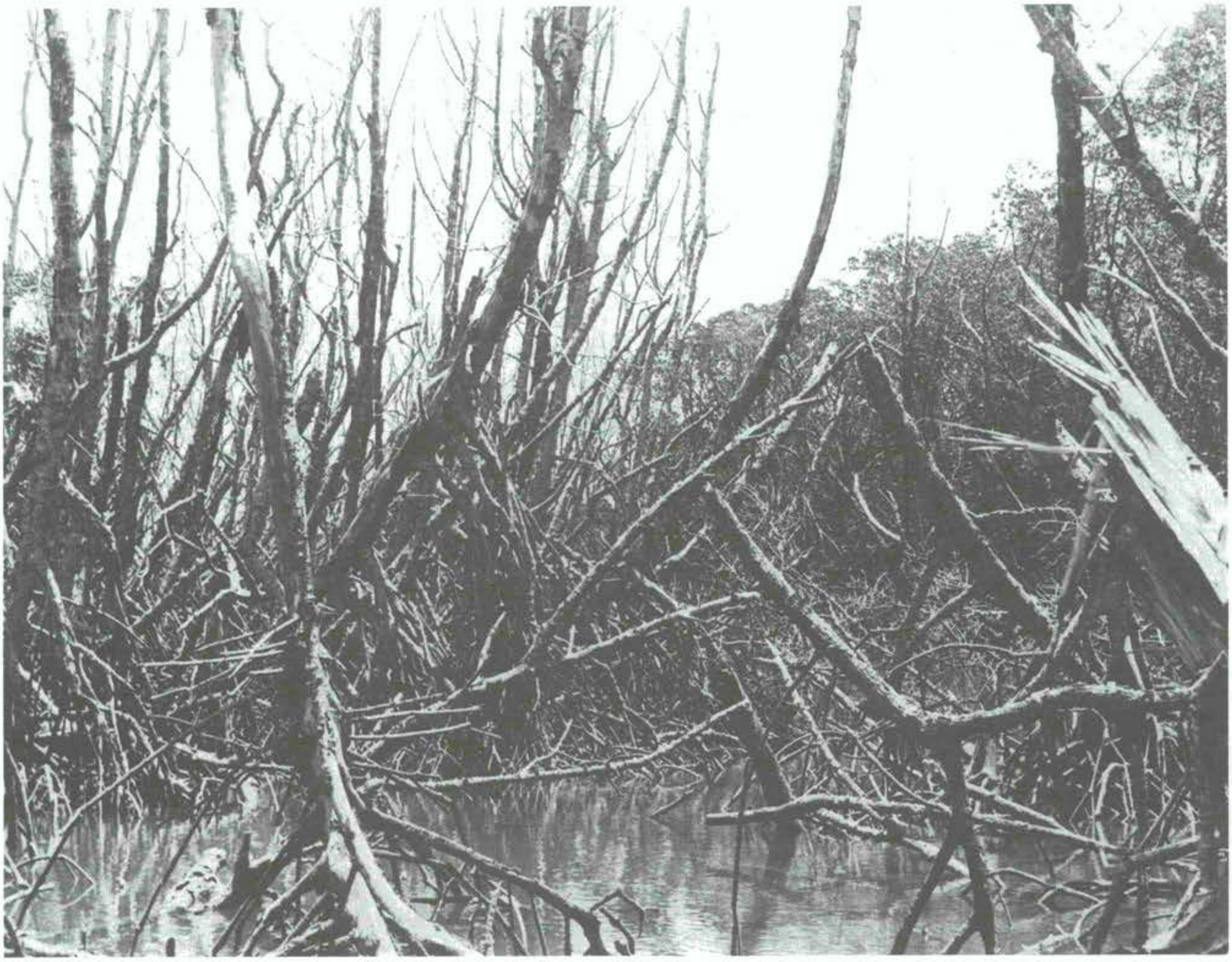


Fig. 20. The construction of a bund wall blocked the freshwater outflow of a tidal creek killing 18 ha of *Rhizophora stylosa* forest near Cairns, Australia. Courtesy: Australian Littoral Society/Eddie Hegerl.

The dominant effects result from progressive increases in dry-season soil salinity and result in the gradual displacement of mangrove species by others more tolerant of the increased salinity. This can have severe consequences when a local industry is dependent on a sustained supply of the species being replaced, for example, the commercial mangrove forest tree, *Heritiera fomes* in the Gangetic delta of Bangladesh.

Reduced dry-season freshwater in the mangrove environment also affects terrestrial fauna dependent on both a source of freshwater and sufficient food during the dry season. The aggravated effects on the Bengal tiger (*Panthera tigris tigris*), for example, have been documented, and similar information is available for other large animal residents of Asian mangroves. In the past in many tropical countries, natural mangrove forests have provided a sanctuary for many species, simply due to their existence in a coastal landscape otherwise modified by economic development.

Mangrove-dependent fisheries are also affected by less favourable habitat conditions imposed by higher water salinities and by the reduced production and export of leaf detritus. The reduced flushing may result in the accumulation of detritus where it is unavailable to dependent offshore communities. Although this debris may be ultimately flushed into nearshore waters during the rainy season, the modified amount and/or timing may cause changes in the dependent communities. The timing of the export of detritus during a year is probably more important than the periodic quantities exported. There are a number of documented instances in which a dam has been associated with the rapid decline and loss of an important fishery due to changes in hydraulic behaviour.

The actual effects of freshwater diversion are proportional to reduction in flow. When all of the dry-season freshwater is diverted, the impact on the mangrove ecosystem is dramatic. For example, so many barrages have been constructed on the Indus River in Pakistan, that there is no seaward discharge of freshwater for about nine months of the year. As a result, the surviving Indus delta mangroves are sparse and stunted.

Dams and diversionary barrages also affect bedload and suspended transport of sediments by capturing this material and preventing its uniform dispersal over mangrove areas during the flood season. Thus, the mangroves are deprived of an annual silting (and input of inorganic nutrients) and the depositional character of the mangrove environment is severely altered. Further, in the absence of flushing, distributary rivers in delta regions become silted and cease to function. The filling and death of distributary rivers has occured and is taking place in such major river deltas as the Ganges and Indus, and the Ord River in Australia.

When dams and barrages are constructed in mangrove environments to create freshwater reservoirs, there are both upstream and downstream effects. Mangroves impounded within the reservoir are killed and the mangroves below the dam are subjected to a variety of stress conditions which lead to shifts in species dominance, reduced structural complexity and lowered productivity.

Some specific cases

Bangladesh

The Sundarbans Forest (407,313 ha) of the Ganges River delta in south-western Bangladesh has been in a state of progressive deterioration for at least the past seven years. The structure and composition of the forest is maintained by a strong salinity gradient extending from the relatively freshwater environment of the north-eastern Sundarbans to a highly saline environment in the south-western Sundarbans in India. The deterioration of the forest is correlated with the reduction of dry-season freshwater flow down the Ganges as a result of diversion barrages, withdrawals for irrigation, groundwater drawdown from pumping and natural death of distributary rivers in the western Sundarbans. Although the Sundarbans is inundated with massive quantities of freshwater during the monsoon flooding, it appears that this flushing is inadequate to stop or reverse the deterioration. The freshwater diversion and withdrawal projects have been carried out, in large part, by various international assistance agencies for the purposes of economic development. In spite of the fact that the Sundarbans Forest is a major source of roundwood and pulpwood in Bangladesh and is a major wildlife refuge for certain rare and endangered species (e.g., the Bengal tiger *Panthera tigris tigris*), only minor attention has been given to the deterioration of the forest. Further, it is doubtful that continuing economic development based on freshwater resource development will be sacrificed or altered to protect the Sundarbans. However, co-operation between India and Bangladesh has resulted in a greater dry-season flow of freshwater to south-western Bangladesh.

Gambia

Gambia is a special case insofar as the water control structure is being built in the middle of an extensive mangrove forest. The dam, or barrage, is proposed to be constructed at Yelitenda, in part to create a road and a reservoir of freshwater for irrigation and other uses. The area upstream of the saltwater intrusion barrage, roughly between Yelitenda and Kau-Ur, contains some 8,700 hectares of mangroves bordering the Gambia River. The only apparent concern for the mangrove forest is to clearfell and harvest as much mangrove wood as can be extracted prior to the completion of the barrage and the filling of the reservoir. Technical assistance for the harvest/extraction of mangroves is to be funded, at least in part, by the United States Agency for International Development and is expected to be supervised by the Gambian Ministry of Agriculture and Natural Resources. The long-term effects of the dam on the downstream mangrove forests and nearshore marine environment are expected to be severe, although it does not seem to have received significant consideration in the planning.

5.4 Forest Exploitation

Throughout the World, firewood and domestic fuel are decreasing in supply, while at the same time the demand is rapidly rising. To offset the deficit, mangrove forests are used directly by country people for firewood (e.g., India and much of Africa) or the wood is turned into charcoal for domestic or small industrial use. In those areas where the annual extraction is less than the annual regrowth of wood, the mangrove forests serve as a sustained-yield resource and could exist in perpetuity in that state. In many areas, however, the extraction far exceeds the annual regrowth and the forests are rapidly being degraded or are disappearing.

The other form of timber exploitation occurs on a very large scale and appears to be based wholly or in part on the cash returns from the sale of timber (minor objective) and roundwood for chips and pulp (major objective). In several instances, it seems that the decision to exploit was based on a sudden recognition of economic gain for what had been considered a worthless swamp forest (e.g., Venezuela) or on the opening-up of new lands for colonization and development (e.g., East Kalimantan, Indonesia).

In some cases large-scale exploitation has resulted in a complete loss of certain areas, mainly due to unsuccessful natural regeneration and the great demand for conversion to other forms of land use. Although attempts have been made to regulate exploitation of these areas on an areal basis (as in Sarawak) or through the retention of seed trees, and leaving a belt of mangrove trees along waterways intact (as in Sabah), in most cases natural regeneration of the exploited areas has been far from successful. Without artificial regeneration, this will result in inferior second-generation crops owing to poor re-stocking of commercial species in these areas.

Some operations associated with large-scale exploitation, such as the construction of rail lines to facilitate transport of timber, may cause long-term detrimental effects due to soil compaction (Fig. 21). The debris left behind as a result of clearfelling accelerates breakdown and recycling of organic matter, but its decomposition is relatively slow. This great mass of debris sometimes acts as an effective barrier in the dispersal of propagules into the cleared areas. It has also been observed that the debris may move with the tide and flatten newly established plants, ensuring that little regeneration can take place in the first few years after exploitation.

In the long term, massive deforestation will result in a gradual decrease in area due to conversion to other forms of land use, and decline in timber productivity as a result of changes in the floristic composition to favour non-commercial species. These changes will affect the mangrove's function as a breeding and feeding area for prawns, oysters, crabs, etc. The fishing carried out within forestry areas may provide an even greater source of employment than the forestry operations, as has been shown in the case of the Matang mangroves in Malaysia.

Some specific cases

Sarawak and Sabah

Massive deforestation of mangrove environments in some South-east Asian countries has been underway since the late 1960s. Large tracts of land are being systematically cut, mainly for the production of woodchips to be exported to Japan for the manufacture of dissolving pulp and rayon. There is also a case in Sarawak where about 6,200 ha of mangrove forests were set aside in 1968 for the production of cord wood for export to Taiwan. In Sabah, a total of 122,748 ha, or 40% of the total

(a) (b) (c) (d)

Fig. 21 (a) and (b). Logging for charcoal production in Western Peninsular Malaysia. Courtesy: Eddie Hegerl. (c) Mangrove wood is converted into woodchips in this Sarawak factory. Courtesy: Paul Chai. (d) Regeneration has been poor after large-scale clearfelling for woodchip production in East Malaysia. Courtesy: Paul Chai.

mangrove area, were the subject of special licences for the production of woodchips for export to Japan. Lately, there has been some interest shown in exploiting the remaining 60% of the mangrove area.

Venezuela

The vast mangrove forest wetlands of the Orinoco delta (495,200 ha) is being opened up by the Government of Venezuela to concessionaires for clearfelling the timber resources. At its inception, designated areas were to be clearfelled each year but the concessionaires have been demanding increases in the annual harvest. The increases are apparently being granted. Although it appears that buffer forests are being retained along watercourses, there is no indication that the overall plan includes provisions for restocking or regeneration of the forest. Certainly, the long-term impact on the delta ecosystem has not been a major factor in the decision-making process leading to the concessions.

Indonesia

Indonesia is one of the greatest timber-producing countries. The Indonesian mangroves had remained little affected by large-scale forest exploitation until 1975. But the situation is drastically changing. One of the first large-scale mangrove clearfelling woodchip operations was established in Tarakan Island near Kalimantan. This industry, initiated by Japanese timber concessionaires, is rapidly spreading throughout the major Indonesian islands such as Kalimantan (250,000 t/year from 85,000 ha), Sulawesi (Celebes) and North Sumatra. More than 200,000 ha of mangrove forests are currently exploited in Indonesia, producing 250,000 m^3/year. This production is increasing rapidly. New plans are being prepared for the exploitation of the virgin mangrove forests of the Musi-Banyuasin estuary in South Sumatra.

5.5 Conversion to Agriculture and Aquaculture

Coastal swamp forests in saline, anaerobic environments have traditionally been considered to be marginal, or totally unsuitable for agricultural and/or aquacultural production. However, with improvements in cultigen hybridization and conversion of saline, acidic soils, and increasing demand for arable land, the mangrove environment is being viewed as a major alternative for the global increase in agricultural production including both small grains and aquatic animal protein. In fact, it is one of the objectives of the International Rice Institute in Los Banos, Philippines, to find ways to utilize this 'marginal' resource which includes not only mangrove-dominated lands but also contiguous areas of tidal flats, beach ridges, intercreek saline open flats and reclaimed lands. It is not apparent that any of the natural values of mangroves are ever taken into account in decisions to convert this self-maintaining coastal ecosystem into an industrially subsidized agricultural or aquacultural factory.

5.5.1 Agriculture

In many areas of the World, for example in Asia and Africa, the pressure on arable land has led to efforts to convert mangrove lands into agricultural lands. This usually involves the digging of a narrow canal (parallel to the shoreline) and piling up the diggings to form bunds on one or both banks of the canal. A number of canals are also often dug perpendicular to the first canal and these lead to the sea to encourage draining (at low tides). The mangroves on the landward side become drained and eventually the salts leached by freshwater runoff and rains. The bunds thus prevent seawater intrusion, and gates in the bunds allow excess water to be drained at low tides.

Such a reclamation can lead to extensive loss of mangrove areas and their high productivity and to adverse effects on the fisheries of surrounding coastal areas. In addition, the canals cause a change in the freshwater regimes of the unreclaimed seaward mangrove and can have deleterious effects on the system.

One of the most unfortunate aspects of reclamation of mangrove areas for agriculture is the high failure rate of many schemes. The main problem is not due to saline conditions as many believe, but to the development of acid sulphate soil conditions. Many mangrove areas have soil containing large amounts of pyrite sulphur (FeS_2). When exposed to the air, oxidation releases sulphuric acid. The soils become extremely acid and very high in soluble salts. This condition often leads to nutrient and fertilizing problems, resulting in crops (e.g., rice) not growing or growing with very reduced productivity.

Large-scale reclamation involves thousands of hectares and, should acid sulphate conditions develop, the loss (financial and environmental) can be extensive. It is thus important that the potential problem be made known so that potential users are made aware of the risks involved.

Since reclamation eliminates the mangroves, the question is not how it affects mangrove, but rather its adjacent ecosystem. Here, the question of its economic impact on the coastal fishery and social impact and benefits on the people the fishery supports needs consideration. Will the reclaimed land bring in more than the loss to the coastal fishery?

Some specific cases

Senegal, Gambia and Sierra Leone

Drainage of mangrove soils for rice cultivation in these lower rainfall areas of West Africa led to acid sulphate soils with consequent failure of rice crops. In the estuaries of the Casamance and Gambia Rivers, rice cultivation in mangrove soils yielded between 1,200 and 2,000 kg of paddy rice/ha, but catastrophic crop failures occurred during drier years due to resalination by tidal floodwaters during a critical phase of the growing cycle.

In Senegal, shrimp and seafood, in general, became scarce and diseases formerly almost unknown in the mangrove area (e.g., dysentery, bilharziosis and typhoid fevers) became endemic.

India and Bangladesh

In India and Bangladesh land-need pressure has led to reclamation of mangroves and adjacent tidal flats by impoundment, causing difficulties of water management and protection against cyclonic floods. In the Sundarbans in particular, substantial areas were cleared and, after subsidence due to drying out, are now situated below mean tide level. Because of the large tidal range and the cyclonic tidal surges, catastrophic flooding and heavy loss of life occurs regularly in these areas. It is believed that at least 1300 to 1550 km^2 of mangrove forests in West Bengal (Indian Sunderbans) have been reclaimed in the last 100 years.

5.5.2 Aquaculture

Impoundment of mangrove areas for aquaculture ponds is not a new activity. However, in recent years the number and scale of aquaculture projects has increased rapidly (Fig. 22). In 1977 it was estimated that 1.2 million hectares of mangrove forests in the Indo-Pacific region had been converted to aquaculture ponds.

Aquaculture operators clearfell the mangrove forest and build small dykes with sluice gates to retain water at all stages of the tide. While individual ponds generally only range from 0.1 to 1.0 ha in size, from hundreds to thousands of hectares of continuous fishponds may be built in an area.

Much of the mangrove flora and fauna in the areas surrounding the ponds may be destroyed as well, because of major changes in drainage conditions, in tidal inundation frequency, and in nutrient availability as well as because of the toxicity of runoff waters from the ponds and drainage channels in areas of acid sulphate soil.

Highly pyritic soils also cause serious difficulties for the operators of aquaculture ponds. The efficiency of phosphate fertilizers is severely inhibited, resulting in inadequate growth of algae on which fishponds depend for high yields. High acidity and high aluminium concentrations will kill the fish or, in less severe cases, weaken them so that they are vulnerable to disease or parasites. During rain the sudden influx of these toxins from the sides of the dykes is commonly lethal to a large proportion of the remaining fish. Finely divided ferric hydroxide subsequently appears in the pond water and clogs the gills of the survivors, killing some and weakening the remainder. The prawns grown in aquaculture ponds appear to be even more vulnerable to the toxins from acid sulphate soils.

Aquaculture ponds sited on acid sulphate soils tend to be uneconomic to operate. To be economically viable ponds are best situated within areas of moderate tidal range with suitable land elevation and soils.

While small-scale pond construction would probably have little significant adverse effects on the mangrove ecosystem and its adjacent coastal ecosystem, this is not the case with large-scale impoundment. The conversion of large areas of mangrove to ponds may result in the reduction of adjacent fishery yields. The question here is: will the ponds be more efficient than the natural ecosystem?

Fig. 22. Despite strongly acid sulphate soil conditions, well-developed mangrove forests in the Merbok estuary of Western Peninsular Malaysia were cleared for aquaculture during 1981. Courtesy: Eddie Hegerl.

Unless pond production can surpass the natural system's production, it becomes an economic disbenefit with the possible added cost of upsetting the ecological balance of the adjacent mangrove areas.

The one important question here is how much can be converted (within a particular area) to aquaculture ponds without significantly affecting the mangrove ecosystem as well as its adjacent coastal fishery. There is a need for more research to answer this question.

This is an important question to answer as increasingly large areas are being earmarked for aquaculture use — particularly in the Asian region.

Some specific cases

Philippines

Fishponds in the Philippines are predominantly used for the culture of Milkfish *Chanos chanos*. Rapid development has led to the area devoted to fishponds increasing from 88,681 ha in the early 1950s to 100,097 ha by 1954, 129,062 ha by 1962, and 174,101 ha ten years later. As of 1981, 3,300 fishpond operators were applying for an additional 70,300 ha of mangrove areas.

While the conversion of additional mangrove lands into fishponds would increase fish production from aquaculture, concern has been expressed that it might also result in decreased production from coastal fisheries. Aquaculture provides 10% of total Philippine fish supply, while marine fisheries provide 90%.

Although two-thirds of all fishponds apply either organic or inorganic fertilizers, productivity has remained low, averaging about 600 kg/ha per year. Some fishponds yield only 100–200 kg/ha per year, while the best produce as much as 1000 kg or more. The low yields have been attributed in part to the fact that at least 60% of the fishponds in the Philippines are affected by acid sulphate soil conditions. In many cases yields have been so poor that ponds have been abandoned.

The industry is also plagued with the perennial problem of a shortage of fry supply. Although there has been some success in spawning *Chanos* in captivity, for the foreseeable future mangrove estuaries will have to provide the fry supply.

Ecuador

Large-scale aquaculture of penaeid shrimps is underway in Ecuador where 42,000 ha of coastal lands are used for this purpose. In southern Ecuador large mangrove areas are being impounded to kill the mangrove vegetation. The site is later cleared, flooded and 'seeded'. Habitat destruction is causing more and more difficulty in obtaining the post-larval and juvenile shrimp that are used to 'seed' the ponds (35–40,000 post larvae/ha or 20–25,000 juvenile shrimp/ha). The industry hinges on the availability of the naturally occurring 'seed'.

The shrimp resource is also exploited by net fishermen and a shrimp boat fleet. Shrimp stocks may be reaching a critical stage owing to the combined predation by man of the post-larval and juvenile shrimp and pre-mature and mature shrimp stocks, as well as the ever-increasing habitat destruction. Productivity in the ponds, which range in size from 5 to 50 ha, is low (about 450 kg/ha per year of whole animals). Higher yields (in the order of 1,400 kg/ha per year) are possible by more intensive management of the ponds, but these high yields are dependent on the availability of 'seed'.

Costa Rica

Penaeid shrimp ponds of 25 to 50 ha in size are often built in mangrove areas by impounding a parcel of land. The vegetation is cleared and levelled and the pond is then drained and dried to promote the decomposition of organic matter and reduce the future oxygen demand of the soil once flooded. Where ponds are built in highly organic soils, high acidity results. The pH of these ponds may drop to 5 and in extreme cases to 4. These ponds develop red-orange layers in the bottom. Shrimp growth is slow in acid water ponds and ceases below pH 5. Where acid conditions develop, frequent pumping is necessary to flush the ponds and remove the acid. This increases substantially the expense of the operation and has the disadvantage that competitors and predators are pumped in and the planktonic assemblages in the pond are diluted. Generally, use of highly organic soils increases the cost and decreases the efficiency of the fishpond operation.

5.6 Coastal Development

The destruction of the mangrove forest and the conversion of mangrove lands to domestic and industrial development is a major problem in high-income countries and is beginning to become a problem of consequence in developing countries (Fig. 23). The most common forms of conversion are to housing and residential development, coastal tourist facilities and industry, including small port development. Although many of the countries where this is a problem (e.g., Australia, New Zealand, United States) have laws protecting the mangrove environment for its high ecological value, such regulations only seem to have slowed the pace of conversion. Developers frequently search for legal loopholes and in one instance in the United States persuaded the federal court to rule in favour of private economic interests as opposed to the interest of the public in protecting the public domain.

The three major types of development (urban, industrial and airport) are very different in character but agree in being high-intensity land use with extensive peripheral impact. Industry and airports tend to be close to major population centres.

Urban development represents maximal density of human settlement and the focus of all regional development. Road concentration and land modification is maximal and the on-site mangrove will be totally reclaimed. On-site rainfall runoff is accentuated by steeper and redirected outflows and reduced penetration. Runoff carries high levels of automotive pollutants. Organic effluents would be treated but still constitute a high nutrient input downstream. Bulk garbage disposal is likely to affect nearby catchments through seepage and often includes high-toxicity pollutants. Water demand is high and likely to affect freshwater output in neighbouring catchments over a wide area. Nearby ecosystems will be subjected to interference by public health management. Recreational pressure and vandalism will be serious. At medium distance, therefore, mangroves will be under heavy pressure. In areas where they provide defence against natural disasters such as typhoons or flashflood, the high human density may give mangroves high priority for maintenance in selected areas and at some distance. It is important to remember the time dimension. Cities attract further development and tend to spread and establish satellites. Long-term maintenance and development of peripheral systems must anticipate such processes.

Industrial development may make higher demands on water supply than residential settlement, though for lower quality. Waste outputs tend to be higher and more toxic. Transport-related effects such as road and channel construction, and automotive pollution will be of high intensity.

Airports are a special case. They are likely to encroach on mangroves because of requirement for flat terrain and approach routes avoiding areas sensitive to noise pollution. They have special sensitivity to wildlife concentrations such as risk from bird-strike. Because the human population is highly transient, with throughflow of non-immunes and carriers of exotic pathogens, public health management is likely to affect a wide peripheral zone. An airport may involve little structural change to nearby systems but a very high intensity of interference.

City development in a catchment is likely to strongly modify the quantity and quality of freshwater throughflow in mangroves. This will be reduced and redirected under low-rainfall conditions, and under high rainfall the response time is likely to be shortened so that special provisions for flashflood control may be needed.

Fig. 23. The conversion of mangrove lands to domestic and industrial development in (a) Bombay, India (courtesy: François Blasco), and (b) Florida, U.S.A. (courtesy: Ariel Lugo).

Marine inputs will be correspondingly modified in that saltwater penetration will be higher upstream and closer to the surface. This will inevitably provoke changes in zonation. Death or modification of significant areas of mangrove can provoke release of organic and inorganic materials from the large organic pool within the system, perhaps fouling areas both up- and downstream.

In-system processes will be directly affected by pest control (e.g., birds and insects), by recreation pressure and by pollution. Of these, routine spraying for the control of mosquitoes and other nuisance insects is probably the most significant detrimental impact. Pesticides will affect the natural fauna and it is now well known that mangroves can take up and accumulate a variety of synthetic organic biocides.

Many established cities are directly associated with estuaries for reasons of transport, water supply, waste disposal and accessibility to interior land areas. In the past, impact on mangroves has probably been disproportionately high because of the failure by planners to appreciate that estuaries, including mangroves, are economically valuable resource areas.

Some specific cases

Singapore

Before the estuary of the Singapore River was developed for human settlement in 1922, between 10–12% of the land surface of what is now the country of Singapore was covered by mangrove forest. By 1969, the area of mangroves had been reduced to 6.17% of the land area. At the end of 1979, mangrove forests remained on only 2.96% of the total land area.

This amounts to 1,822 ha, of which the 1,245 ha located on the main island are mostly in a disturbed and degraded condition. The remaining 577 ha located on the offshore islands are, by comparison, relatively undisturbed, at present, although plans exist for future development of much of this area.

The mangrove forests which have been reclaimed have been utilized to provide sites for housing, industry, parks, solid waste disposal, agriculture, water impoundments, and fish and prawn ponds.

Australia

Canal estate housing projects have destroyed large areas of mangroves in southern Queensland. On Queensland's Gold Coast, the Nerang River's original extensive mangroves have been replaced by Australia's largest system of man-made waterways. Of the 14 other major estuaries within 130 km of Queensland's capital, eight have been modified substantially by construction of at least one residential canal estate.

5.7 Salt Pond Construction

Salt ponds or brine evaporation ponds (Fig. 24) are built on mudflats or more commonly in mangrove areas. The decision to grant concessions to salt pond operators is one involving the total, irreversible clearcutting of a certain mangrove area.

Salt ponds require a complete eradication of the trees and shrubs, levelling and diking of the land, construction of a flooding canal system, and intensive mechanical compaction of the soil surface, and their operation is facilitated by solar heat input. Under operation, the salt ponds are subjected to an inundation regime dependent on local evaporation rates and labour available for gathering the raw salt. The repeated inundation and drying of the soil surface increases the salt content of the soil and also alters the soil structure. Such ponds may later be abandoned for various reasons. However, as experience shows, the drastically changed physical and chemical soil conditions will not allow recolonisation from adjacent mangrove stands, as may occur in areas that have been clearcut without further changes of the land.

Brine evaporation ponds in mangrove areas are widespread over the tropical coasts of Asia and Africa. They are, however, almost unknown in everwet areas such as Malaysia, or Sumatra and Kalimantan in Indonesia.

Under subhumid climates, as for example in the Cauvery Delta in south-eastern India, these ponds usually do not exceed a few hectares. However, under arid and semi-arid conditions the situation is entirely different and the damage caused to the mangroves by salt pond construction is much more extensive.

Some specific cases

India

In the north-western coastal zone on the Indian state of Gujarat, not far from the Indo-Pakistan border, a huge chemical-salt industrial complex has been constructed and has adversely affected a considerable area of mangroves.

Fig. 24. Brine evaporation ponds constructed on reclaimed mangrove land near Manila, Philippines. Courtesy: Eddie Hegerl.

Benin

In the coastal zone of Benin in west tropical Africa, salt extraction from mangrove areas is leading to almost total destruction of the mangrove ecosystems of the country.

Malaysia

A large system of solar salt ponds and an accompanying processing factory failed in western Peninsular Malaysia because it did not occur to the project's sponsors that evaporation rates were inadequate in an area of equatorial rainfall. This unfortunate project resulted in the destruction of some 1600 ha of mangrove forest.

5.8 Construction of Channels and Harbours

Since the early 1970s, there has been an increase in industrial harbour/port construction for the transhipment of ores, fuels and other raw materials. This increase has been due largely to the development of new mines and oil and gas fields in remote areas, and to an increased tonnage of transporting vessels. Included in these new initiatives are liquified natural gas facilities such as the major installation proposed for Natura Island (Indonesia) in the South China Sea. Owing to the high costs of harbour development, coastal areas are sought which involve the least amount of dredging. In at least one example (Port Hedland, Australia), the preferred location was a pre-existing small harbour dominated by one of the most extensive mangrove forests in the region. In Latin America, a Japanese company is engaged in the preliminary design of a new oceanic canal in Panama at the same time that others are discussing an oil pipeline through either Panama or Costa Rica, connecting with new ports on the Atlantic and Pacific coasts. Either of these projects will involve major coastal modifications in areas dominated in parts by mangrove forests.

Creation of harbours, ports, anchorages and loading/unloading facilities, and the dredging of deep channels has certain obvious impacts on the mangrove environment, and some that are less obvious. Dominant among the latter is the change in the local hydrology, particularly with respect to mean water levels and the mixing of freshwater and seawater in the nearshore environment. Such alterations have profound effects on the intertidal environment, resulting in chronic salinity stresses and eventual changes in species composition and dominance. It is interesting to note that the presence of mangroves is seldom considered in the early planning or initial feasibility studies, and is a topic of concern only to construction contractors who may have to remove them from a construction site in the intertidal zone and cope with mangrove sediments for foundations.

In addition to the effects of harbour and channel development and subsequent operation, loading/unloading facilities also become potential spill sites both for routine discharges and accidental spillages. Contingency plans and spill control equipment are often not incorporated.

Some specific cases

Australia

Construction of breakwaters and wharves in Botany Bay, Sydney, has resulted in a changed reflection pattern of shore waves and has led to the serious erosion of a mangrove area which had previously been sheltered. In addition, the operation of the wharf facilities has led to the spillage of oil and other pollutants, with their consequent deleterious effect on the mangrove and seagrass communities within the Bay.

5.9 Solid Waste Disposal

Where human populations have been doubling in urban areas, the garbage and solid wastes generated have increased three to four times in most countries. Characteristically, this waste has been transported and dumped where it would not be highly visible to people. It has therefore been put in depressions or on flat lands. Since most major tropical and subtropical urban centres are located on coasts or estuaries, and since mangrove areas have traditionally been regarded as wasteland, much solid waste and garbage refuse has been dumped into mangrove ecosystems (Fig. 25).

Apart from the loss of the mangroves resulting from this activity, disposal of waste so close to waterways has produced many unforeseen problems. The leachate of materials, plus any toxic

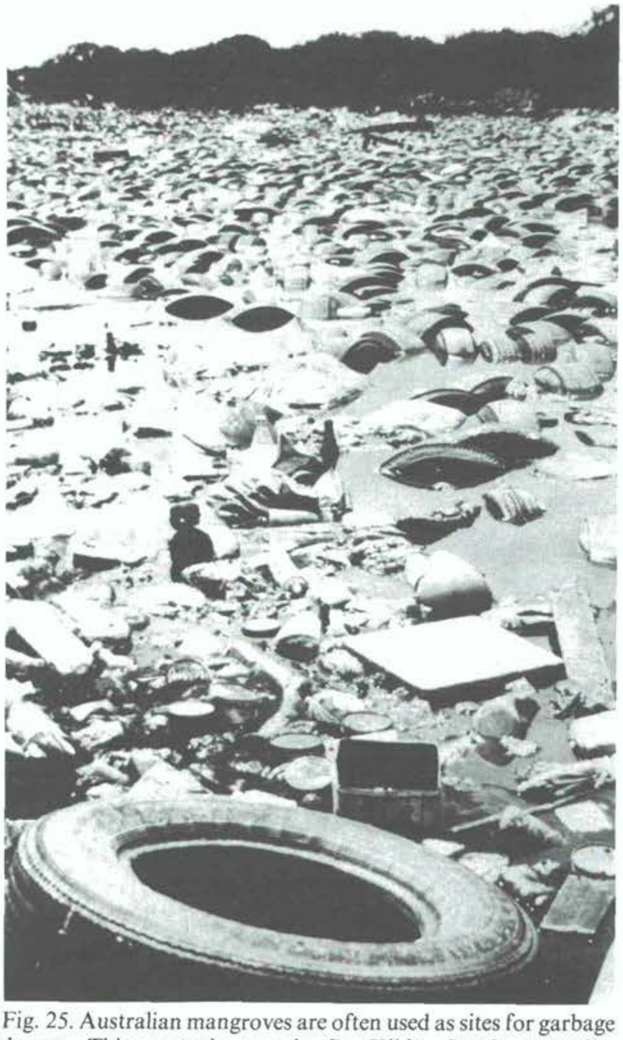


Fig. 25. Australian mangroves are often used as sites for garbage dumps. This example was in St. Kilda, South Australia. Courtesy: Des Connell.

materials included in containers, will flow to adjacent areas unless bunds or dikes have been built to prevent surface flow away from the site. Even plastics, believed by many people to be biologically inert, slowly weather and break down, releasing toxic phthalate esters (a plasticizer) into the environment. In those countries where laws limit toxic waste disposal, there is an increasing tendency for illegal dumping of liquid toxic wastes in mangroves.

The near-urban-centre mangroves, which are frequently the locale for solid waste disposal, are often important areas of open space and, as a forest, offer opportunities for education and nature study. They may also represent an aesthetic resource which is destroyed by society's refuse. Animal scavengers such as rats and seagulls replace natural fauna, and pathogen-bearing insects may present human and animal health hazards.

Though the area affected by this activity is very small in global terms, these areas are very important ones because of their proximity to urban population centres.

Some specific cases

Brazil

Solid wastes are currently deposited at a rate of 130 tons/day in the Hacorobi mangrove swamp near the city of Florianopolis (Santa Catarina). More than two-thirds of the wastes are domestic, the remainder being industrial and hospital wastes. The deposited material is covered with fill and there are no obnoxious odours in the area. A government study has shown, however, that liquids leached from this sanitary landfill have high concentrations of ammonia and phosphate and high total coliform and faecal coliform counts. The study has recommended that the sanitary landfill be closed.

Puerto Rico

Several mangrove areas were used as garbage dumps in the past. (Present government policy does not sanction this use of mangroves and most old dumps have been moved to upland areas.) The old dump sites were open and garbage was spread over wide areas by the wind and periodic flood waters. In dry areas, spontaneous combustion is a problem and smoke and heat frequently caused damage to the outlying swamp. Solid wastes in abandoned open dump sites have subsided into the soft mud, rotted and/or corroded, and some of these areas have rehabilitated naturally. Sanitary landfill accumulations do not readily subside because of the large volumes of dirt fill added to the garbage. These higher elevations, and their access roads, may enhance flooding in nearby areas by acting as dykes.

5.10 Liquid Waste Disposal

Many agricultural, agro-industrial, chemo-industrial and domestic processes create varying quantities of basic organic material as unwanted waste, and discharge it—in contrast to the solid waste and garbage—as suspended or dissolved matter into nearby rivers and coastal waters. Though the major part of this material is naturally occurring organic substances and not toxic *per se,* the load in the aquatic environment can become too great for natural recycling. Excessive concentrations of livestock waste, food processing wastes and domestic sewage can deteriorate riverine environments to conditions (e.g., oxygen depletion) unfavourable to aquatic living resources.

Waste material which is potentially toxic to the living environment is generated in most of the industrial production processes, whether agricultural, forestry, chemical or mining industry. Also, urban and domestic human activities generate effluents containing substances with potential toxicity.

Virtually all industrial processes involve at various stages one or several organic or inorganic compounds necessary to clean, change or convert the basic material or finish and upgrade the end-product. The process additives range from inorganic and organic salts, often heavy metal salts, and petrochemicals of simple as well as complex structures, to an array of newly synthesized pharmaceutical and agro-chemical compounds unknown and undetectable to the environmental analyst.

In many cases, a certain percentage of the original material, intermediate process products, or even the finished product is discharged as wastes with the effluents. There are various technological and economic, justified or unjustified reasons why these compounds are discharged to the environment.

The potential toxicities of these numerous waste products do not necessarily make them toxic *per se* to the environment, but their way of discharge into the water courses, their resulting concentrations and accumulation in the biota do.

The introduction into the food chain at very low levels and rates can give rise to bioaccumulation of these compounds or elements which then reach concentrations that become toxic or lethal at certain steps of the ladder.

The toxic effect may be visible in a single, particularly sensitive species, but its direct effect may also remain undetected and only be revealed by the disruption of a particular food chain, or break of a basic recycling or regeneration process.

Though many individual mangrove species are resistant to various degrees to these impacts, the equilibrium of the system may be upset, and result in a shift to another ecosystem structure.

Some specific cases

Lesser Antilles

Mangrove areas on Guadeloupe and Martinique Islands are seriously polluted by industrial wastes and sewage. All mangrove areas surrounding Fort of France Bay (Martinique) are highly polluted. In spite of constant complaints no steps are being taken to reduce these water pollution problems. In fact, new dumping grounds are being created in the mangroves.

United States

Studies in Florida have shown that some mangroves may grow faster when bathed in tidal waters enriched with sewage effluents. The white mangrove (*Laguncularia racemosa*) showed the greatest response. Litterfall, however, did not increase.

Puerto Rico

In contrast to Florida, where the sewage was diluted in the tidal waters, direct disposal of liquid sewage wastes into a mangrove caused defoliation and death of the stand. This could be attributed to the stagnation of high BOD and chlorine containing wastes in an area of restricted tidal flushing.

In other locations, where secondary treated wastes are discharged into mangrove channels, the mangrove root associated flora and fauna has completely disappeared. High loadings of liquid wastes, suitably diluted, may increase growth of the forest as in Florida, but may be deleterious to the mangrove associated fauna and flora.

5.11 Oil and Other Hazardous Chemicals

The increasing ocean transport of bulk liquids, particularly crude and refined petroleum products, is associated with an increasing frequency of spills. Owing to the presence of mangrove-dominated shorelines close to major shipping corridors, mangroves are more frequently being impacted by accidental or wilful spillage. Although certain governments (e.g., Malaysia, Puerto Rico, United States) have recovered damages from responsible shipping interests, spill areas have not been restored to former levels of productivity.

The problem of oil spillages in mangrove zones is that, in contrast to rocky shores which have a greater self-cleaning capability through highly energetic wave action, mangrove forests are excellent traps for drifting oil slicks. The tidal water circulation in the mangroves is favourable to deposition of slicks on the mangrove aerial root systems and to accumulation by the soil.

Two classes of effects are observed following oil spills in mangrove forests. The first class of effects is acute, immediate and relates to the physical smothering effect of oil on the plant surfaces (e.g., sediment, bark, prop roots, pneumatophores) responsible for gas (carbon dioxide and oxygen) exchange. Under circumstances of heavy oiling, mangrove plants can be killed within 48–72 hours. The second class of effects relates to the long-term chronic poisoning of mangroves and associated fauna by the toxic components of the retained oil. Surviving mangroves exhibit numerous symptoms of chronic stress, reduced productivity and lowered rates of leaf litter production. In this state of chronic stress, mangroves are highly susceptible to any additional perturbation or stress. Years following the *Peck Slip* spill in Puerto Rico and the *Howard Star* in Florida, USA, mangroves died, presumably as a secondary effect of the original spill that was triggered by an unrelated perturbation.

Though the long-term consequences of a spill, particularly as they relate to the toxicity of weathered oil components and other hazardous substances in the bleedwater from mangrove soils, are still not well established, it is clear that the increased retention of oil and other substances subjects the system to a prolonged impact.

With respect to all of the destructive activities in mangrove areas, it is only in the area of oil spills that legal/political action has been taken to recover damages and/or prevent the wilful dumping or spillage of hazardous liquids. Predictably, this has led to adversary litigation in which government agents argue for recovery of damages and agents of shipping interests argue that any observed damages are minor and/or ecologically inconsequential.

In view of the expanding oil exploitation and shipping activities in a number of countries with mangrove forests, spillages can be expected to increase in the future.

Some specific cases

Puerto Rico

The vessel *Zoe Colocotroni* spilled 5,170 tons of crude oil near Cabo Rojo. Of this oil, some 3,100 tons were stranded along a mangrove lined bay. Most of this oil was removed in a costly ($218/ton) cleanup effort. This oil caused the immediate death of invertebrates associated with the mangrove roots and shallow seagrass beds. Defoliation and death of mangrove trees in the most heavily impacted area started within 4 to 5 weeks. Oil penetrated into the porous peat substance and large amounts of oil still remain today trapped in the sediments, eight years after the spill. Seedlings have begun to grow, but after eight years have failed to develop into trees as their mortality is abnormally high.

Ecuador

Following a considerable oil spillage in northern Ecuador/southern Columbia in 1976, acute effects to the mangrove communities included defoliation of trees, mortality of sessile organisms, and the migration of semi-sessile and mobile crustaceans and molluscs. Dead fish, sea snakes and birds were found. Within four months some recovery had occured but, where the mangroves had died, erosion became severe. The oil spill also affected the local fishery in a number of ways. For example, the absence of tuna in the region following the spill suggested an avoidance reaction in this species.

5.12 Species at Risk

As a result of the many forms of exploitation and conversion of mangrove ecosystems, a number of species of plants and animals which are largely or exclusively dependent on them, are 'at risk'. This broad conservation status can be subdivided into the following categories:
- 'found only in ...' — the species has not been recorded in any other country;
- 'believed extinct'—the species is believed to be extinct, *at least in this country,* as it has not been seen or recorded in recent years;
- 'endangered' — the species is in serious risk of disappearing from the wild state within one or two decades if present resource use patterns continue;
- 'vulnerable' — the species is not presently endangered, but is at risk over a longer period, or could become endangered if present resource use patterns change;
- 'collecting prohibited' — the collecting of the species is prohibited by law in this country;
- 'protected within reserves'—significant populations of the species are located within reserves which seek to protect them.

These conservation categories have been used to compile Table 7 which provides an assessment of the conservation status of those species which on present data should be considered at risk. This is a preliminary list only. Virtually no information was available from Africa, and very little was available from South America.

TABLE 7. *Plants and animals at risk*

Species	Common name	Status
PLANTS AT RISK		
Bruguiera gymnorhiza	Mangrove	Extinct—Taiwan
Bulbophyllum avicella	Orchid	Believed extinct—Singapore
Bulbophyllum blumei	Orchid	Endangered—known only from one or two localities in Singapore and southern Johore
Bulbophyllum botryphora	Orchid	Endangered—known only from one or two localities in Singapore and southern Johore
Bulbophyllum concinnum	Orchid	Endangered—known only from one or two localities in Singapore and southern Johore
Ceriops tagal	Mangrove	Vulnerable in Taiwan where only one stand remains Vulnerable—South Africa
Dendrobium cruentum	Ueang nok kaeo	Endangered—Thailand
Dendrobium flavidulum	Orchid	Endangered—known only from one or two localities in Singapore and southern Johore
Dendrobium flexile	Orchid	Endangered—known only from one or two localities in Singapore and southern Johore
Dendrobium kelsalii	Orchid	Endangered mangrove form in Singapore; the mountain form is fairly widespread
Dendrobium pensile	Orchid	Endangered—known only from one or two localities in Singapore and southern Johore
Eria pudica	Orchid	Endangered—known only from one or two localities in Singapore and southern Johore
Finlaysonia obovata	Mangrove liane	Vulnerable—occurs only in Malaysia and Sundarbans but only grows in virgin mangroves, not in regrowth area
Grammatophyllum speciosum	Queen Orchid	Endangered—Thailand
Lumnitzera racemosa	Mangrove	Vulnerable—South Africa
Oberonia flabellifera	Orchid	Endangered—known only from one or two localities in Singapore and southern Johore
Paphiopedilum exual	Lady Slipper	Endangered—Thailand

TABLE 7 (continued)

Species	Common name	Status
Plocoglottis lowii	Orchid	Vulnerable—occurs only on sandy soil in Borneo, Sumatra and Malaysia at landward mangrove margin
Rhizophora mucronata	Mangrove	Endangered—Taiwan
Schoenorchis perpusillus	Orchid	Believed extinct—Singapore
ANIMALS AT RISK		
Mollusca:		
Strombus gigas	Botuto	Vulnerable—Venezuela
Terebralia palustris	Mangrove whelk	Vulnerable—South Africa
Reptiles:		
Alligator mississippiensis	American alligator	Threatened—Florida, USA
Caiman crocodylus	Baba	Endangered—Venezuela
Crocodylus acutus	Gran caiman/American crocodile	Believed extinct—Venezuela Endangered—Florida, USA
Crocodylus porosus	Saltwater crocodile	Vulnerable; protected within reserves—India and Malaysia; collecting prohibited—Australia, India and Sri Lanka
Drymarchon coarais couperi	Eastern indigo snake	Endangered subspecies—Florida, USA
Epicrates striatus fosteri	Bimini boa	Vulnerable—found only in Bahama Islands
Nerodia fasciata taeniata	Atlantic saltmarsh snake	Endangered subspecies—Florida, USA
Birds:		
Agelaius xanthomus	Yellow-shouldered blackbird	Endangered—USA
Agelaius xanthomus xanthomus	Puerto Rico yellow-shouldered blackbird	Vulnerable—found only in Puerto Rico
Amazona arausiaca	Red-necked parrot/Jacquot	Endangered—found only in Dominica
Amazona vittata	Puerto Rican parrot	Endangered—found only in Puerto Rico; protected within a reserve
Anas acuta	Pin tail duck	Endangered—Puerto Rico
Anas bernieri	Madagascar teal	Vulnerable—found only in Madagascar
Anas clypeatra	Shoveler	Endangered—Puerto Rico
Anas crecca	Green wing teal	Endangered—Puerto Rico
Anas platyrhynchos	Mallard	Endangered—Puerto Rico
Ardea cinerea	Grey heron	Endangered—Malaysia
Ardea herodias	Great blue heron	Endangered—Puerto Rico
Ardea purpurea	Purple heron	Endangered—Malaysia
Ardea sumatrana	Dusky-grey heron/ Great-billed heron	Endangered—Malaysia
Aythya collaris	Ring neck duck	Endangered—Puerto Rico
Bebrornis sechellensis	Seychelles brush warbler	Vulnerable—found only in Seychelles; protected within a reserve; collecting prohibited
Botaurus lentiginosus	American bittern	Endangered—Puerto Rico
Casmerodius albus	Garza real/Royal heron	Vulnerable—Venezuela
Catoptrophorus semipalmatus	Willet	Endangered—Puerto Rico
Circus buffoni	Long-winged harrier	Vulnerable—Trinidad and Tobago
Coccyzus melacoryphus	Dark-headed cuckoo	Vulnerable—Trinidad and Tobago
Cochlearis cochlearis	Boat-billed heron	Vulnerable—Trinidad and Tobago
Columba leucocephala	White crown pigeon	Endangered—Puerto Rico
Dendrocygna arborea	West Indian tree duck	Endangered—Puerto Rico
Dendrocygna bicolor	Fuluus tree duck	Endangered—Puerto Rico

(continued overleaf)

TABLE 7 (continued)

Species	Common name	Status
Dendroica petechia petechia	Barbados yellow warbler	Endangered subspecies—Florida, USA
Dichromanassa rufescens	Reddish egret	Endangered—Puerto Rico
Dryolimnas cuvieri aldabranus	Aldabra white-throated rail	Vulnerable—found only in Aldabra; protected within a reserve
Dupetor flavicollis	Black bittern	Endangered—Malaysia
Egretta alba	Large egret/Great egret	Endangered—Malaysia and Puerto Rico
Egretta thula	Snowy egret	Endangered—Puerto Rico
Eudocimus ruber	Corcora/Scarlet ibis	Vulnerable—Venezuela, Trinidad and Tobago
Falco peregrinus	Peregrine falcon	Endangered—Florida, USA
Fulica caribaea	Caribbean coot	Endangered—Puerto Rico
Halcyon senegaloides	Mangrove kingfisher	Vulnerable—South Africa
Haliaeetus leucocephalus	Bald eagle	Endangered—Florida, USA
Ibis cinereus	Milky stork	Endangered—Malaysia
Ixobrychus cinnamomeus	Common bittern	Endangered—Malaysia
Ixobrychus involucris	Stripe-backed bittern	Vulnerable—Trinidad and Tobago
Laterallus jamaicensis jamaicensis	Black rail	Endangered—Puerto Rico
Leptoptilus javanicus	Lesser adjutant stork	Endangered—Malaysia
Limnodromus griseus	Short-billed dowitcher	Endangered—Puerto Rico
Limosa fedoa	Marbled godwit	Endangered—Puerto Rico
Limosa haemastica	Hudsonian godwit	Endangered—Puerto Rico
Mycteria cinerea	Milky stork	Vulnerable—protected within a reserve on Pulau Dua off western Java; collecting prohibited in Malaysia except by aborigines
Numenius phaeopus hodsonicus	Whimbrel	Endangered—Puerto Rico
Nycticorax nycticorax	Black-crown night heron	Endangered—Malaysia and Puerto Rico
Ortalis vetula deschavenseei	Utila chachalaca	Endangered—found only on Utila Island in Caribbean
Oxyura dominica	Masked duck	Vulnerable—Trinidad and Tobago
Oxyura jamaicensis	Ruddy duck	Endangered—Puerto Rico
Pandion haliaetus	Aquila pesadora/Osprey	Endangered—Puerto Rico Vulnerable—Venezuela
Paroaria gularis nigrogenis	Red-capped cardinal	Vulnerable—Trinidad and Tobago
Pelecanus occidentalis	Brown pelican	Endangered—USA
Phalacrocorax carbo	Common cormorant	Endangered—Malaysia
Plegadis falcinellus	Glossy ibis	Endangered—Puerto Rico
Pluvialis dominica	Golden plover	Endangered—Puerto Rico
Podiceps dominicus	Least grebe	Endangered—Puerto Rico
Porphyrula martinica	Purple gallinule	Endangered—Puerto Rico
Porzana carolina	Sora rail	Endangered—Puerto Rico
Porzana flaviventer	Yellow-breasted crake	Endangered—Puerto Rico
Pseudocolopteryx sclateri	Crested doradito	Vulnerable—Trinidad and Tobago
Sterna albifrons	Least tern	Endangered—Puerto Rico
Sterna hirundo	Common tern	Endangered—Puerto Rico
Sterna maxima	Royal tern	Endangered—Puerto Rico
Sterna sanvicensis	Sandwich tern	Endangered—Puerto Rico
Xiphorhynchus picus altirostris	Trinidad straight-billed woodcreeper	Vulnerable—found only in Trinidad; protected within a reserve

TABLE 7 (continued)

Species	Common name	Status
Mammals:		
Canis rufus	Red wolf	Believed extinct—Florida, USA
Cyclopes didactylua	Silky anteater	Vulnerable—Trinidad and Tobago
Felis concolor coryi	Florida panther	Endangered subspecies—Florida, USA
Felis pardalis	Ocelot	Vulnerable—Texas to Argentina; collecting prohibited in most countries of its range
Macaca fascicularis	Long-tailed macaque	Protected within reserves—Malaysia
Nasalis larvatus	Proboscis monkey	Found only in Borneo; protected within reserves
Odocoileus virginianus clavium	Key deer	Endangered subspecies—Florida, USA
Panthera onca	Jaguar	Vulnerable—South American countries; protected within reserves in Colombia, Peru, Bolivia and Brazil; collecting prohibited within most of range
Panthera tigris sumatrae	Sumatran tiger	Vulnerable—found only in Sumatra; collecting prohibited
Panthera tigris tigris	Bengal tiger	Endangered—protected within reserves in India, Bangladesh, Bhutan, Burma and Nepal
Presbytis cristata	Leaf monkey	Some geographic subspecies are vulnerable—Thailand
Procyon cancrivorus	Crab-eating racoon	Vulnerable—Trinidad and Tobago
Pteropus vampyrus	Malaysian flying fox	Protected within reserves—Malaysia
Sciurus niger avicennia	Mangrove fox squirrel	Found only in southern Florida where two breeding populations remain; protected under Florida legislation
Trichechus manatus latirostris	Manatee	Endangered—Venezuela and Florida, USA

6. Management of the Mangrove Resource

6.1 Establishing National Plans

In the majority of the countries containing mangrove resources, both the types of plants and animals associated with mangrove forests and the distribution and extent of the mangrove plant communities are poorly known.

Decisions on future use of mangrove ecosystems which are based on inadequate knowledge of the resource may result in unanticipated and irrevocable loss of valuable mangrove resources. An essential first-order priority for proper management of a nation's mangrove resources is to develop a National Mangrove Plan.

The National Plan should:

(a) define the total national resource, as defined in §2.1, by means of maps and inventories;

(b) assess people's needs in relation to sustainable uses of the resource while ensuring adequate reserves for preservation purposes;

(c) assess the national and international significance of the resource in relation to:

(i) waterfowl migration,
(ii) genetic reservoirs,
(iii) regional sedimentary stability, and
(iv) marine species migration;

(d) define the criteria which must be satisfied for non-sustainable uses of the resource prior to any allocation of the resource to such an activity;

(e) use (a) – (d) to define the areas necessary for sustainable uses, and to define the areas necessary for preservation; and

(f) define the strategies necessary for the management and preservation of the nation's mangrove resources.

Because of heavy utilization of mangrove resources in many countries, the opportunities to protect pristine mangrove areas are rapidly disappearing (Fig. 26). It is important that governments act quickly and establish reserves which are 'representative' of the untouched mangrove forests of their country as well as reserves that will protect 'unique' and threatened species (see § 5.12).

In countries where opportunities to protect pristine areas no longer exist, it will still be valuable to establish reserves in the better quality stands in disturbed areas. Despite the fact that areas are no longer in pristine condition, they may still be essential nursery areas for fish and prawns, stopover places for migratory birds, and important habitats which, if properly managed in the future, will protect rare plants and animals associated with the mangrove ecosystem.

Each country will need to assemble an expert group to develop its National Plan. Some countries have already formed National Mangrove Committees and in many cases these Committees will be the most appropriate group to assume responsibility for the preparation of a National Plan. Once governments have a National Mangrove Plan, they will have the necessary framework to go on to develop effective coastal zone management plans.

6.2 International Co-operation

Aside from considerations for the optimal use of the resources at a national level, development plans of two or more countries may have conflicting interests. Two types of problems arise:

- geographical conflicts between neighbouring countries; and
- conflicts of countries linked through economic interests.

The first type of problem is represented in all those cases where the destructive activity is separated from the affected mangroves by national borders. This applies, for example, to freshwater diversions, upstream mining and logging, or upstream waste discharge (see § 5).

The second type includes the large-scale exploitation of a mangrove forest by a foreign company, or a transnational mining or oil company exploiting the mineral resources in or near mangrove forests. Oil transportation through mangrove-lined shipping lanes also poses a risk for large-scale destruction which may affect the mangrove forests of more than one country (see § 5).

It is clear that in the first case a national management plan alone cannot provide guarantees for the optimal use of the mangrove resources in question. Here, dialogue between the respective countries is called for, which it is hoped this report will help to initiate.

In the case of destructive resource exploitation through transnational interests, the principles for optimal management on a national basis may also be subject to international compromises. To optimize management in this situation co-operation may be required between national governments and a number of international bodies.

However, such international co-operation requires the willingness on all sides to accept long-term management principles. Some examples are

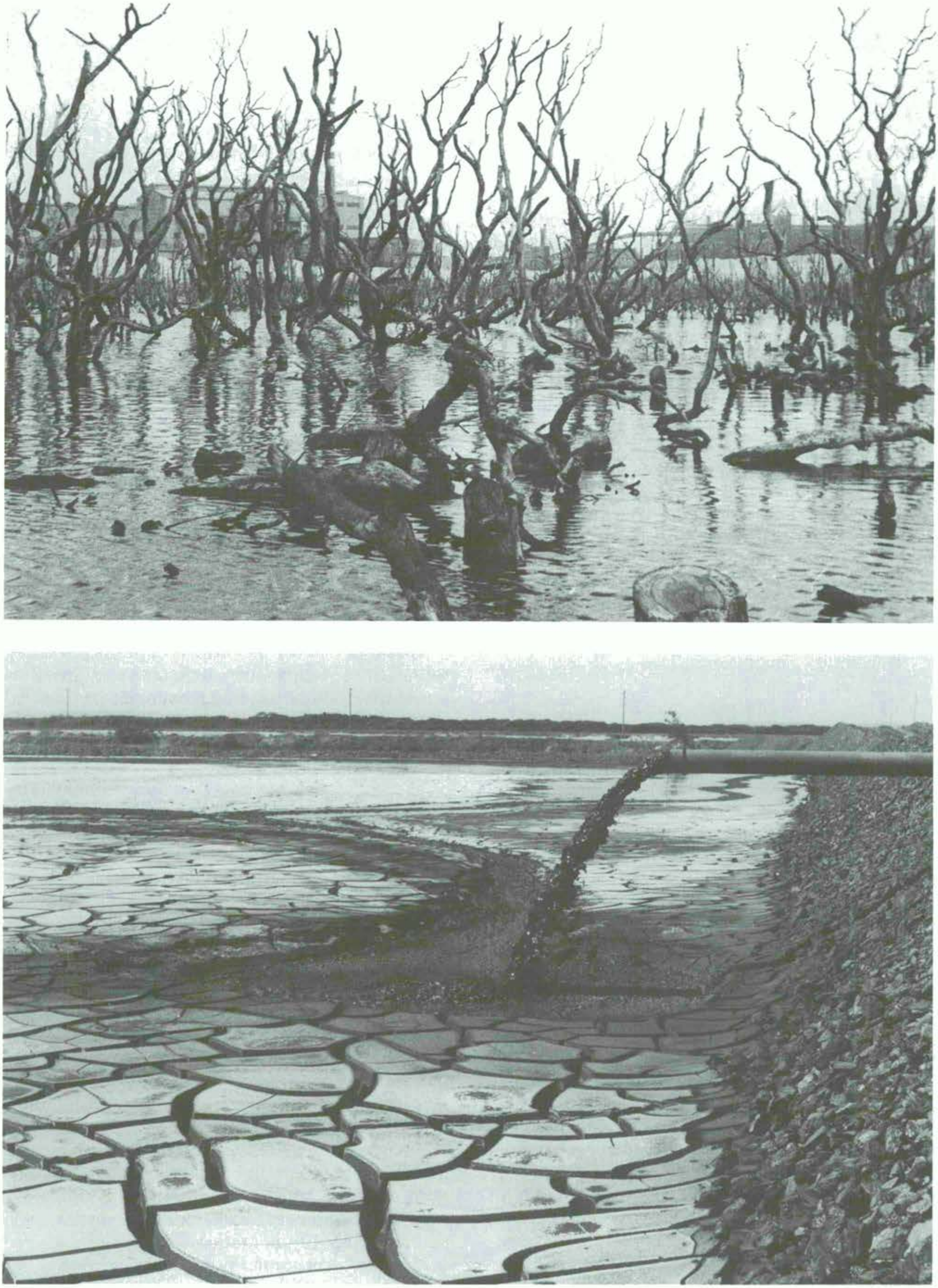


Fig. 26. Disappearance of mangrove areas in Hunter River estuary, Australia. Courtesy: Trevor Ward.

already apparent in various regions through the stimulating assistance of the UN system, e.g., the Regional Seas Programme of the United Nations Environmental Programme which helps to develop national and co-operative international management schemes for protection of coastal zones, including, where appropriate, mangrove ecosystems. One example of international arrangements for protection of mangroves is the regional oil spill contingency plans.

Summing up, the need for international agreements on national management plans for mangrove resources is becoming increasingly urgent as the influences of widespread development and exploitation activities encroach alarmingly on neighbouring, as well as distant nations.

6.3 Policies for Sustainable Uses

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 although, unfortunately, this is often not done. 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. The latter part tends to be much more difficult to attain except for a few cases (e.g., the use for tourism). Thus, sustainable use often does not mean sustaining the original natural system: this can be achieved almost solely through preservation. Preservation can be part of a sustainable use management plan where it has the added advantage of being placed in a buffered system.

Management on a sustainable use basis often does not involve added costs — not on a long-term basis. There is no rational basis for governments not to insist on such a management regime when it has been demonstrated to be possible.

6.3.1 Sustained yield management for forestry

Mangrove areas have either been left largely intact where populations are sparse (e.g., northern Australia and Papua New Guinea), exploited at subsistence level (the intensity depending on population pressures), merely exploited on a large scale with little or no effort of reafforestation, or used on a sustained yield basis. Sustained yield management of mangroves for timber is neither a new nor a localised practice. Pioneered by the British Administration in the early part of this century, this practice is still evident in, for example, Bangladesh and Peninsular Malaysia.

Developed essentially by rule of thumb, this practice involves a 20–40 year cycle. The mature trees are clearfelled in batches (usually a few hectares in area) and the timber is removed (e.g., for conversion to charcoal). The tree stumps and prop roots as well as slash (branches, twigs, leaves and propagules) are left for about three years to decompose. If no natural regeneration occurs, these areas are planted (usually with *Rhizophora apiculata* if charcoal production is the end-product). The trees are allowed to grow unattended. Thinning of the trees is carried out once or twice (at between 15–20 years and/or 20–25 years), before clearfelling in a 30–35 year cycling plan. Timber extracted at thinnings is used as poles for pilings and scaffolding as well as for firewood.

In Malaysia, particularly at Matang (Fig. 27), this practice is now in its third cycle with a number of revisions of the original working plan. There appears to be a drop in timber production with each cycle (the drop in production at the end of the first cycle is understandable since the first fellings were of large mature virgin stands). The reason for the subsequent drop in production is not clear.

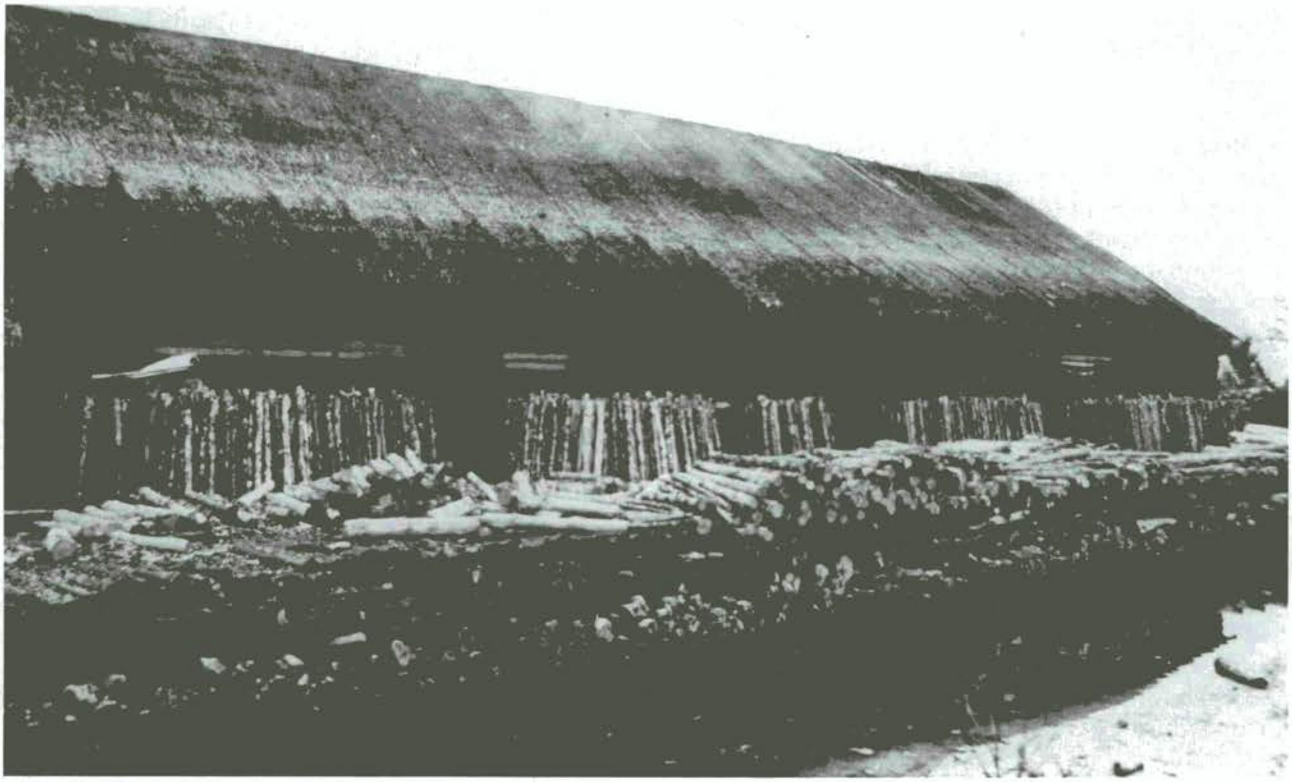
There are quite a number of advantages in sustained yield management. It is possible to harvest a large amount without disrupting the vital ecosystem processes. In the Matang reserves, Malaysia, approximately 40,000 ha are being managed on a sustained yield basis for the production of charcoal, firewood and poles, i.e., the whole area is eventually worked over in a 30 year cycle. There is no reason why this system cannot be extended to other areas (e.g., so that woodchips can be produced on a sustainable yield basis). Primarily, it involves better management, and a more forward-looking policy.

The sustained yield system described above has one drawback — a shift to a monoculture plantation, because regeneration does not result in the replacement of the original flora. This can be partly overcome by setting aside areas of the original flora. Such areas not only provide an undisturbed system, but also an extremely important source of propagules and genetic diversity.

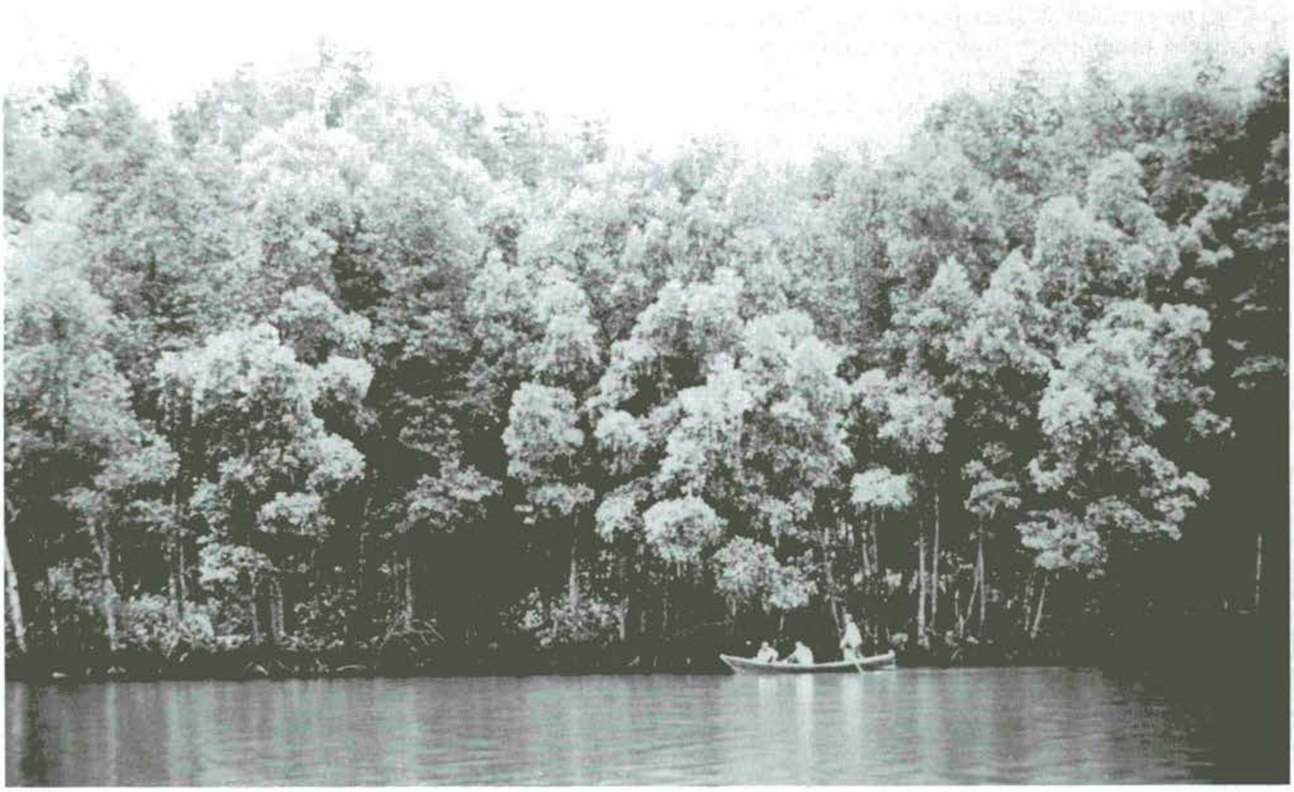
While the above management practice has met with success in Malaysia, the silviculture methods to be employed in other geographic regions must clearly be developed in relation to the flora and conditions of that region. Extrapolation from the Malaysian practice may provide a general framework, but the details must be based on local research using the local raw materials.

6.3.2 Sustained yield management for coastal fisheries

It is well known that the mangrove forests support the fishery resources within the ecosystem. There is evidence that the mangrove swamps are used as sheltering nursery grounds, as permanent habitat for some species, and as breeding grounds



(a) ▲



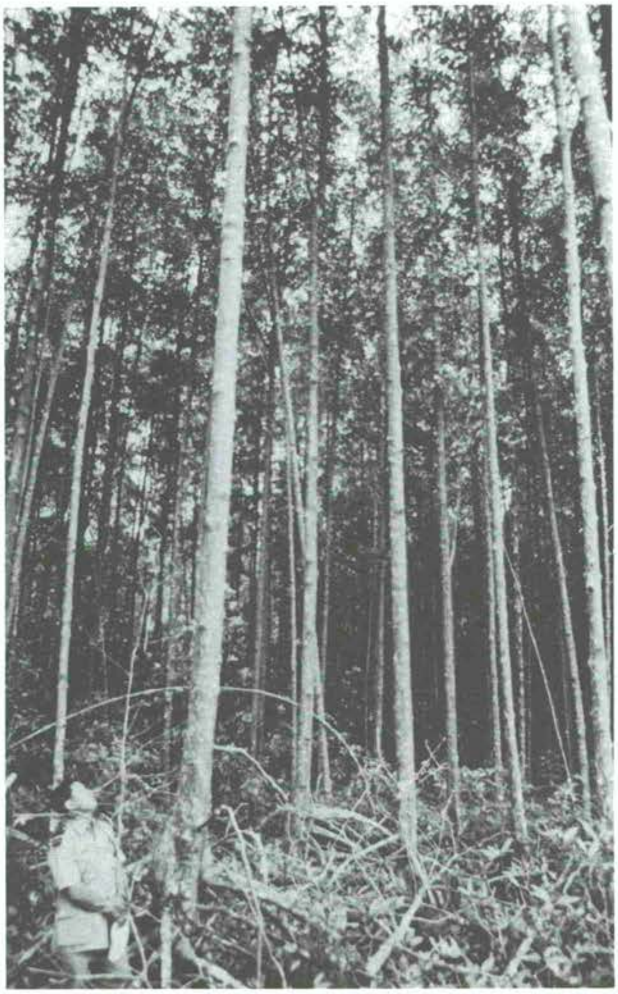
(b) ▲

Fig. 27. The Matang forestry area, western Peninsular Malaysia. (a) The forest harvesting programme at Matang is organised to provide the wood for large-scale charcoal production. (b) The fishing industry supported by the Matang forest area is an even greater source of employment than the very labour-intensive forestry operations. (c) The small virgin forest reserve in Matang is providing valuable data on mangrove growth and mortality. (d) A crop of 25 years old *Rhizophora*. (e) Weeding of *Acrostichum* fern to assist regrowth. Courtesy: Eddie Hegerl.

(c) ▲

(d) ▼

(e) ▼



for some coastal species—including commercially important ones. It has been shown that in some mangroves, most fishes feed at least partially on mangrove detrital material. Other groups of aquatic animals depend on planktonic or benthic organisms—a food supply generated within the ecosystem (see § 4). The species that are fished, trapped or collected in the mangrove creeks, rivers and estuaries comprise finfish, crustaceans (prawns, crabs) and molluscs (e.g., oysters growing on the mangrove prop roots).

The influence of the mangrove ecosystem, however, extends beyond the mangrove forest limits into the coastal waters. Organic detritus produced in the mangroves is exported at high rates into the coastal zone and supports the productivity of these waters. The link and significance between mangroves and its adjacent fisheries is still being investigated. At a number of localities a positive relationship has been found between the area of intertidal vegetation and commercial yields of penaeid shrimp. A similar relationship appears to exist with certain finfish species.

If a world-wide link does exist between mangroves and its fisheries, internal and coastal, then this link is mediated through the litter production and decomposition. Under this aspect a sustained production of mangrove litter and nutrient cycling is vital. The influence of this productivity factor on fish populations cannot be denied, and should be given full consideration when allocating the mangrove resource.

Fisheries in the mangroves, i.e. in the rivers and estuaries, are commonly subsistence fisheries for local, small-scale fishermen, fishing below the optimal fishing level.

A management plan for maximum sustained yield fishing should consider the parameters for productivity of fisheries, in addition to fishing effort and stock assessment. The input of nutrients from the mangroves is one of the factors responsible for productivity of fisheries, and it is readily influenced by the manipulation of mangrove ecosystems. Destruction of mangrove forest, direct or secondarily through other activities (see § 5), will result in lower litter production and consequently influence the productivity of the coastal waters. Even at maintained levels of fishing effort, the diminished fish stocks would then become overfished. Overfished coastal stocks can, in turn, also affect the mangrove fisheries as breeding or juvenile populations of the transitory species may decrease in size.

Management plans should also recognize the need to attempt to protect any adjacent seagrass beds, tidal flats and tidal marshes as they are important not only to the mangrove ecosystem, but also to the fisheries they help support (Fig. 28).

6.3.3 Problems related to aquaculture

Several Asian countries have developed sizeable aquaculture programmes in mangrove areas. As outlined in § 5.5.2, in the Philippines the construction of fishponds has become a major threat to mangrove resources.

The situation is becoming somewhat similar in Sulawesi and in Java which contain 63% (120,000 ha) of the total Indonesian area under brackish water aquaculture. In Bangladesh, Thailand and Malaysia, aquaculture is also practised, but on a much smaller scale.

The rapid expansion of fishculture in ponds has resulted in the intensification of mangrove destruction and probably also in the decline of fish and prawns caught from the neighbouring coastal zones.

There is possibly an optimum ratio of pond area to mangrove tree area, and ponds should be constructed so that sufficient mangrove litter is produced to sustain the detritus/detritivore link essential to maintaining the adjacent natural fisheries.

Obviously aquaculture has been seen in several Asian countries as a means to meet the increasing demand for cheap protein. It should be possible to construct fishponds in such a way that neither the mangrove ecosystem nor the fisheries they support are seriously affected. In order to minimise the impacts of fishpond construction, it has been suggested that the amount of mangrove forest converted into fishponds should not exceed 1 ha of ponds for 4 ha of natural mangrove kept untouched.

Naturally, this ratio is only an approximation which would be expected to vary from one country to another or from one mangrove type to another. It can be determined only after appropriate research has been carried out by specialized scientists.

Among alternatives to be more thoroughly explored is cage culture, for which experimental data are limited at present, but which is being used successfully in several countries on a small scale (Fig. 29). In Indonesia the total production of cultured fish was about 53,000 tons in 1973, of which about 10,000 tons were produced by cage culture.

Some criteria, therefore, that may be considered in developing policies for establishing fishponds in mangrove areas are:

(1) Vegetation — Areas without vegetation or areas with sparse growth that are easy to clear should be used instead of those densely populated with trees. In dry parts of the tropics, e.g. parts of India or some West African countries, these areas would be more productive as a grazing area. Clearly, a scientific identification of areas convertible into fishponds needs to be made.

(2) Water supply — There should be a continuous supply of water.

(a) ▲

(3) Size of ponds—Ponds should be of such a size that adjacent mangroves are minimally affected and the supply of fry to coastal fishery areas is not reduced.

(4) Aquaculture practices—Some aquaculture practices are undesirable, like the use of chemicals which kill not only predators and other undesirable species, but also non-target organisms involved in detritus conversion.

(5) Most importantly, unless the aquaculture scheme can improve on the natural productivity—both qualitatively and quantitatively—and sustain it, then this use of the mangrove ecosystem is self-defeating in the long term.

(b) ▼

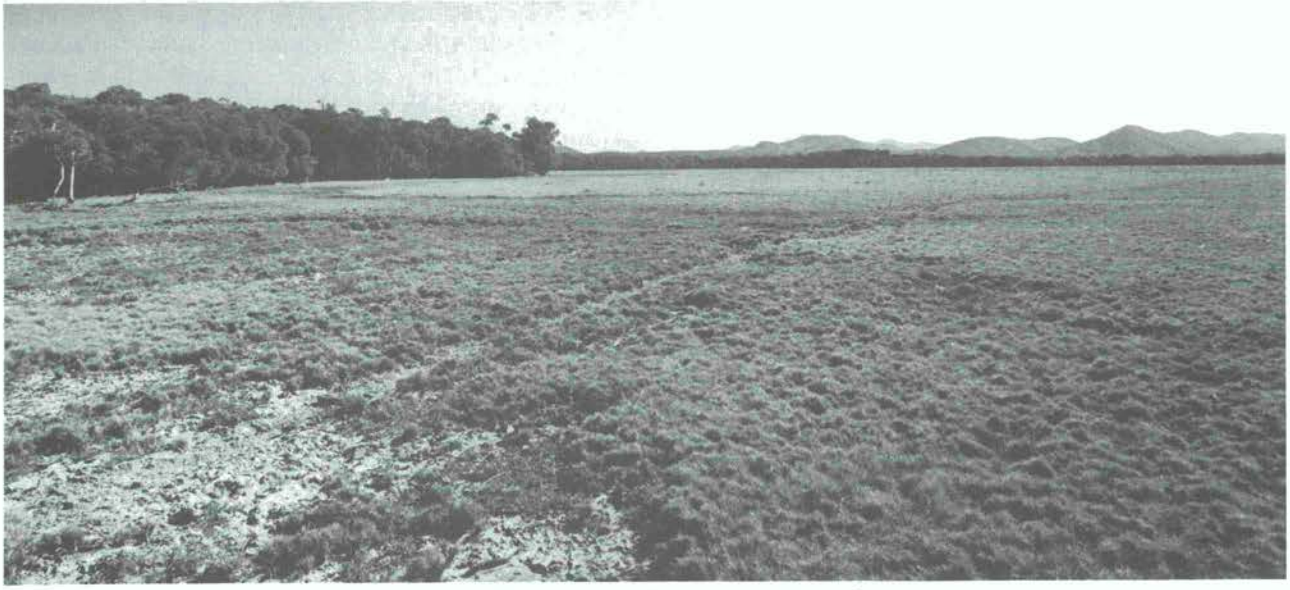


Fig. 28 (a) and (b). Seagrass beds, tidal flats and tidal marshes adjacent to mangrove forests.

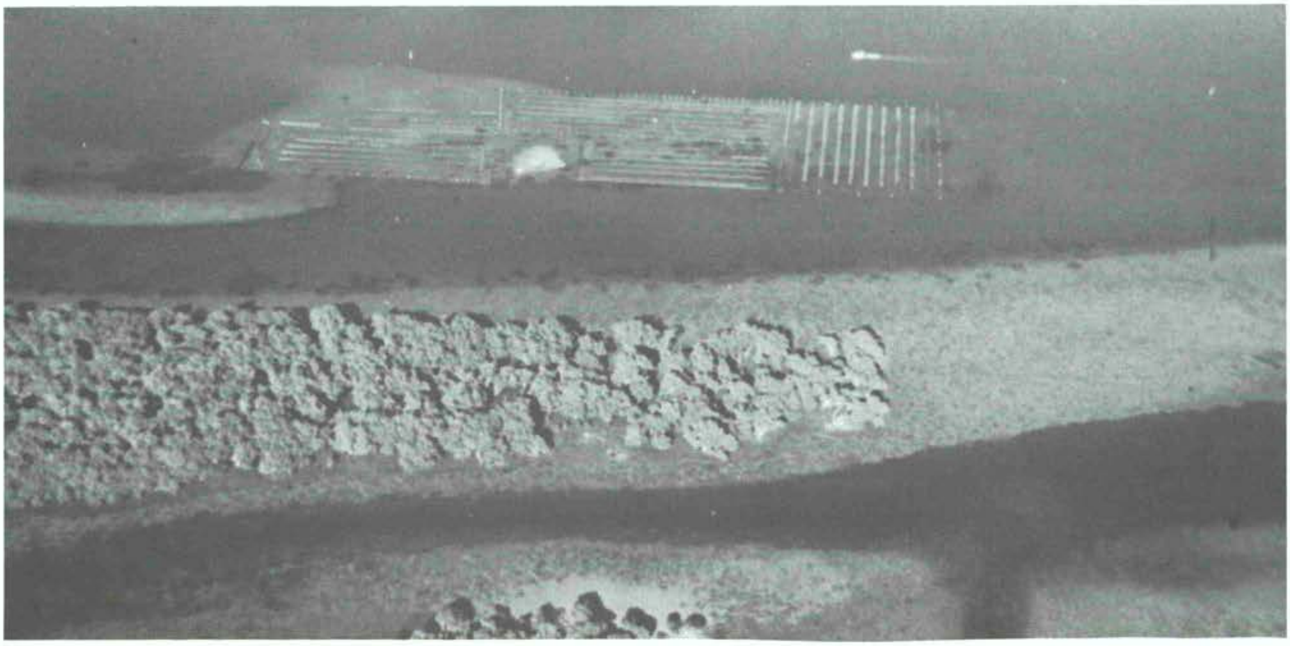


Fig. 29. Mangrove estuaries are used to support a sizeable Australian oyster industry. The oysters, grown on racks adjacent to the mangroves, feed on the bacteria which decompose mangrove leaf detritus.

6.3.4 Sustained yield management for sugar and alcohol production with the Nypa palm

Sustained yield plantation actually within intertidal mangrove in Asia has been well developed for *Nypa* sugar. It does imply extensive replacement of natural complex mangrove systems by the plantation. The plantation, however, is itself a mangrove system, and once established is effectively permanent, and contributes to detritus production and other natural values within the estuarine complex.

A system of raised ridges at about high-tide level for access, separated by planting drains, is established and seedlings transplanted into pockets in the drain sides. Planting density should be about 740 per hectare, and once established should not need replanting since it is a rhizomatous perennial with no natural age limit. Once grown, trees need regular thinning to fruit. Bearing rate is at full level at five years from planting and trees average two tappable stalks all year round at any one time. Juice is tapped from the fruit stalk which must first be manipulated to prevent embolic blockage ('gon-changing') and then cut daily. The tapping life of a stalk depends on careful cutting, but is long because its great Sapflow is about 1 litre/palm per day, and sugar content about 13% Brix.

Output in Malaya averaged 150,000 litres/hectare per annum, giving 10% by value of 95% alcohol, or 20 tons recoverable sugar/hectare per annum. Estate force requirements work out about 38 people per 10 hectare plot for maintenance and collection with boiling station, distillery and management staff numbering about five per hectare, so it is very labour intensive. However, unlike sugarcane economies, the production and employment is continuous rather than seasonal, and does not introduce a labour displacement problem. Replanting and rotation do not interrupt production or involve periodic upset to the ecosystem. There are no serious waste disposal problems. Fuel may be a problem, if fuel wood forestry is not planned as part of the mangrove management complex.

Nypa foliage is also widely used in Asia for thatching ('attap'). This requires leaf cutting at an entirely different stage to that produced by thinning tapped trees, so the two uses are not compatible. Thatch plantations are closer planted and much more severely cut.

6.4 Expanding the Resource

The whole strategy of forward planning for any coastal development presupposes knowledge of major characteristics of the area—whether it is a stable, rising or sinking coastline; the general topography, climate and projected land use of the hinterland; and existing and projected use of offshore, dependent systems.

Coastal, purely maritime, barrier mangroves are unlikely to be expanded seawards but may well be extended by planting along the coast to provide new land development with protection from erosion and storm damage. This will be an ecological problem involving choice of tree species appropriate to existing and expected substrate and erosional characters of the site. The drowned valley systems, such as in some parts of West Africa, may pose similar problems and their special natural mangroves seem well adapted to their conditions.

Accreting coastlines, even without substantial freshwater inputs, may offer special opportunities for intertidal forest development. The Government of Bangladesh has undertaken a large-scale planting programme to protect the Bangladesh coastline from storm damage. To date, 25,000 ha have been planted. Present plans call for the planting of another 40,000 ha over the next five years.

The most extensive mangrove development possibilities today exist in stable or rising coastlines with major estuarine outflows. Minimal policy here may only include accelerated stabilization of existing directions of accretion by planting of pioneers. This may be no more than extensions of existing replanting programmes for previously exploited areas.

The other extreme would be the deliberate construction of expanded estuarine conditions to make maximal use of riverine outflows in the intertidal zone at the expense of direct outflow to the sea.

This assumes that river flow and silt load can be redistributed by landfill derived from the terrestrial system, or perhaps dredged from the sublittoral. In effect, a new base level is to be established, which existing riverine and tidal inputs would supposedly be able to maintain in a condition analogous to the existing mangrove systems. Careful planning of the redirected tidal and riverine flows would be needed. Depending on the site, possibilities might include redirecting outflow to run for considerable distances along suitable coastlines, or even the impoundment of whole offshore island complexes. All such development would be quite expensive and have to include provision against seasonal or catastrophic changes in conditions.

Such proposals are only likely to be of interest where large-scale, high yielding intertidal systems of proven capabilities have been developed. At present only the widespread use of *Nypa* for fuel alcohol seems promising, and even this only as an element in fully integrated land use schemes with associated fuel-wood plantations, fishery/aquaculture programmes and a full land-based development of settlements and co-ordinated industries.

7. Legislation and Administration

7.1 Introduction

Ultimate decisions of mangrove resource allocation depend on the interplay of community pressure which results from community perception of the resource (see § 3.3) and corporate pressure largely determined by economic factors and the distribution of political power. Clearly, in the situation where a national government has developed a rationale for resource allocation based on community pressure, the pressure that can be brought to bear by a transnational agency or corporation will be proportionately diminished, and subjected to the regional needs. Where the national government is not in such a position, it is clearly vulnerable to transnational pressures, and resource allocations may be made which are not in the long-term interests of the community.

The objectives of this section are to examine the legal and administrative frameworks within which decisions on mangrove resource allocation are made, to identify the factors which frustrate rational allocation, and to compare the strengths and weaknesses of the existing approaches.

The agencies responsible for administering mangroves from each country from which data are available are listed in Table 8.

7.2 Selected approaches

7.2.1 Philippines

The Philippines is an archipelago of approximately 7,100 islands. In 1978, it had 246,699 hectares of mangrove forest. For the period 1967–1976, the area of mangroves declined from 418,990 ha to 249,138 ha, or approximately 16,741 ha annually. These areas were cleared for fishponds or denuded of fuelwood and timber. The rate of decline has slowed; from 1977 to 1978, the area cleared was 2,439 ha.

Policies/regulations governing the development, preservation and/or conservation of the mangrove areas: At the ministerial level, the Ministry of Natural Resources (MNR) is the principal government agency responsible for the development, management and conservation of mangrove resources in the Philippines. Under the MNR are agencies whose functions relate to the utilization of mangrove areas. These are the Bureau of Forest Development (BFD), the Bureau of Fisheries and Aquatic Resources (BFAR), and the Bureau of Lands. Also attached to the MNR are the Forest Research Institute (FORI), the Natural Resources Management Center (NRMC), the Fishery Industry Development Council (FIDC), and the National Environmental Protection Council (NEPC).

Other Government agencies whose functions and jurisdiction relate to mangrove resources are the following: the National Pollution Control Commission (NPCC); the Philippine Coast Guard (PCG); the National Science Development Board (NSDB); the Philippine Council for Agriculture and Resources Research (PCARR); and various state colleges and universities.

Mandates to implement policies and guidelines concerning the development, management and conservation of mangrove resources are embodied in several Presidential Decrees, plus Administrative and Special Orders.

A. Classification and survey

Policies on the classification and survey of mangrove areas date back to 1952 with Forestry Circular No. 95 formulated for the purpose of zoning swamplands. Mangrove areas were to be zoned according to:

(1) areas to be retained permanently for forest purposes, for the gathering of firewood, charcoal, *Nypa* shingles, *Nypa* sap and tanbark, for the construction of saltwork, stream bank protection and others; and

(2) those areas that could be released for fishpond purposes.

The zoning was not completed owing to lack of funds and technical expertise.

In 1975, Presidential Decree No. 705, otherwise known as the Forestry Reform Code of the Philippines, directed the Ministry of Natural Resources to devise guidelines and methods for the proper and accurate classification and survey of all lands of the public domain into agricultural, industrial or commercial, residential, resettlement, mineral, timber or forest, and grazing lands.

The system of classification stipulated that mangrove and other swamps not needed for shore protection and suitable for fishpond purposes should be released to and placed under the administrative jurisdiction and management of the BFAR. For this purpose, Special Order No. 3 creating the Land Classification Composite Teams of the BFD was issued on July 22, 1975. Mangrove areas have been delimited by this team for such purposes as forest and fishpond development. This process of land classification has been a vital factor in con-

TABLE 8. *Agencies responsible for administering mangroves in various countries*

Country	Administering Agency
Oceania	
Australia	State Fisheries Depts.
Asia	
Pakistan	Dept. of Wildlife & Forestry; Forest Dept., Government of Sind (276,410 ha); Port Oasim Authority (64,376 ha)
India	Dept. of Science & Technology, Government of India; Forest Service State Forest Departments: West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Maharashtri, Gujarat, Madras, Bombay region, Andaman & Nicobar Islands
Sri Lanka	Forest Dept. (but does not refer to mangroves specifically)
Bangladesh	Government Forest Dept., Ministry of Agriculture (c/Chief Conservator of Forests)
Thailand	National Committee on Mangrove Resources; Royal Thai Forestry Dept.
Malaysia	Forestry Depts. of each State
Singapore	Nature Conservation Board, Ministry of National Development (currently no protection afforded to mangroves)
Indonesia	PPA (Directorate of Nature & Conservation); Dept. of Agriculture and Directorate General of Forestry; Directorate General of Fisheries; plus others
Taiwan	Taiwan Forestry Bureau, Ministry of the Interior
Japan	Ministry of Education and Environment Agency
Philippines	Ministry of Natural Resources (Forest Research Institute, Bureau of Forest Development, Bureau of Fisheries and Aquatic Resources)
Africa & Middle East	
Senegal	Water & Forest State Secretariat; Water & Forest Service
Sierra Leone	Ministry of Agriculture & Forestry
Ivory Coast	Ministry of Water & Forests
Nigeria	Forestry Research Institute of Nigeria
Cameroon	Ministry of Agriculture (Forests)
Gabon	Ministry of Water & Forests
South Africa	Generally the local (provincial) Parks Boards
Mozambique	Secretariat of State for Fisheries
Israel	Israel Nature Reserves Authority
The Americas & the Caribbean	
United States	Federal agencies with responsibilities for natural resources share efforts relative to mangroves depending on the specific government missions of each. Agencies include: U.S. Army Corps of Engineers, U.S. Fish & Wildlife Service, U.S. Environmental Protection Agency, U.S. Coast Guard, Bureau of Land Management, National Oceanographic & Atmospheric Agency, U.S. National Park Service, and other protectors of the public trust
USA—Florida	Dept. of Natural Resources, Division of State Lands, Division of Parks & Recreation and Division of Marine Resources; Dept. of Environmental Regulation; Dept. of Transportation; Dept. of Administration, Community Affairs and Bureau of Land & Water Management. Each county and city in Florida also have varying responsibilities under their respective ordinances
USA—Texas	General Land Office of Texas, and Texas Parks & Wildlife Dept.
Mexico	Secretaria de Recursos Hidraulicos a Traves de la Subsecretaria Forestal y de la Fauna; Secretaria de Agricultura y Ganaderia (Recursos Forestales)
Belize	Fisheries and Forestry Depts.
El Salvador	Servicio Forestal y de Fauna (Ministerio de Agricultura y Ganaderia)
Honduras	None practically—theoretically COHOEFOR
Costa Rica	Ministerio de Agricultura y Ganaderia and INDERENA
Panama	Natural Renewable Resources (RENARE) and Marine Resources (MICI), Ministerio de Desarrollo Agropecuario—Direccion Nal. de Recursos Naturales Renovables
Colombia	Instituto Nacional de los Recursos Naturales Renovables (INDERENA)

TABLE 8 (continued)

Country	Administering Agency
Ecuador	Armada del Ecuador, Ministerio de Agricultura y Ganaderia and Ministerio de Recursos Naturales y Energeticos
Peru	Ministerio de Agricultura and Ministerio de Pesqueria
Brazil	SEMA and IBDF; FEMA—Ministerio de Interior. 1. Instituto Brasileiro de Desenvolvimento Florestal (IBDF); 2. Secretaria Especial do Meio Ambiente (SEMA) Secretarias Estaduales del Medio Ambiente; IBDF, SEMA—Secretaria Especial del Medio Ambiente; Secretaria del medio ambiente y otras agencias del gobierno, localisadas en los estados riverenos; (Maranhao)—Secretaria de Recursos Naturais, Tecnologia e Meio Ambiente SERNATE/ITEMA/COPENAT/IBDF (Minist. Agric.) (do Estado)
French Guiana	National Office of Forests
Guyana	Guyana Forestry Commission and Guyana Sea Defence Board
Venezuela	Ministerio del Ambiente y de los Recursos Naturales Renovables (MARNR)
Curaçao	Dept. of Agriculture and Dept. of Spatial Planning (L.V.V. and R.O.V.)
Trinidad & Tobago	Forestry Division—Ministry of Agriculture, Lands and Fisheries
Turks & Caicos Islands	No management programme
Cayman Islands	Physical Planning Dept. and MRCURNRL
Jamaica	Natural Resources Conservation Dept.
Dominican Republic	Direccion General Forestal
Bahamas	Bahamas National Trust; Ministry of Agriculture and Fisheries
Puerto Rico	Dept. de Recursos Naturales
Guadeloupe	Office National des Forêts
Martinique	Office National des Forêts
Montserrat	Dept. of Agriculture—Forestry Division
St. Kitts	Forestry Dept.
Barbados	Ministry of Housing and Lands
Bermuda	Dept. of Agriculture and Fisheries

trolling conversion of mangrove areas into fishponds.

In another Special Order No. 309 of December 13, 1976, the National Mangrove Committee of the NRMC was created. This Committee was charged with the areal assessment of mangrove areas through remote sensing with the use of Landsat satellite imagery. In collaboration with BFD, BFAR, FORI, and FIDC, the Committee would undertake ground inventory and assessment of selected mangrove areas with the following expected outputs:

(1) taxonomic research surveys on mangal fauna and flora;

(2) qualitative studies on fish and shellfish resources; and

(3) productivity and standing crop of mangrove resources.

B. Utilization

For purposes of utilization, Presidential Decree No. 705 stipulates that an evaluation of mangrove areas shall be conducted before exploitation, utilization or occupation is allowed. It further specifies that optimum benefits should be derived from the exploitation of these resources. The issuance of licences, leases and/or permits is required, whether the resource will be used for fishpond development or for forest purposes.

For forest purposes, control of utilization and exploitation is effected through the issuance by the BFD of an Ordinary Minor Timber Licence for the extraction of mangrove products for firewood and construction materials, and an Ordinary Minor Products Licence for *Nypa* shingles, tanbarks and other similar products.

Among the requirements for licence application are: a sketch map of the area applied for; evidence of capital investment of at least ₱1,000 per hectare; a business plan; a recommendation from an office concerned with cultural minorities (if the area falls within the area set for such purposes); a waiver of rights of existing licences; a contract to supply a NACIDA (National Cottage Industry Development Administration) registered manufacturer or processor; a copy of the NACIDA certificate; and the payment of fees (application fee of ₱1.00 per hectare and an oath fee of ₱2.00). The licence fee is equivalent to 5% of the allowed cut multiplied by the average forest charge per unit measure. A bond deposit of ₱1.00 per cubic metre in the case of bakawan (*Rhizophora* spp.) and ₱0.60 per thousand shingles in the case of nipa (*Nypa fruticans*) has to be posted.

For fishpond development, Presidential Decree No. 704 (the Fishery Decree) maintains that the country's fishery resources be in optimum productive condition. Applicants wishing to lease swamplands for fishpond purposes are required by the BFAR to submit a project feasibility study concerning the development of the area and making it productive at optimum levels. The government prohibits the disposal by sale of public lands suitable for fishpond purposes. These lands should only be leased to qualified persons, associations, co-operatives, or corporations. A qualified and interested applicant is granted a lease for a period of 25 years renewable for another 25 years. The lease contract gives the leasee 5 years to develop 50% of the fishpond to commercial scale and another 5 years to develop the remaining portion to commercial scale. All areas not fully developed within this given period automatically revert back to the Bureau for disposition and are declared open/available for other applicants. The same holds if the leased area is abandoned or is not developed. This system helps prevent acquisition of fishpond leases for speculative purposes. Furthermore, the aquaculture programme concentrates on increasing the yield of existing ponds by introducing improved technology, rather than expanding the present hectarage to boost fish production. This is in recognition of the importance of the mangrove areas for economic uses other than ponding the biological system for commercial fishes.

C. Development, preservation and/or conservation and management

Simultaneous to optimum utilization, proper management of mangrove resources is embodied in a number of decrees and administrative orders. For example, the BFD has prescribed the seed-tree-and-plant method of silviculture treatment. This system of clearcutting requires that 20 or more seed trees per hectare with diameters of 20 cm or larger, that are well-scattered and strategically located in the forest area, be left undamaged. Artificial regeneration or reforestation by the licensee concerned should augment this system, especially in open and heavily depleted areas.

With regard to conservation, Presidential Decree No. 953 requires a holder of a lease agreement to plant trees extending at least 20 metres from the edge of river banks or creeks. Under the same decree, any person who cuts, destroys or injures naturally growing or planted trees of any kind in this area without authority from the government agency concerned is liable to a fine and/or imprisonment.

In addition, Presidential Decree 705 states that the following are needed for forest purposes and therefore may not be classified as alienable and disposable land:

(a) 20 m strips of land along the edge of the normal high-water line of rivers and streams with channels at least 20 m wide, along shorelines facing oceans, lakes and other bodies of water, and strips of land at least 20 m wide facing lakes;

(b) strips of mangrove forests bordering the numerous islands which protect the shoreline, the shoreline roads, and even coastal communities from the destructive force of the sea during high winds and typhoons; and

(c) all mangrove swamps set aside for coast-protection purposes shall not be subjected to clear-cutting operations.

Mangrove and other swamps released to the BFAR for fishpond purpose which are not utilized or which have been abandoned five years from the date of release shall not revert to the category of forest land.

The National Mangrove Committee has provided guidelines for the selection of mangrove areas to be preserved/conserved or to be declared as Mangrove Forest Reserves. Based on ecological and socio-economic reasons, the mangrove areas to be recommended for preservation/conservation or to be declared as mangrove forest reserve are the following:

(1) Mangrove areas adjoining the mouth of major river systems. To maintain the ecological balance of estuarine areas, mangrove forests adjoining the mouth of major river systems should be closed from fishpond development. The area to be preserved should cover at least a 3 km stretch of mangroves on both sides of the mouth of the river fronting the sea.

(2) Mangrove areas near or adjacent to traditional productive fry and fishing grounds. Considering the importance of mangroves as breeding, spawning and nursery grounds for a variety of fishes and shellfishes, mangroves near or adjacent to traditional productive fry and fishing grounds should not be alienated or released for fishpond purposes.

(3) Mangrove areas near populated areas/urban centres. These mangrove areas should be conserved for utilization by people who are dependent on mangrove forest products for their livelihood or domestic needs (e.g., firewood, wood for making charcoal (Fig. 30), and timber for household construction).

(4) Mangrove areas of significant hazard if developed, because of storms, erosion, floods, etc. Mangrove forests which act as natural buffers

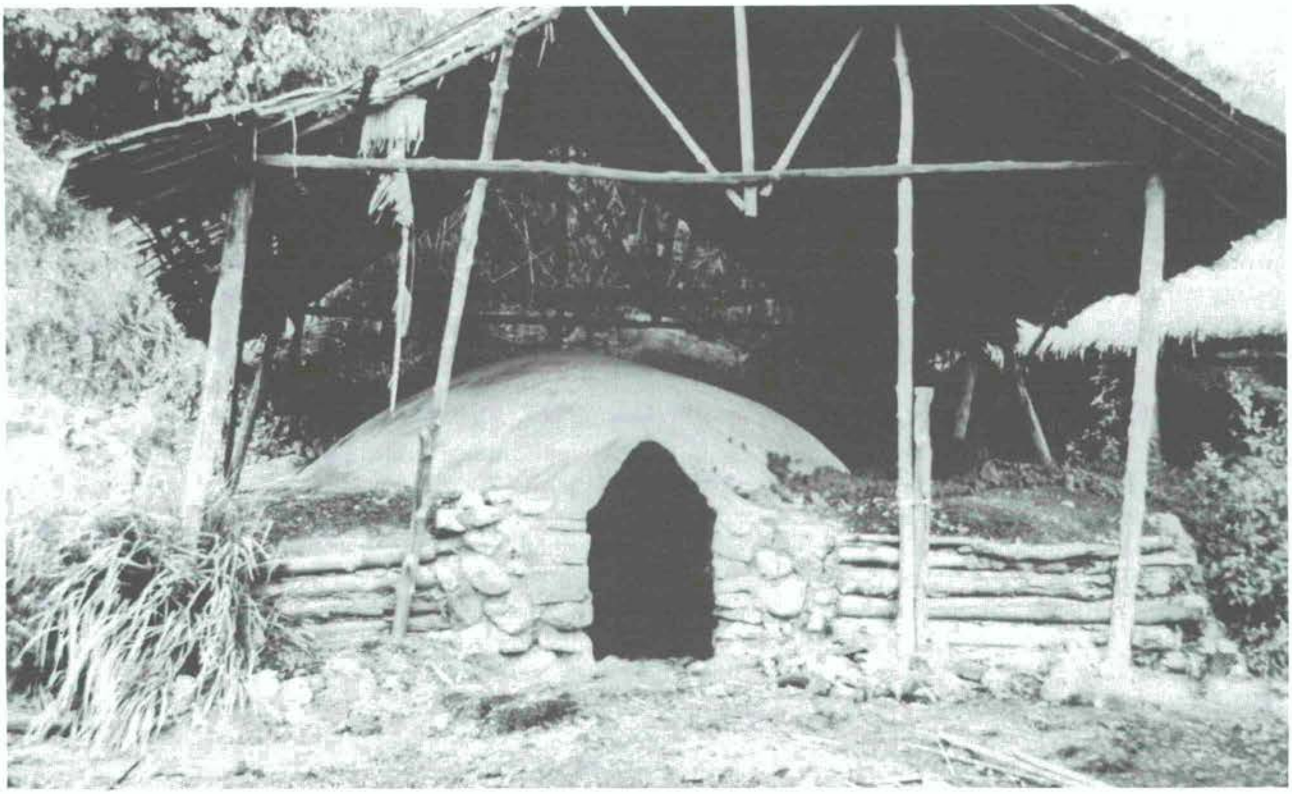


Fig. 30. A charcoal producing kiln on Palawan Island, Philippines. One quarter of Philippine charcoal production comes from mangrove forests. Courtesy: Eddie Hegerl.

against shore erosion, strong winds and storm floods should be left untouched.

(5) Mangrove forests which are primary/pristine and have dense young growth. Regardless of location, swamplands which are covered with virgin mangrove forest and dense young growth should be preserved or declared as forest reserves because these areas are important in maintaining ecological balance in the mangrove ecosystems. These areas are also needed for riverbank and shore protection, wildlife sanctuaries, and for educational or research purposes.

(6) Mangrove forests on small islands. Mangrove forests on small islands serve as a major ecological component of the island ecosystem and should in no case be disturbed.

7.2.2 Australia

The administration of the mangrove resource in Australia is probably typical of most federally constituted states. At least two levels of government are directly or indirectly involved in legislative responsibility for the resource, and the constitutional limitations are not clear. This is not surprising since the Australian Constitution was drafted in 1898–1901 and, with the exception of some minor alterations, has not been reviewed since that date. Nevertheless, under section 52 of the Constitution, the Commonwealth Parliament (i.e., the national government) has power over fisheries in Australian waters beyond the territorial limits of the States, which, in 1974, the High Court determined to be extreme low-water mark. Since nearly all the mangroves in Australia occur on Crown Land between mean sea level and extreme high-water mark, the States have assumed legislative control over the mangroves, generally under the respective Fisheries Acts, which have afforded the mangrove resource a minimal measure of protection.

Two problems are immediately apparent as a result of this arrangement. Firstly, many processes affecting the mangrove resource occur outside the extreme low-water mark line and consequently become the responsibility of the Commonwealth Government. Secondly, the fact that the mangrove resource is being administered by the various State Fisheries Departments has two limitations: the mangrove resource is mainly defined in terms of harvestable fisheries products; and most Fisheries Acts apply only in State waters, i.e., below extreme high-water mark. Consequently, no legislative competence exists for these Acts to control or regulate any activities which might affect the resource but which occur above extreme high-water mark. It is apparent that general catchment management, for example, is essential to maintain the mangrove resource, but the various Fisheries Acts lack the jurisdiction for such legislative control. To achieve such control other Acts or departments must be involved. Yet the underlying purpose or intent of such a move may be outside the scope or charter of the invoked Act or department: for example, in Queensland the Fisheries Act cannot control catchment usage, but this can be achieved under the Soil Conservation Act; however, regulations under the Soil Conservation Act designed specifically to protect the mangroves may be *ultra vires* (beyond power) of the Soil Conservation Act, and therefore invalid.

While various Fisheries Departments have assumed the primary responsibility for mangroves, other government instrumentalities, often with overlapping areas of interest, are involved and always with a finely tuned sense of interdepartmental rivalry. For example, mangrove and estuarine planning and management of the Hawkesbury River system in New South Wales (Fig. 31) presently involves more than 70 government instrumentalities!

Fig. 31. Canal-estate housing developments have been a major cause of mangrove destruction in south-east Queensland and New South Wales. Courtesy: Australian Littoral Society/Andrew Elliott.

The situation, as it exists in Queensland, illuminates the difficulties in defining who is responsible for management of the mangrove resource and therefore is discussed in some detail. Early legislation in Queensland (Fish and Oyster Act of 1914) was reasonably enlightened and it set aside certain areas as 'protected'; in these areas the cutting of oyster stakes was controlled by permits issued by Fisheries authorities. The legacy of the 1914 Act was carried through to the Fisheries Acts of 1957–1962, where under Part IV Oystering, section 65 prohibited the cutting, lopping, etc. of mangroves except by a permit, in all Queensland waters with the exception of areas excluded by Order-in-Council. An almost identical requirement is included in the Fisheries Act 1976, section 71.

Although these measures were designed to regulate the removal of mangroves for oyster stakes, the Fisheries Acts were clearly useful in preventing direct damage to the mangroves. However, in relation to the mangrove resource, these Acts were clearly inadequate. In addition to the general concern felt by Fisheries authorities about disruption of mangrove ecosystems, the activities of commercial diggers of the polychaete bait worm *Marphysa sanguinea* and the crustacean *Callianassa australiensis* from the intertidal mudflats adjacent to the mangroves had become increasingly destructive, interfering with traditional seining grounds of professional net fishermen. Much to the dismay of the Fisheries authorities, they found they were unable to prosecute to protect the ecosystem owing to a legal interpretation of the Fisheries Act. The Court had held that worms do not constitute 'fish' under the meaning of the Act, nor a 'marine product', and were therefore not covered by the Act despite the Act's intent. These definitions were enlarged in the revised 1976 Fisheries Act.

However, under the previous Fisheries Act, the Fisheries authorities were thus powerless to prevent sediment disturbance in the mangrove ecosystem. To circumvent this dilemma, legislation for Fisheries Habitat Reserves was passed in 1968 (The Fisheries Habitat Reserve Regulations of 1968) and similar regulations have been continued under the Fisheries Act of 1976. The Fisheries Habitat Reserves are the first attempt in Queensland to provide protection to more than the mangroves themselves, and although these regulations were initially inspired by concern over damage to traditional fishing grounds, they are nevertheless used in a wider context today, even though inadequacies still exist (Fig. 32). At present, 23 such reserves exist, ranging in size from a few hectares to 4,460 ha.

The status of Fisheries Habitat Reserves is granted by an Order-in-Council of the Queensland Government and this can only be altered by the same authority. Executive Council is composed of the Governor and the Cabinet, assuring the Fisheries Habitat Reserves of the strongest authority. Further, the authority is vested in 15 men, not in a single Minister, as is so often the case in Queensland, with natural areas set aside for some purpose. This spread of responsibility among a number of senior decision makers, reduces, though it does not eliminate, the risks of removal of 'reserve' status through the political and economic pressures which can be effectively focused on a single Minister.

At present, then, the legislative framework seems to exist in Queensland for proper decision making in mangrove ecosystem utilization. However, the present structures and procedures exhibit certain weaknesses which it is instructive to discuss.

Authority for the 'development' of mangrove ecosystems is vested in three separate Ministries

(Minister for Lands, Minister for Primary Industries, and Minister for Harbours and Marine). Regional planning, which often involves large mangrove areas, is usually the responsibility of the Coordinator General's Department which is part of the Premier's Department. An attempt is made to overcome this split responsibility by referrals to the various interested sections of Government. However, since the authority to grant or refuse an application for certain forms of exploitation is vested solely in one section (e.g., Lands Administration Commission for permission to reclaim mangrove areas; Fisheries Service for permission to 'cut', etc., mangroves; and Harbours and Marine for permission to develop canals in mangrove areas), advice tendered may, if it conflicts with the views of others, still be ignored. Furthermore, it may appear that the Minister with primary responsibility, the Minister for Primary Industry, is in an impossible position in that he is also responsible for the management of the sugar industry which, as a whole, is well documented for its major depradations of mangrove areas. While such conflict could be resolved through adequate techniques of environmental impact assessment, in practice this seldom happens. The Queensland 'Impact of Development Projects' guidelines make it clear that if the 'Developer' is a Government instrumentality (e.g., the Mines Department), that same instrumentality can also be the 'responsible authority' with which lies the ultimate decision as to 'whether it is necessary in any particular instance for an impact assessment study to be performed'. It follows that those Government instrumentalities whose charter includes the development of resources (be they mangrove or others), are in the position of being both the 'accused' and the 'judge', and while they are obliged to consult other interested Government instrumentalities, the final decision rests with that particular body.

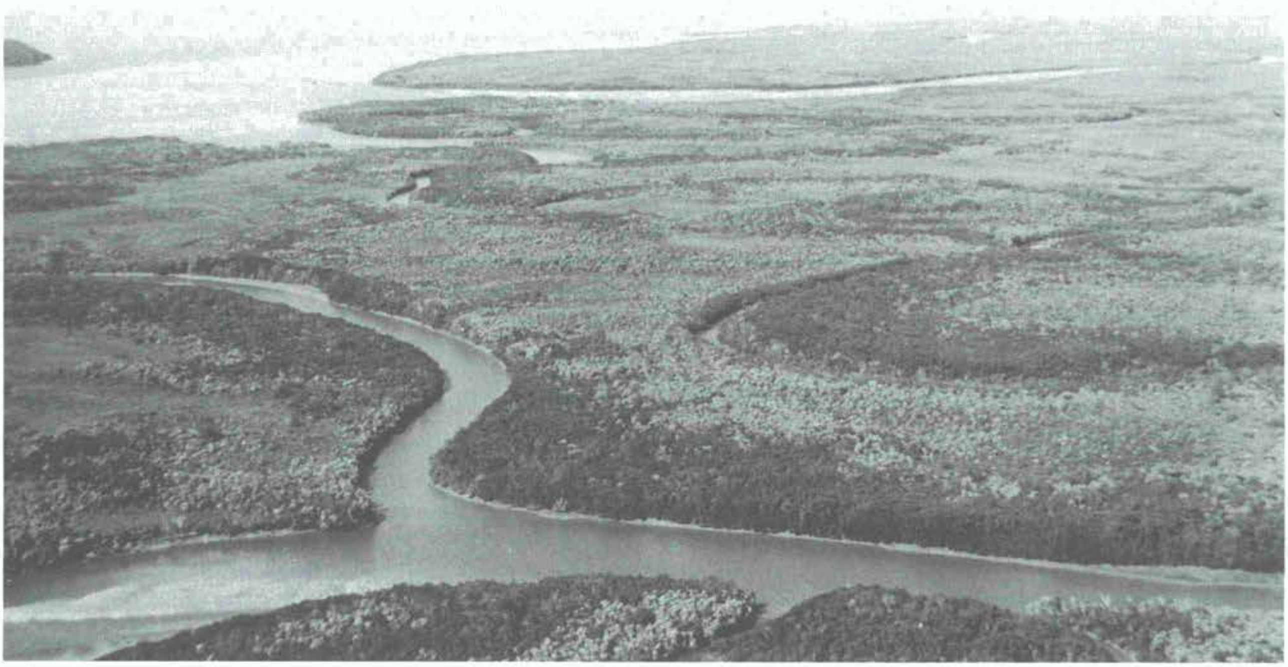


Fig. 32. Most of Australia's best developed pristine mangrove forests are unprotected. Courtesy: Australian Littoral Society/Andrew Elliott.

The diffusion of responsibility for the mangrove resource is further compounded by the responsibility for waste discharges to mangrove areas. In Queensland, the discharge of liquid wastes is controlled by the Water Quality Council, gaseous wastes by the Clean Air Council, solid wastes by the Department of Local Government, and radiological wastes by the State Health Department, each of which have varying permit requirements and are able to make final decisions without necessarily referring to other instrumentalities which may have an interest or to the Queensland Fisheries Service which has the primary responsibility for the mangroves themselves.

It is doubtful whether meaningful policies of natural resource utilization can be devised where the administrative responsibility is so fragmented. A more balanced assessment of alternatives for the utilization of the mangrove resource could be provided by a decision-making unit which had sole responsibility for the mangrove ecosystem. However, administrations are rarely structured on the basis of ecosystems. Mangrove ecosystems suffer more from this division of authority than do most others as their fate is complicated by two sea level lines (extreme low-water mark and extreme high-water mark) which separates the ecosystem into three parts to which different legislation applies, and over which different governments and instrumentalities hold authority. This is a problem for other coastal ecosystems as well, though in Queensland the Beach Protection Act of 1968 has enabled a more environmentally realistic administrative approach to the management of beach areas, which also extend into both marine and terrestrial environments.

7.2.3 Fiji

To the rural indigenous Fijian, land, and all that grows upon it, together with the people who draw their sustenance from that land, are one and indivisible. Adjacent mangrove and coral reef ecosystems are seen as integral components of that land, not as distinct entities conceptually separated from terrestrial ecosystems by an upper tidal water level. This comprehensive, ecologically sensible concept of man/resources interdependence is implicit in a Fijian word, 'vanua'.

In Fiji this enlightened perception of resources persists. However, it is at odds with British tidal law, which has prevailed in Fiji for over one hundred years, and which is based on a perception of coastal resources which developed under the very different social and environmental circumstances of ancient England.

The European colonists saw mangrove areas as 'wastelands', a jaundiced view which may have stemmed at least partly from the physical and mental privations which they suffered in attempting to adapt to life on mangrove-dominated coasts. To some extent this view, which was originally imposed on the people of Fiji, has now been accepted into the thinking of urban populations.

While mangroves have long been appreciated in Fiji as sources of a variety of foods, construction materials, dyes and drugs, twentieth century ideas on natural resource development began to relegate these earlier uses to a position of secondary importance.

With the aid of newly introduced technology and skills, some 2,713 ha of mangroves were reclaimed for sugar cane 72 years ago in Vanua Levu. Elsewhere in Fiji during the first half of this century, mangroves were increasingly used as a source of fuel for domestic and industrial purposes.

From 1933, when all mangroves were constituted Forest Reserves, the Department of Forestry had responsibility for controlling, by licence, cutting for fuel and structural timber. No provision had been made for any customary rights. By the late 1930s there were frequent complaints from Fijians, coupled with requests by District Councils, for village mangrove reserves—particularly for house building materials. The greatest threat was to the limited stands of *Bruguiera gymnorhiza*, the preferred species for firewood.

At least one District Commissioner at this time referred to a decrease in crab populations as being one important cause of the concern expressed about the extent of mangrove cutting permitted by the Department of Forestry. The important link between mangrove trees and the food species associated with them was not appreciated by decision makers of the day. The point was dismissed with scorn.

However, the concept of village mangrove resources as sources of firewood and construction timber was eventually accepted—though not before a number of incidents of physical confrontation between villagers and licensed cutters in the 1940s had lent some urgency to the problem.

Early in the 1940s the system of licensing was overhauled and Divisional Working Plans, based on forest management principles of sustained yield, were prepared as bases for the issuing of licences. Village mangrove reserves were, in effect, established—by not issuing licences for certain areas.

Ironically, having established these Working Plans as a basis for fuel harvests (of several thousand tons of wood each year), industrial fuel demands began to decline markedly in the late 1950s. The availability and convenience of imported fuel oil had brought about the virtual disappearance of the mangrove fuel industry by the early 1960s.

The Forestry Department also administered, for a time, a system of Temporary Occupation Licences (T.O.Ls) which was designed to encourage small-scale reclamation by individual farmers. Few, if any, of these small reclamations succeeded.

In 1955, however, a soil scientist raised the possibility of further large-scale conversions of mangrove areas to agricultural soils. During the 1960s interest in this idea grew, culminating in the initiation of projects at Navakai (1969), Raviravi (1971) and Rakiraki (1972), all of which were established in the context of a forceful reclamation policy outlined in Development Plan Six (1971–1975).

The conflict between a need for expansion of agriculture and the importance of maintaining natural fisheries was expressed in various forms in inter-agency correspondence and in the press during the early 1970s.

In the Raviravi project, some easing of the conflict was obtained by retaining a margin of mangroves seaward of the seawall, a decision which also ensured additional protection for the seawall from storm seas. Within part of this seaward margin, several fishponds were constructed for a Fisheries Department pilot project in fish farming.

A 1971 move to promote discussion and formulation of a rational policy for mangrove areas was turned aside as 'premature'. Nevertheless, differences of opinion over the most effective form of development of the country's mangrove resources continued to surface. While there were strong pressures for further reclamation, with Raviravi a prototype for a series of new agricultural areas, concern about fisheries losses grew—particularly in terms of the impacts of these losses on holders of customary fishing rights.

Late in 1971, the then Ministry of Agriculture, Fisheries and Forests took an important initiative and convened a multidisciplinary meeting of professionals from both the Government and the University of the South Pacific. The objectives were a consideration of the broader view of mangrove resources and their development and, particularly, the initiation of long-term monitoring studies to evaluate the consequences of the Raviravi project. This meeting ended indecisively and no monitoring studies were established (though soil chemistry analyses, a necessary adjunct of the reclamation process, continue). Subsequently, two separate, inconclusive moves were made by Government agencies to obtain the services of a consultant on mangrove resource use.

In 1974 the Government of Fiji took an innovative step with the development of new procedures to compensate for customary fishing rights lost as a consequence of mangrove reclamation. Where customary fishing rights may be affected, a prospective foreshore developer must pay the costs of arbitration to decide any loss of fishing rights and to assess compensation for that loss. Any compensation fixed is invested, and interest from this is paid annually to the community affected. This concept is attractive because it derives from the view that fishing rights are passed on to future generations and that payment should, accordingly, be paid in perpetuity. However, on a per capita basis the annual amount is usually infinitesimal. Compensation is assessed only on present usage of fishing rights, i.e. current harvests, and not on the fisheries potential of the area. The full cost of a foreshore development therefore may be much greater than that which is assessed. This is a cost which is borne by the holders of customary rights and has to be balanced against anticipated community gains from the foreshore development.

Considering the developments of the early 1970s, the pause in large-scale mangrove area destruction, as outlined in Development Plan Seven, was not unexpected. This called for:

"No extensive reclamation of mangroves ... before the completion of a thorough survey of Fiji's mangrove resources provides a basis for fully assessing their value in social, environmental and economic terms...".

This mangrove policy, for which the Lands Department has responsibility, has been adhered to, in spite of some moves to subvert its intentions. However, numerous small-scale impacts, legal and illegal, on mangrove areas continue to diminish their fisheries potential. These impacts result from cutting and from waste disposal, the latter probably generating an as yet almost unrecognised health hazard to consumers of marine foods taken from areas adjacent to rubbish tips or industrial waste outlets.

The final decision on any application for a foreshore development lease to reclaim a mangrove area is made by the Cabinet, representing the collective responsibility of all Ministers.

7.3 A Comparison of Approaches

In an overview of resource allocation decisions, three broad frameworks can be recognised, each with certain strengths and weaknesses. These include:

(1) authority based on a single national body;

(2) authority based on several national or regional bodies; and

(3) the imposition of a transnational body lacking any legislative authority, but having enormous political and financial powers.

Authority based on a single national body

In this decision-making approach, the authority for resource allocation decisions resides in a single national body which is part of, or responsible to, the national government. The decision-making body may be a political body (e.g., the Cabinet in Fiji), or it may be a resource-based body (such as a forestry or fisheries department). The inputs to the decision-making process may be determined by the composition of the body; political bodies are subject to community pressures via the electoral system, and resource-based bodies, while receiving scientific inputs, may be strictly focussed by the charter of that body. For example, if this body is a fisheries department, then the scientific input to a resource allocation decision is likely to be predominantly of a fisheries nature, while a forestry department would generally base such a decision on forestry information.

Authority based on several national or regional bodies

The authority for resource allocation decisions in this approach does not reside in any one body but rather is divided, with various bodies having different, often ill-defined responsibilities towards the resource. This is a common approach in federated states and in those countries based on the British legal system (e.g., Australia, Malaysia, USA).

The decision-making authority may be divided between federal and regional governments and/or between different departments at the same government level. In addition, the ecosystem may be segmented on non-ecological lines, e.g. high- or low-water lines, with different governments or departments exercising authority over these segments.

In this approach, an efficient referral system to link the various bodies is essential; in practice, this is often rendered less efficient by problems of demarcation and by the different attitudes and jurisdictions of the bodies involved.

While this approach is generally less responsive to political inputs (community pressures), it equally dilutes the broad scientific inputs into the decision-making process. Consequently, forward planning of resource allocation is often an inefficient compromise which may be further compounded by problems of the enforcement of decisions actually made.

The intervention of a transnational body

Even where national authorities exist, resource allocation decisions are often influenced and in some cases made by transnational authorities, despite their lack of legislative powers in this field. For example, funds may be made available for specific development projects, generally selected on economic grounds, which take little cognizance of real community needs nor of the ecological consequences of the proposed project. Since national governments are often not in a position to refuse these advances, the decisions of the transnational body are imposed.

The inputs to this decision-making process are largely economic, sometimes paternalistic and, more often than not, they reflect the needs of the transnational body rather than those of the community.

A summary of the respective strengths and weaknesses of the three models is given in Table 9.

Based on these considerations, the most effective administrative view of the mangrove resource appears to be that in which this resource is regarded as a component of the coastal regions. Decisions concerning the use of the mangrove resource could then be made in the context of its dependency on adjacent water catchment land use and on its important interrelationships with estuaries, lagoons and coral reefs.

The legal revisions and administrative rearrangements necessary to permit and encourage such an ecologically foresighted perspective, would in most instances be formidable. However, the consequences flowing from such restructuring—a much closer approximation to optimal natural resource allocation—would make the effort worth while.

TABLE 9. *A comparison of approaches*

Approach	Advantages	Disadvantages
Single national body	Sensitive to community needs Can be ecologically based Allows direct scientific input Reasonably simple decision making, forward planning and enforcement	Can be pressured by minorities May have narrow approach Unwillingness to enforce No objective, built-in system of checks and balances
Several national or regional bodies	Inputs from many directions Development proposals can be stalled in the system	Less sensitive to community pressure Inputs may be diluted Demarcation problems Cumbersome decision making, forward planning and enforcement Ecosystem may be split arbitrarily Split jurisdictions, sometimes overlapping, sometimes conflicting
Transnational body	Availability of international development funds	Little sensitivity to community needs No sensitivity to ecological consequences Motivation largely paternalistic and economic No political responsibility No constituency

8. Recommendations

The mangrove ecosystem plays an important role in fishery production, coastal stabilization, and in the maintenance of critical habitats for many common, threatened and endangered species. Many mangrove areas form parts of international flyways for migratory birds. Mangrove areas provide numerous products of commerce and generate economic opportunities in many countries. Millions of people use products of mangroves and the mangrove environments for subsistence and survival (Fig. 33).

Realising the importance of mangroves, the following recommendations are made to international, regional and national organisations and ministries.

8.1 Data Base Development

International and national planners and researchers have been confronted with problems of data availability. It is very important that a comprehensive data base be developed. Such a data base should include quantitative information on the biological, physical and socio-economic aspects of the mangrove system. Specifically, it should include the area and distribution of mangroves, their flora and fauna, quantification of yields from various uses both actual and potential, and the socio-economic structure of mangrove-dependent human populations.

8.2 Development of National Plans

Each country with mangrove resources is urged to develop a National Mangrove Plan.

Countries which have not yet formed National Mangrove Committees are urged to do so. These committees should assume responsibility for preparing the National Mangrove Plan (see § 6.1).

8.3 Creating Awareness

An extensive programme to create awareness of the value of mangroves and mangrove conservation and utilization among decision makers in different countries should be instituted. All countries

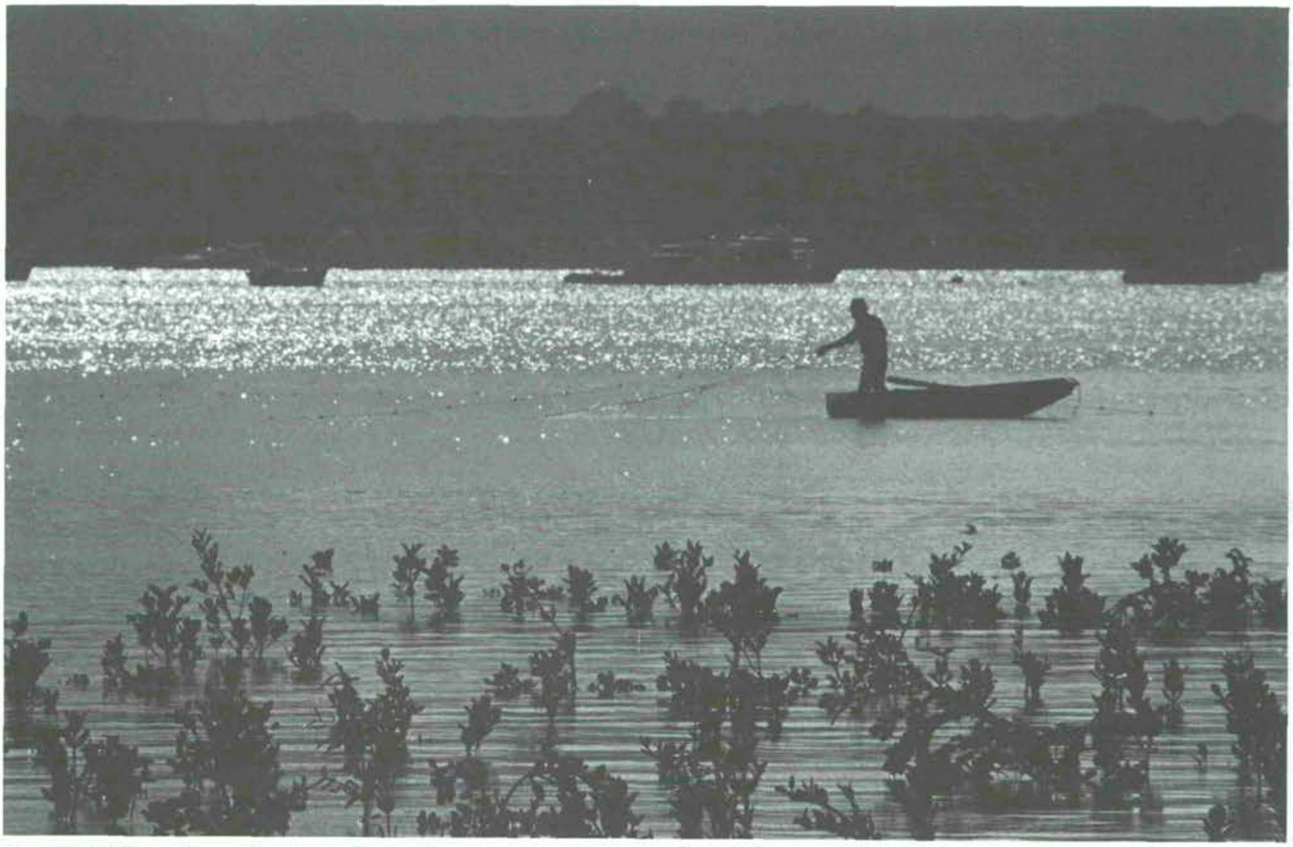


Fig. 33. Millions of people use products of mangrove environments for subsistence and survival.

containing mangroves should take immediate steps to create awareness among local decision makers, programme implementors, and mangrove users about the relevance of mangroves and the short-term and long-term consequences of exploitation, and that such resources should not be allocated for short-term 'quick dollars'.

International development-assistance institutions should consider the full value of mangroves and their hydrological sensitivity relative to direct and indirect impacts resulting from such projects as road and drain construction and irrigation projects.

Guidelines and recommendations aimed at increasing awareness of important, specific groups are listed below.

8.3.1 For government officials granting mangrove logging concessions

– Large-scale clearcutting for woodchips may seem like a desirable foreign exchange earner for what many mistakenly consider a worthless swampland resource. As currently conducted, however, it should be recognized that it is like a *mining operation* rather than a sustained yield process, which it can and ought to be.

– The value of the mangrove ecosystem lies not merely in its useful wood for industry. There are *numerous direct uses* of importance to local people (see § 3.1).

– The value of the mangrove ecosystem may indeed be greatest in terms of its *support for nearshore and estuarine fish, shellfish and crustacean production.* Destructive clearfelling, with its usual consequential degradation or conversion, can spell the end of this support system.

– Concession permits should *require* that *regeneration* of mangroves be obtained by natural or artificial means, with appropriate standards of stocking and composition.

– Concession permit holders should be required to follow a *sustained yield* management system in their extraction and regeneration methods.

See §§ 5.1 and 5.4.

8.3.2 For large-scale commercial wood exploiters

– Large-scale clearcutting presents serious and varied problems in maintaining the area as productive forest. Intensive woodchip operations are particularly prone to problems, and as presently practised constitute a 'mining' of the resource rather than sustained management for future harvests. *This may be your own future resource.*

– Control over the area should not be relinquished when the last tree has been cut and removed. Clearcut areas are very prone to conversion to other uses. *Control should be extended* through the regeneration and establishment phase.

– An adequate density of the appropriate species *must be obtained.* Where natural regeneration is not obtained, planting should be employed.

– The associated primary industry, *fishing, suffers when mangrove ecosystems are disrupted* by clearfelling over large areas in a short time, and suffers drastically when the areas are converted from forest to other uses.

– *Slash management* or disposal may be required in some instances to prevent mechanical damage to the new seedlings or sprouts. *Weeding,* particularly of the mangrove fern, may also be needed in particular cases.

– Within an area set aside for mangrove forestry purposes, *some natural areas should be retained* in order to provide scientific reference sites and genetic reservoirs.

See §§ 5.1 and 5.4.

8.3.3 For water resource development planners

– *The impacts of impoundments or diversions upstream extend all the way to the estuary.* Mangrove ecosystems are likely to be adversely affected or even destroyed by consumptive or diversion uses, or changes in timing of water delivery. These external, offsite costs must enter into any benefit/cost analysis.

– It may be necessary to regularly *release freshwater* from the dam to maintain the mangrove ecosystem downstream.

– Impoundments may increase the salinity and reduce sediment inputs to the lower estuary, and through a reduction of the estuarine surface area, alter tidal currents in the lower estuary; the *effects* of these *must be considered* at the feasibility/planning phase of the project.

– Just as the engineering/construction professions follow strict performance standards in the actual construction, so should planners and design engineers follow *performance standards* to ensure perpetual functioning of affected downstream ecosystems.

See § 5.3.

8.3.4 For road engineers and transportation planners

– The construction of roads through mangrove areas poses many engineering difficulties. If it is not possible to avoid locating roads through these areas, the following essential precautions should be taken to minimise the ecological impacts:

– *Minimize interference with water flow.* Roads and access should whenever possible be *parallel* to surface flow patterns, including tides, and *not perpendicular.* Any unavoidable obstructions to flow should follow natural water divides, when present, or contain culverts with a total flow cross-section sufficient to accommodate *50 year flood levels.* Culverts should be sited as closely as possible to the original major flows.

– Consider *mitigation measures* to compensate for areas lost or adversely affected. If a seed source is available, planting may not be necessary if a suitable physical environment is maintained or created. On the other hand, *planting of embankment margins* would provide not only bank stability but a protection buffer to the exposed inner mangrove system.

– In demucking and/or grouting operations, *waste muck and clays should not be discharged* into adjacent mangrove areas, or otherwise allowed to flow into intertidal or nearshore environments.

8.3.5 For aquaculture pond developers

– Mangrove destruction for aquaculture development may eventually result in *decreased natural* fish and shellfish *production* in estuarine and nearshore areas.

– Consider *maintaining rather than replacing mangroves* with ponds. Floating *cage culture* has proven a viable method.

– *Intensify existing pond culture* wherever possible to reduce demand for conversion of remaining natural mangrove areas.

– Beware of mangrove *areas* which are *not suitable* for aquaculture because of tidal range, land elevation, soils, etc. For instance, acid sulphate soils, which are quite common, require intensive preparation and management if used for fishponds and chances of success are poor.

– If there is a choice, pond development should be made *first in degraded or severely damaged mangroves* before it is made in undisturbed mangrove.

– Always *plant* the outer *banks* of aquaculture ponds *with mangroves* in order to improve bank stability and help compensate for losses to the original area.

– If ponds have to be abandoned, the *bunds should be breeched* to allow renewed natural flushing and mangrove recolonisation.

See § 5.5.2.

8.3.6 For agricultural developers

– Where agricultural developments are a sound conversion, consider the possibility of *leaving some mangrove systems* unconverted in order that they may continue to provide their many uses and services (see § 3.1).

– The *acid sulphate soil problem* has caused the failure of many coastal lowland conversions to rice, coconut and other crops in former mangrove areas. Soil testing and land resource assessment should precede opening up and conversion of mangroves.

– *Intensification* of agricultural activities *on* already *cleared land* may be a more economical, sustainable and desirable option than pushing agriculture onto these saline lands.

– It should be taken into account when planning conversion of mangrove lands that *the effects of agriculture will cross ecosystem boundaries*. Pesticides and fertilizers may find their way into the neighbouring mangroves and cause serious food chain contamination through biological magnification. Acid sulphate soil conditions in converted mangroves may cause fish kills in the adjacent estuary. Similarly, clearing of freshwater and/or peat swamp forests nearby may have deleterious effects on inter-related mangrove ecosystems which are not the targets for alteration.

See § 5.5.1

8.3.7 For developers of housing and estates

– *Minimize interference with water flow*. Roads and access should always be *parallel* to surface flow patterns, including tides, and *not perpendicular*. When perpendicular barriers cannot be avoided, they should either follow natural water divides, when present, or contain culverts with a total flow cross-section sufficient to accommodate *50 year flood levels*.

– *Avoid forcing all* of the *alterations* of the environment *in one forest type* or in an area defined by one particular species. Determine the minimum permissible area and distribute proportionately over all forest types, where possible.

– *Avoid filling areas* to meet minimum grade requirements. Build houses and facilities on stilts, poles and pilings to allow for continued surface water circulation and normal sediment movement.

– There is a high likelihood of conversions creating *habitats favourable to biting insects* (e.g., midges) which have a high nuisance value for residents. *Selective planting of mangroves* and other halophytic plants as part of the new landscape may help to control this problem and may make the development more attractive.

See § 5.6.

8.3.8 For persons engaged in shellfish and fish harvesting

– It is important to realise that the welfare of the fishery may depend on *activities which are taking place on shore and even far inland* where rivers are being 'managed'. The maintenance of the mangrove system must be of concern and resource harvesters should be heard at the planning table where decisions on land and water developments are being made. Concern should be made known to politicians and decision makers.

– Because any *harvesting* means frequent re-entry, be on guard against *cumulative damage* to vegetation or surface structure. The mangrove system is very sensitive to physical disturbance.

See § 5.3.

8.3.9 For tourism promoters

– Mangrove ecosystems are interesting and beautiful, and can be an important part of a tourism resource base. Most of the tourists from developed countries have not encountered mangrove plants and animals, and will respond to different and interesting features. *The tropics and subtropics have three unique major ecosystem formations: rainforests, coral reefs and mangroves.* Capitalize on them.
– Note that the mangrove ecosystem is highly *sensitive to local degradation from intense visitation.* In particular, trampling can lead to erosion and channelling of drainage, and root damage to the plants. Changing the substrate will affect the many colourful crabs and other marine animals found there. Access to mangroves is best achieved along *boardwalks.*
– Any major infrastructure for tourism such as access roads, accommodations and other services may degrade the very resource being used. Refer to guidelines or recommendations for *highways* (§ 8.3.4), and *housing* (§ 8.3.7).
– Because tourists often seek comfort, *access by boat* involves a minimum of hardship and is least destructive. Design routes, timing and choice of boat so as to be least damaging (no speeding and major waves). Where this has been done it has been most successful.
– During bird *nesting seasons temporary curtailment* of human visitation may be necessary.

8.3.10 For urban sanitation officials

– Consider the many direct products/values and indirect services provided by mangroves (see § 3) prior to decisions to create landfills in converting mangrove communities. *These are not unproductive wastelands.*
– Even where waste dumps are established on flat land outside mangroves, but upstream from them, remember that materials *leaching* from urban solid waste dumps *can be toxic* to plant and animal organisms. It is important to remember that containers with chemical wastes gradually deteriorate and leak. This may lead to *serious food chain contamination.* The mangrove ecosystem and the public should be protected from these contaminants.

See §§ 5.9 and 5.10.

8.3.11 For small-scale and subsistence product users

Persons engaged in the small-scale cropping of mangrove products for firewood, charcoal, minor forest products, wildlife and other subsistence products for local use:
– should remember that these uses are sustainable only if they are conducted so as not to damage the physical environment or to exceed the output of the system; and
– should be informed of local endangered species and refrain from exploiting them or disrupting their habitat.

8.3.12 For the mining industry

– Mineral extraction in mangrove areas involving removal of the mangrove overburden (e.g., tin and chromium mining), is, at present, a total destructive conversion of the site. Because of the high natural values of the mangrove ecosystem, the mining industry should explore *techniques of rehabilitation.* The cost of attempting rehabilitation to former productive uses must be included in assessing costs of the mining operations.
– Where surface mining takes place in areas adjacent to mangroves, care should be taken to avoid *direct spoil dumping* onto mangrove lands, *increased sedimentation* in the mangroves from spoil washings, and *interference with the hydrological regime* in the land adjacent to the mangroves.
– Where oil or gas are extracted from under mangroves, the greatest *damage* usually comes from *pipelines and roads.* Unless properly designed and located, these structures alter drainage patterns. Guidelines for road engineers are applicable here (§ 8.3.4). Every precaution should be taken to *minimize the risk of oil leakage* from pipes, tanks and wells because of the risk of damage to plants and animals.

See §§ 5.2 and 5.11.

8.3.13 For port and harbour authorities

– Maintenance dredging spoil should not be dumped in mangroves, tidal marshes or where seagrass beds or reefs are present. Opportunities to utilize dredging spoil to *create new habitats for* expanding the area of *mangroves* should be investigated with the assistance of ecologists.
– *Oil spill contingency planning* should be implemented and should include identification of required containment and clean-up equipment, protocols for co-ordinating spill response activities, and maps which delineate mangroves, saltmarshes, seagrass beds, reefs and other vulnerable habitats.
– If use of dispersant compounds is contemplated for oil spill clean-up, remember that some *dispersants are* themselves *harmful* to flora and fauna.
– *Discharge of ballast, bilge waste and slop tank materials* should not be permitted in the nearshore environment. Shorebased holding tanks and treatment plants should be considered for high traffic ports.

See § 5.8.

8.3.14 For forest managers

– In developing management plans, large-scale clearfelling may result in subsequent conversions of the area to other uses. *Control* over the *area must continue through the regeneration and establishment period.*

– Forest management planning should give *high priority to local needs* for minor forest products and wood supplies. A local 'satisfied' clientele dependent on a continuous flow of products from the forest is more likely to support the forestry agency in resisting ill-planned schemes to convert mangroves to other uses.

– *Planting* can be *minimized* if proper conditions for *natural regeneration* are *maintained.*

– The *effects* of management practices *on other users* (e.g., fisheries) should be considered.

See §§ 5.1 and 5.4.

8.3.15 For international development funding and implementing organisations

– The requirement for *environmental assessment* prior to project approval is applauded. It is important that such assessment be extended to *embrace the whole affected system,* even though the effects may be indirect or geographically far removed. Major upstream water development projects, for instance, affect mangroves and the fauna which they support. These effects are usually adverse, and must be considered as a cost in any *benefit/cost analysis* or environmental impact statement.

– Funding of projects which convert mangroves to agriculture or grazing should be carefully scrutinized to make certain that the new use is sustainable and that the expected *benefits exceed the economic, social and ecological costs* resulting from the loss of the mangrove system and also the attendant reduction of fisheries use and potential.

– Funding of new conversions to aquaculture should be examined in terms of the loss of mangrove-related fisheries. The rehabilitation or better management of existing ponds would be a better investment. *Support* of what has become a *shifting aquaculture is a questionable activity* for funding organisations.

– Provision should be made in projects for *continuous monitoring* of effects during implementation so that plan adjustments can be made. Monitoring should continue after completion so that subsequent similar projects can be more soundly planned, based on what has already been learned.

8.3.16 For educators

– It is suggested that greater attention be given in *lectures* and *educational books* to the subject of mangroves. These are interesting and valuable ecosystems worthy of study and the level of awareness of students should be raised.

– When mangrove areas are used for *field studies* their sensitivity to trampling and the removal of biological specimens should be recognized. If persistent use of an area is contemplated, then *boardwalks* should be constructed to *minimize impact.*

– Opportunities should be sought to provide or participate in *training programmes* for development planners, technologists, engineers and others engaged in land use planning or management, in order to present mangrove ecology and issues of conservation.

– Environmental educators should consider the development of simply and attractively presented *audio and audiovisual materials* to communicate the values of mangrove ecosystems to the general public.

8.3.17 For legislators

– In establishing administrative/management machinery for the mangrove, the unique tidal location of the resource must be recognized. It is both 'of the land' and 'of the water' in its habitat. Few existing institutions and laws reflect this situation. *Comprehensive coastal zone management is required.*

– It should also be recognised that mangroves are at the receiving end of a water catchment, and therefore systems of planning, management and administration must in some way also be concerned with the *whole watershed.*

– The *split in jurisdiction* which often occurs between forestry, conservation and fisheries departments needs to be resolved by close co-ordination at the least (see § 7.3).

– Mechanisms should be provided so that scientific, user and general public input may be heard *during the planning* of any project which affects mangroves.

– Where adequate laws do exist for mangrove conservation, provision should be made for *effective implementation and enforcement.*

8.4 Research Promotion

Lack of information about mangroves, and the need to develop technology for better conservation and utilization necessitates the promotion of relevant research.

An assessment should be made of the long-term consequences of large-scale clearfelling of mangroves for short-term economic exploitation. Until this assessment is made, it is recommended that no additional large-scale clearfelling projects be approved.

The importance of national and international collaboration in research activities should be stressed.

Exchange of information and sharing of expertise on mangrove systems should be strengthened and promoted.

8.5 Sustainable Management

In the conservation and management of the mangrove ecosystem, the resource must be managed on a sustained yield basis, taking into account not only forestry and fishery aspects, but also all other possible aspects of the mangrove and adjacent ecosystems.

Increased efforts should be devoted to finding more suitable ways to utilize the mangroves and the mangrove environment without concommitant loss of their values and services.

8.6 Preservation

With the currently rapid rate of degradation of the mangrove ecosystem due to the destructive activites of man, a number of scientifically important species of flora and fauna are rapidly disappearing. In order to conserve these species, steps should be taken to protect threatened and endangered species through the establishment of suitable reserves.

It is also desirable that adequate areas of unique and representative mangrove communities of scientific interest be allocated as 'Biological Reserves' for research, recreational and educational purposes.

8.7 Education and Training

The number of professional and non-professional staff involved in applied research related to the management of mangrove systems is inadequate. A much larger number of trained people are needed to study and manage mangroves, and the provision of adequate funding to overcome this problem is urgently required.

9. Applied Research Needs

Four broad areas of applied research needs have been identified; these are impact research, socio-economic studies, demand for mangrove products, and evaluation of management policies/programmes. While each area is considered to be important, priorities cannot be set arbitrarily but must reflect the current usages and/or threats to the resource in any particular region. These research needs and their objectives are given below.

9.1 Impact Research

This is a multidisciplinary study that will determine the biological, physical and socio-economic effects of the major uses of mangrove areas. The objectives are to determine:

(a) the inter-relationship between fishing, current forestry practices and other human activities and these resources;

(b) the costs and benefits — both social and economic — of different uses, e.g., fishponds, agriculture, etc.;

(c) alternative aquaculture systems in mangrove areas with minimum alteration of the ecosystem; and

(d) criteria for site selection of mangrove areas for aquaculture development.

9.2 Socio-economic Studies

The objectives would be to analyse:

(a) the social and economic conditions of the human population surrounding mangrove areas;

(b) income, income sources, and income distribution in such village communities;

(c) alternative economic opportunities;

(d) market structure for mangrove products; and

(e) practices/techniques followed in gathering mangrove products.

9.3 Demand for Mangrove Products

Objectives are:

(a) to estimate the quantity demanded for products derived from mangrove areas in the domestic and international markets;

(b) to analyse the trends in quantities supplied and demanded;

(c) to determine trends in prices; and

(d) to analyse factors affecting the demand for such products.

9.4 Evaluation of Mangrove Management Policies/Programmes

Objectives are:

(a) to review policies relevant to utilization, management and conservation of mangrove areas;

(b) to determine the extent of implementation of such policies and programmes; and

(c) to analyse the impact of such policies and programmes on the mangrove-dependent population.

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Dr. Walter Kunhold, FAO/UNEP South China Sea Programme, Metro Manila, Philippines
Mr. Dennis Murphy, Department of Zoology, National University of Singapore, Singapore

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Dr. Paul R. Dingwall, Department of Lands and Survey, Wellington, New Zealand
Dr. I.H. Dost, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands
Mr. Rabesan Dratana, Department of Botany, Tulear, Malagasy
Dr. F. Duhme, Landschaftsökologie Weihenstephan, Tech. Universität, Munich, Federal Republic of Germany
Dr. J. Fontes, I.C.I.T.V., Toulouse, France
Dr. J.A. Gonzalez-Liboy, Department of Natural Resources, San Juan, Puerto Rico
Dr. John Hanks, Director, Institute of Natural Resources, University of Natal, Pietermaritzburg, South Africa
Dr. David C. Hassall, School of Natural Resources, University of the South Pacific, Suva, Fiji
Dr. R. Letouzey, Paris, France
Mr. J. Moverley, Queensland Ornithological Society, Brisbane, Australia
Dr. Carlos E. Lopez Ocana, Centro de Investigaciones de Zonas Aridas, Universidad Nacional Agraria, Lima, Peru
Dr. B.A. Ola-Adams, Forestry Research Institute of Nigeria, Ibadan, Nigeria
Dr. G. Paradis, University of Abidjan, Abidjan, Ivory Coast
Dr. T. Petr, Fishery Resources Officer, Fishery Resources & Environment Division, FAO, Rome
Professor L.J. Pons, Department of Soil Science and Geology, Agricultural University, Wageningen, The Netherlands
Mr. Andrew Price, Coral Reef and Tropical Marine Research Unit, York University, UK
Dr. B. Souleye, Dakar, Senegal
Dr. R. Wilson, Bedale, North Yorkshire, UK
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Bibliography

The Resource

Chapman, V.J. (ed.) (1977) *Ecosystems of the World. I. Wet Coastal Ecosystems,* Elsevier, Amsterdam, 428 pp.

Macnae, W. (1968) A general account of the flora and fauna of mangrove swamps and forests in the Indo-West Pacific Region. *Adv. Mar. Biol., 6,* 73–270.

Watson, J.G. (1928) Mangrove forests of the Malay Peninsula. *Malay Forest Rec.,* Vol. 6, 275 pp. illus.

Source Material for Table 3

Bacon, P. (1968) *The Ecology of Caroni Swamp, Trinidad,* Central Statistical Office, Trinidad, 68 pp.

Boye, M., Baltzer, F., Caratini, C., Hampartzoumian, A., Olivry, J.C., Plaziat, J.C., and Villiers, J.F. (1975) Mangrove of the Wouri estuary, Cameroon. *Proc. Int. Symp. on Biology and Management of Mangroves,* Vol. 2, Inst. Food and Agr. Sci., Univ. of Florida, Gainesville, pp. 431–455.

Cerame-Vivas, M.J. (1974) *Mangroves of Puerto Rico* PFZ Properties Inc., San German, 64 pp.

Cintron, G. and Schaeffer-Novelli, Y. (1980) *Introduccion a la Ecologia del Manglar,* Dept. of Natural Resources, San Juan.

Day, J.H. (1975) The mangrove fauna of Morrumbene estuary, Mozambique. *Proc. Int. Symp. on Biology and Management Mangroves,* Vol. 2, Inst. Food and Agr. Sci., Univ. of Florida, Gainesville, pp. 415–430.

Chou, L.M., Ho, S.H., Khoo, H.W., Lam, T.J., Murphy, D.H. and Tan, W.H. (1980) *Report on the Impact of Pollution on Mangrove Ecosystems in Singapore and Related National Research Programs,* 35 pp., 2 figs., 8 tables, 30 pp. species lists. Discussion paper presented at FAO/UNEP Expert Consultation Meeting on Impact of Pollution on the Mangrove Ecosystem and its Productivity in Southeast Asia, Manila, Philippines, 4–18 February, 1980.

Decraemer, W. and Coomans, A. (1978) Scientific report on the Belgian expedition to the Great Barrier Reef in 1967. Nematodes XII. Ecological notes on the nematode fauna in and around mangroves on Lizard Island. *Aust. J. Mar. Freshwater Res., 29,* 497–508.

Gomez, E.D. (1980) *The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution,* SCS/80/Wp/94, South China Sea Fisheries Development and Coordinating Programme, Manila, Philippines, 102 pp.

Haverschmidt, F. (1965) The utilization of mangroves by South American birds. *The Ibis, 107,* 540–542.

Hegerl, E.J. and Davie, J.D.S. (1977) The mangrove forests of Cairns, northern Australia. *Mar. Res. Indones., 18,* 23–57.

McNeely, J.A. (1977) Mammals of the Thai mangroves. *Tiger Paper, 4,* 10–15.

Milward, N.E. (1979) *The Character of Australian Mangrove Communities Dependent Biota,* 27 pp. Discussion paper presented at the Australian Institute of Marine Science National Mangrove Workshop, Cape Ferguson, Australia, 18–20 April, 1981.

Murphy, D.H. (1981) Insects and public health in the mangrove ecosystem. *Proc. Unesco Reg. Semin. on Human Use of the Mangrove Environment,* Unesco, Paris.

Pena, G.M. (1970) Descripcion de los gasteropodos de los manglares del Peru. *An. Cient., 9* (1–2), 46–55.

Saenger, P., Specht, M.M., Specht, R.L. and Chapman, V.J. (1977) Mangal and coastal salt-marsh communities in Australia. In *Ecosystems of the World. I. West Coastal Ecosystems,* Elsevier, Amsterdam, pp. 293–345.

Saenger, P., Stephenson, W. and Moverley, J. (1979) Fouling organisms of the Calliope River and Auckland Creek, central Queensland. *Mem. Queensl. Mus., 19,* 399–412.

Saenger, P., Stephenson, W. and Moverley, J. (1980) The estuarine macrobenthos of the Calliope River and Auckland Creek, Queensland. *Mem. Queensl. Mus., 20,* 143–161.

Sahavacharin, O., Boonkerd, T. and Patanaponpaiboon, P. (1979) *N° 10,* 51–58.

Stevens, G.N. (1979) Distribution and related ecology of macro lichens on mangroves on the east Australian coast, *Lichenologist, 11,* 293–305.

Value of the Resource

Carlton, J.M. (1974) Land-building and stabilization by mangroves. *Environ. Conservation, 1,* 285–294.

Davis, J.H. (1940) The ecological and geological role of mangroves in Florida. *Publ. Carnegie Inst., 517,* 303–412.

Navalkar, B.S. (1961) Importance of mangroves. *Trop. Ecol., 2,* 89–93.

Rollet, B. (1975) Les utilisations de la mangrove. *J. Agric. Trop. Bot. Appl.,* 7–9.

Rollet, B. (1975) Les utilisations de la mangrove. Les usages forestiers. *J. Agric. Trop. Bot. Appl.,* 10–12.

Sattar, A. (1979) Opening address by the Vice-President of the People's Republic of Bangladesh. In *The Mangrove Ecosystem: Human Uses and Management Implications,* Unesco, Paris, pp. 15–16.

Snedaker, S.C. and Lugo, A.E. (1973) *The Role of Mangrove Ecosystems in the Maintenance of Environmental Quality and a High Productivity of Desirable Fishes,* Bur. Sports Fisheries and Wildlife, Washington, DC, 381 pp.

Wallace, J.H. and vander Elst, R. (1975) *The Estuarine Fishes of the East Coast of South Africa,* Investigational Report N° 42, Oceanographic Research Institute, Durban.

Factors Which Maintain Ecological Processes

Clarke, L.D. and Hannon, N.J. (1967) The mangrove swamp and saltmarsh communities of the Sydney dis-

trict. I. Vegetation, soils and climate. *J. Ecol., 55*, 753–771.
Clarke, L.D. and Hannon, N.J. (1969) The mangrove swamp and saltmarsh communities of the Sydney district. II. The holocoenotic complex with particular reference to physiography. *J. Ecol., 57*, 213–234.
Clarke, L.D. and Hannon, N.J. (1970) The mangrove swamp and saltmarsh communities of the Sydney district. III. Plant growth in relation to salinity and waterlogging. *J. Ecol., 58*, 351–369.
Clarke, L.D. and Hannon, N.J. (1971) The mangrove swamp and saltmarsh communities of the Sydney district. IV. The significance of species interaction. *J. Ecol., 59*, 535–553.
Clough, B.F., Andrews, T.J. and Cowan, I.R. (1982) Physiological processes in mangroves. In B.F. Clough (ed.), *Mangrove Ecosystems in Australia – Structure, Function and Management*, Australian Institute of Marine Science, Cape Ferguson, pp. 193–210.
Lugo, A.E. and Snedaker, S.C. (1974) The ecology of mangroves. *Ann. Rev. Ecol. Syst., 5*, 39–64.
Odum, W.E. (1971) Pathways of energy flow in a south Florida estuary. *Univ. Miami Sea Grant Tech. Bull., 7*, 1–162.
Odum, W.E. and Heald, E.J. (1972) Trophic analysis of an estuarine mangrove community. *Bull. Mar. Sci., 22*, 671–738.
Odum, W.E. and Heald, E.J. (1975) The detritus based mangrove community. In *Estuarine Research*, Vol. 1, Academic Press, New York.
Saenger, P. (1982) Morphological, anatomical and reproductive adaptations in Australian mangroves. In B.F. Clough (ed.), *Mangrove Ecosystems in Australia – Structure, Function and Management*, Australian Institute of Marine Science, Cape Ferguson, pp. 153–192.

Causes and Consequences of Mangrove Destruction

Blasco, F. (1977) Outlines of ecology, botany and forestry of the mangals of the Indian subcontinent. In V.J. Chapman (ed.), *Wet Coastal Ecosystems*, Elsevier, Amsterdam, pp. 241–260.
Breen, C.M. and Hill, B.J. (1969) A mass mortality of mangroves in Kosi estuary. *Trans. R. Soc. S. Afr., 38*, 285–303.
Christensen, B. (1979) Industrial uses of mangroves. *Forest News for Asia and the Pacific, 3*, 70–72.
Hegerl, E.J. (1975) The effects of flooding on Brisbane River mangroves. *Operculum, 4*, 156–157.
Hegerl, E.J. (1982) Mangrove management in Australia. In B.F. Clough (ed.), *Mangrove Ecosystems in Australia – Structure, Function and Management*, Australian Institute of Marine Science, Cape Ferguson, pp. 275–288.
Hutchings, P.A. and Recher, H.F. (1977) The management of mangroves in an urban situation. *Mar. Res. Indones, 18*, 1–11.
Lindall, W.N. (1974) Alterations of estuaries of south Florida: a threat to its fish resources. *Operculum, 4* (2), 63–69.
Pannier, F. (1979) Mangroves impacted by human-induced disturbances: a case study of the Orinoco delta mangrove ecosystem. *Environ. Management, 3* (3), 205–216.
Sasekumar, A. (1978) The value of the mangrove ecosystem and its pollution problems. In *Fifth Workshop on Aquatic Pollution in Relation to Protection of Living Resources, 17 Jan.–27 Feb., 1977, Manila, Philippines*, FAO/SIDA, Rome, Suppl. 1, pp. 332–342

Management of the Resource

Australian Littoral Society (1978) *An Investigation of Management Options for Towra Point, Botany Bay*, Australian National Parks and Wildlife Service, Canberra, 396 pp., 46 pp. appendices, 72 figs.
Australian Marine Sciences Association (1978) *Guidelines for the Protection and Management of Estuaries and Estuarine Wetlands*, A.M.S.A., Sydney, 12 pp.
Forest Division, Trinidad and Tobago (1979) *Management and Development Plan: Caroni Swamp National Park*, Forest Division, Port of Spain, 54 pp., maps.
Huberman, M.A. (1957) Mangrove silviculture. *Trop. Silvicult., 13*, 188–195.
Lugo, A.E. and Cintron, G. (1975) The mangrove forests of Puerto Rico and their management. *Proc. Int. Symp. on Biology and Management of Mangroves*, Vol. 2, Inst. Food and Agr. Sci., Univ. of Florida, Gainesville, pp. 825–846.
Macnae, W. (1974) *Mangrove Forest and Fisheries*, FAO, Rome, 35 pp.
Martosubroto, P. and Naamin, N. (1977) Relationships between tidal forests (mangroves) and commercial shrimp production in Indonesia. *Mar. Res. Indones., 18*, 81–86.
Noakes, D.S.P. (1952) *A Working Plan for the Matang Mangrove Forest Reserve Perak*, Forest Dept., Kuala Lumpur, 173 pp., map.
Pannier, F. (1974) Uso y proteccion de nuestros manglares. *Lineas, 207*, 22–25.
Rabanal, H.R. (1977) Forest conservation and aquaculture development of mangrove areas. *Proc. Int. Workshop on Mangrove and Estuarine Area Development for Indo-Pacific Region*, pp. 145–148.
Snedaker, S.C. (1978) Mangroves: their value and perpetuation. *Nat. Resour., 14* (3), 6–13.
Teas, H.J. (1979) Silviculture with saline water. In *Biosaline Concept*, Plenum Press, New York, pp. 117–161.
Turner, R.E. (1977) Intertidal vegetation and commercial yields of Penaeid shrimp. *Trans. Am. Fish Soc., 106* (5), 411–416.
Womersley, J.S. (1975) Management of mangrove forests: utilization versus conservation with special reference to the forests of the Papuan Gulf. *Proc. Int. Symp. on Biology and Management of Mangroves*, Vol. 2, Inst. Food and Agr. Sci., Univ. of Florida, Gainesville, pp. 732–741.

Legislation and Administration

Baines, G.B.K. (1975) Patterns of exploitation of mangrove ecosystems. *Proc. Int. Symp. on Biology and Management of Mangroves*, Vol. 2, Inst. Food and Agr. Sci., Univ. of Florida, Gainesville, pp. 742–752.

Appendix 1

Types of mangrove ecosystem reserves

Key – no reserves have been established in this country to date. X at least one mangrove reserve established for this purpose in this country. * including National Parks.

	Flora	Wildlife (i.e. fauna)	Nature (i.e. flora & fauna)*	Forestry (timber)	Fisheries	Scientific	Historic	Recreational
Oceania								
Australia			X		X			X
Papua New Guinea								
Solomon Islands								
Fiji								
New Caledonia								
New Zealand			X				X	
Asia								
Pakistan	X	X		X				
India	X	X	X	X	X			
Sri Lanka		X	X	X	X			
Bangladesh		X	X	X	X			
Burma				X				
Thailand	X	X	X	X	X			
Malaysia	X	X	X	X				
Singapore	–	–	–	–	–	–	–	–
Indonesia	X	X	X	X	X			
Brunei								
Kampuchea								
Vietnam								
Taiwan		X	X		X			
Hong Kong								
China								
Japan	X	X	X					
Philippines	X	X	X	X	X			
Africa & Middle East								
Mauritania								
Senegal	X	X	X	X				
Gambia								
Guinea Bissau								
Guinea								
Sierra Leone								
Africa & Middle East (continued)								
Liberia								
Ivory Coast		X						
Ghana								
Togo								
Benin								
Nigeria				X				
Cameroon	–	–	–	–	–	–	–	–
Sao Tome								
Equatorial Guinea								
Gabon								
Congo								
Zaire								
Angola								
Namibia								
South Africa		X						
Mozambique			X			X		
Seychelles			X					
Comoro Islands								
Malagasy								
Mauritius								
Tanzania								
Kenya								
Somalia								
Ethiopia								
Sudan								
Egypt								
Israel		X						
Saudi Arabia								
Yemen								
South Yemen								
Oman								

(continued overleaf)

Appendix 1 (continued)

The Americas & The Caribbean

	Flora	Wildlife (i.e. fauna)	Nature (i.e. flora & fauna)*	Forestry (timber)	Fisheries	Scientific	Historic	Recreational
United States		X	X		X			X
Mexico		X	X		X			
Guatemala								
Belize		X			X			
El Salvador								
Honduras	–	–	–	–	–	–	–	–
Nicaragua								
Costa Rica		X	X					
Panama								
Colombia		X	X	X	X			
Ecuador			X		X			
Galapagos Islands								
Peru			X		X			
Brazil		X	X	X	X	X		
French Guiana		X						
Surinam								
Guyana								

The Americas & The Caribbean (continued)

	Flora	Wildlife (i.e. fauna)	Nature (i.e. flora & fauna)*	Forestry (timber)	Fisheries	Scientific	Historic	Recreational
Venezuela			X	X				
Curaçao			X					
Trinidad & Tobago		X	X	X	X			
Cuba								
Cayman Islands	–	–	–	–	–	–	–	–
Jamaica			X		X			
Haiti								
Dominican Republic			X		X			
Bahamas		X	X		X			
Puerto Rico	X	X	X	X				
Virgin Islands								
Guadeloupe			X					
Martinique								
Montserrat		X						
Barbados	–	–	–	–	–	–	–	–
Bermuda		X						

Appendix 2

Details of some mangrove ecosystem conservation reserves

Country	Name of Reserve	Purpose	Location	Features or species of particular interest	Year Est.	Total area of man-groves (ha)	Total area of Reserve (ha)	Administering Agency
Australia (in New South Wales)	Towra Point	Nature conservation, particularly protection of major stopover point for migratory bird species	34°S, 151° 20′E Sydney, New South Wales	176 species of birds including 30 species of trans-equatorial migrants and 59 species covered by International Wetlands Convention. Contains largest remaining saltmarsh in Sydney region	1975	142	291	New South Wales National Parks & Wildlife Service with Aust. National Parks & Wildlife Service in advisory role
Australia (in Northern Territory)	Kakadu National Park	Protect flora and fauna, scenic attractions, and aboriginal culture and artifacts	12° 06′S, 132° 33′E Northern Territory	Provides significant protection to major wetlands system—East Alligator River and its tributaries. Provides major saltwater crocodile *(Crocodylus porosus)* reserve	1979	~1,000	614,400	Australian National Parks & Wildlife Service
Australia (in Queensland)	Nipa Palms National Park	Protection of Australia's southernmost stand of *Nypa fruticans*	18° 32′S, 146° 16′E	*Nypa fruticans*			340	Queensland National Parks & Wildlife Service
	Habitat Reserve (H.R.) No. 1—Myora	Protect area of importance to fisheries	27° 29′S 153° 25′E	Areas of *Avicennia marina* and extensive seagrass beds	1969		480	Queensland Fisheries Service
	H.R. 2—Hay's Inlet	Protect area of importance to fisheries	27° 15′S 153° 02′E		1969		950	Queensland Fisheries Service
	H.R. 3—Kippa Ring	Protect area of importance to fisheries	27° 12′S 153° 02′E	Important wading bird habitat	1969		730	Queensland Fisheries Service
	H.R. 4—Deception Bay	Protect area of importance to fisheries	27° 11′S 153° 04′E	Mangrove forest and adjacent tidal flats of considerable value as fish, crab and prawn nursery	1969		1,200	Queensland Fisheries Service
	H.R. 5—Jumpinpin	Protect area of importance to fisheries	27° 45′S 153° 25′E	Estuarine complex with deltaic mangrove islands	1969		4,650	Queensland Fisheries Service

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Appendix 2 (continued)

Country	Name of Reserve	Purpose	Location	Features or species of particular interest	Year Est.	Total area of man-groves (ha)	Total area of Reserve (ha)	Administering Agency
	H.R. 6—Pumicestone Passage	Protect area of importance to fisheries	26° 59′S 153° 02′E	Includes forest of *Bruguiera gymnorhiza* near its southern distribution limit	1969		2,670	Queensland Fisheries Service
	H.R. 7—Moreton Banks	Protect area of importance to fisheries	27° 19′S 153° 21′E	Offshore mangrove island and extensive seagrass beds. Important to dugong	1969		4,460	Queensland Fisheries Service
	H.R. 8—Peel Island	Protect area of importance to fisheries	27° 30′S 153° 20′E	Fringing mangroves and adjacent coral reef	1971		1,180	Queensland Fisheries Service
	H.R. 9—Lucinda	Protect area of importance to fisheries	18° 30′S 146° 10′E	Estuarine complex with deltaic mangrove islands	1971		21,000	Queensland Fisheries Service
	H.R. 10—Tallebudgera Creek	Protect area of importance to fisheries	28° 07′S 153° 27′E	Mangroves and tidal flats in lower reaches of creek	1971		16	Queensland Fisheries Service
	H.R. 11—Tipplers	Protect area of importance to fisheries	27° 47′S 153° 25′E	Extensive area of *Ceriops tagal* near its southern distribution limit	1971		790	Queensland Fisheries Service
	H.R. 12—Couran	Protect area of importance to fisheries	27° 50′S 153° 24′E	Includes several mangrove islands and banks rich in benthic fauna	1971		390	Queensland Fisheries Service
	H.R. 13—Broadwater	Protect area of importance to fisheries	27° 54′S 153° 25′E	Mangrove islands, seagrass beds and tidal flats	1971	~100	490	Queensland Fisheries Service
	H.R. 14—Halfmoon Creek	Protect area of importance to fisheries			1974		190	Queensland Fisheries Service
	H.R. 15—Yorkey's Creek	Protect area of importance to fisheries			1974		25	Queensland Fisheries Service
	H.R. 16—Barr Creek	Protect area of importance to fisheries	16° 03′S 145° 44′E	Mainly mangrove forest	1974		500	Queensland Fisheries Service
	H.R. 17—Corio Bay	Protect area of importance to fisheries	22° 55′S 150° 44′E	Extensive estuarine landscape of mangroves and sandflats	1974		4,000	Queensland Fisheries Service
	H.R. 18—Lake Cootharaba	Protect area of importance to fisheries			1974		4,000	Queensland Fisheries Service
	H.R. 19—Lake Weyba	Protect area of importance to fisheries			1974		600	Queensland Fisheries Service

Appendix 2 (continued)

Country	Name of Reserve	Purpose	Location	Features or species of particular interest	Year Est.	Total area of man-groves (ha)	Total area of Reserve (ha)	Administering Agency
	H.R. 20—Maroochy River	Protect area of importance to fisheries		Riverine landscape and mangroves in middle reaches of Maroochy River	1974			Queensland Fisheries Service
	H.R. 21—Hervey Bay	Protect area of importance to fisheries	25° 30′S 153°E	Extensive mangrove islands and muddy shoals. Contains dugong	1976		38,000	Queensland Fisheries Service
	H.R. 22—Tin Can Bay	Protect area of importance to fisheries	25° 50′S 153°E	Extensive seagrass beds and tidal flats fringed by mangroves	1976		6,400	Queensland Fisheries Service
	H.R. 23—Tin Can Bay	Protect area of importance to fisheries	25° 56′S 153° 01′E				1,200	Queensland Fisheries Service
Bangladesh	Sundarbans East Wildlife Sanctuary	Protect Bengal tiger and other wildlife					5,436	
	Sundarbans South Wildlife Sanctuary	Protect Bengal tiger and other wildlife					17,863	
	Sundarbans West Wildlife Sanctuary	Protect Bengal tiger and other wildlife					9,061	
Brazil	Parque Estadual da Ihla do Cardoso	Natural reserve	Estado de São Paulo, Brazil	Contains mangroves	1962			São Paulo Government
	Parque Estadual da Serra do Tabuleiro	Protect mangroves and estuarine nursery area	Estado de Santa Catarina	Contains mangroves, lagoons and dunes	1977			SEMA
Colombia	Parque Nacional Tayrona	Protection of natural ecosystems and genetic resources	Municipio de Santa Marta Dpto de Magdalena	Contains *Rhizophora* fringe forests			11,600	
Costa Rica	Parque Nacional Corcovado	Protection of natural ecosystems	Osa Peninsula, Pacific Coast	Contains well-developed mangrove stands	1975–1976		36,000	Servicio de Parques Nacionales Ministerio de Agricultura y Ganaderia
	Parque Nacional Cahuita	Protection of natural ecosystems	Provincia de Limon, Atlantic Coast	Contains small red mangrove forest	1970		1,100	Servicio de Parques Nacionales Ministerio de Agricultura y Ganaderia
	Parque Nacional	Protection of green turtle	Provincia de Limon,	Contains halophytic	1975		21,000	Servicio de Parques

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Appendix 2 (continued)

Country	Name of Reserve	Purpose	Location	Features or species of particular interest	Year Est.	Total area of mangroves (ha)	Total area of Reserve (ha)	Administering Agency
	Tortuguero	nesting sites	Atlantic Coast	vegetation				Nacionales Ministerio de Agricultura y Ganaderia
Dominican Republic	Parque Nacional del Este	Natural reserve		Mangroves, seagrass beds and coral reefs	1975	533	43,400	Instituto Nacional de Parques
Malaysia	Sg. Miang Forest Res., Pahang Virgin Jungle Res. No. 14	Protect mature mangrove forest area	3° 30′N, 103° 20′E Eastern Peninsular Malaysia	30–40 year old *Rhizophora apiculata* forest with some *Bruguiera parviflora* understorey	1969?			Forestry Department
	Pulau Kecil Forest Res., Perak Virgin Jungle Res. No. 21	Protect mature mangrove forest sample plot	4° 50′N, 100° 35′E Western Peninsular Malaysia	27–30 m *Rhizophora* forest	1969	33	33	Forestry Department
Malaysia (Sabah)	Pulau Tiga National Park	Protect area of coastal forests, corals and hot mud volcanoes	6°N, 116°E north of Labuan Island	Some mangroves present	1978	?	15,870	Sabah National Parks Authority
	Klais National Park	Mangrove reserve adjacent to major prawn fishery	5°N, 116°E Brunei Bay, Sabah	Mainly mangroves	1978		39,230	Sabah National Parks Authority
Malaysia (Sarawak)	Bako National Park	General national park	Near Kuching, Sarawak	Portion of park is mangroves	?	?	2,720	Forestry Department
Mozambique	Ilha de Inhoca	Nature reserve and scientific study area	25° 58′S 32° 53′E	Mangroves, seagrass beds and coral reefs	1965	~620	~2,400	Instituto de Investigacao Cientifica de Mocambique
New Zealand	Waitangi National Reserve	Historic area	Bay of Islands, North Auckland	280 m long boardwalk to provide public access for educational and interpretative use	1932	82		National Trust Board
	Tauhoa Nature Reserve	Nature reserve	Kaipara Harbour, North Auckland	Reserve contains both *Avicennia marina* and saltmarsh communities	1948	300	301.5	Dept. of Lands & Surveys
Papua New Guinea (Bismarck Archipelago)	Talele Island Provincial Park, East New Britain			Eight islands of 2–40 ha with mangrove, beach forest, coral reefs, seabird and turtle nesting areas				

Appendix 2 (continued)

Country	Name of Reserve	Purpose	Location	Features or species of particular interest	Year Est.	Total area of man-groves (ha)	Total area of Reserve (ha)	Administering Agency
	Lake Dakataua National Park, New Britain			Crater lake, hot springs, mangrove, secondary rainforest, crocodiles, megapede				
Puerto Rico	Ceiba Natural Reserve	Natural reserve	Eastern Puerto Rico	Contains mangroves	1979	140	143	Dept. of Natural Resources
	Boqueron Natural Reserve	Natural reserve	Western Puerto Rico	Contains mangroves	1979	714	802	Dept. of Natural Resources
	Pinones Natural Reserve	Natural reserve	North coast of Puerto Rico	Important coastal lagoons and mangroves	1979	581	613	Dept. of Natural Resources
	Joyuda Natural Reserve	Natural reserve	West coast of Puerto Rico	Coastal lagoon containing mangroves	1980	48	163	Dept. of Natural Resources
	Parguera Natural Reserve	Natural reserve	South west Puerto Rico	Offshore keys and mangrove islets	1979			Dept. of Natural Resources
South Africa	Kosi Bay						33	
	St. Lucia						12	
	Mlalazi						10	
	Richards Bay						40	
	Umgeni (Beachwood)						12	
Taiwan	Tan-sui Mangrove Reserve	Education and recreational value; just outside Taipei, in high population density area	25° 09′N 121° 26′E	One species only, *Kandelia candal.* Rookery of egrets and herons. Chinese egret (rare, listed in Red Data book) found here. Used by migrating shorebirds and waterfowl	1981	65	65	Ministry of Economic Affairs, Dept. of Agriculture & Forestry
Tonga	Fanga'uta and Fangakakau Lagoons		Centre of Tongatapu	Shallow, nearly enclosed lagoon with mangroves and important fish breeding areas			2,830	
Trinidad & Tobago	Caroni Swamp Forest Reserve		Near Port-of-Spain	Important recreational area within easy reach of 75% of population of country. Important tourist attraction	1936	Mostly man-groves	2,997	Forestry Div., Ministry of Agriculture, Lands & Fisheries

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Appendix 2 (continued)

Country	Name of Reserve	Purpose	Location	Features or species of particular interest	Year Est.	Total area of mangroves (ha)	Total area of Reserve (ha)	Administering Agency
	Caroni Swamp Wildlife Sanctuary	Wildlife sanctuary mainly for Scarlet Ibis	Near Port-of-Spain	Caroni Swamp is only habitat in country for scarlet ibis	1953 exten. 1954, 1959, 1960, 1966	Mostly man-groves	200	Forestry Div., Ministry of Agriculture, Lands & Fisheries
United States	Everglades National Park	Nature conservation	Southern Florida	American alligator and crocodile. Extensive *Rhizophora mangle* and *Avicennia germinans* forests. Important bird rookery	1947	100,000	500,000	US National Parks Service
Venezuela	Parque Nacional de Morrocoy	Protect mangroves, wildlife and fisheries, and provide recreation and education. Important tourist attraction	10° 47′11″N–10° 59′27″N, 68° 09′30″W–68° 22′35″W	Mainly mangroves with associated coral reefs and seagrass beds (*Thalassia testudinum*). Very rich birdlife and fish fauna	1974	4,580	32,090	Instituto Nacional de Parques, Ministerio del Ambiente
	Parque Nacional Laguna de La Restinga	Protect mangroves, wildlife and fisheries, and provides for recreation and education	10° 05′22″N–10° 58′15″N, 64° 01′32″W–64° 17′09″W	Coastal lagoon with mainly mangrove vegetation. Permanent habitat of the red ibis, *Eudocimus ruber*	1974	1,380	10,700	Instituto Nacional de Parques, Ministerio del Ambiente
	Monumento Natural Laguna de Las Marites	Protect mangroves, wildlife and fisheries, and provides for recreation and education	10° 53′10″N–10° 56′47″N, 63° 53′07″W–63° 58′30″W	Mainly mangrove vegetation. Rich birdlife	1974	2,360	3,674	Instituto Nacional de Parques, Ministerio del Ambiente
	Parque Nacional Laguna de Tacarigua	Protect mangroves, wildlife and fisheries, and provides for recreation and education	10° 11′35″N–10° 20′28″N, 65° 41′22″W–65° 57′12″W	Important coastal lagoon. Rich fish nursery and abundant birdlife	1974	3,060	18,400	Instituto Nacional de Parques, Ministerio del Ambiente

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