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THE VALUE OF THE MANGROVE ECOSYSTEM AND ITS POLLUTION PROBLEMS

by

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1. INTRODUCTION

Among the many environmental degradation problems facing the world today is man's interference of the coastal zone. This impact has resulted in the pollution and contamination of the coastal waters, and the critical modification of the coastal ecosystems. With the advent of industrialization mangrove coastlines too have come under increasing pressure for development. To accommodate landless people government authorities are reclaiming mangrove land. Extensive areas of mangrove forests are being reclaimed at an unprecedented rate in many parts of South East Asia, with complete disregard of its actual value to the coastal living resources. In other areas mangrove forests have been partially destroyed or subjected to pollution. The purpose of this review is to examine the value of the mangrove ecosystem to mankind, and discuss some of the pollution problems affecting this ecosystem.

2. IMPORTANCE OF MANGROVE ECOSYSTEMS TO MAN

2.1 Mangroves

Mangroves are trees or bushes growing in the intertidal zone of sheltered tropical and subtropical shores. Mangrove communities colonize about a quarter of the world's tropical shorelines.

Mangrove swamps are almost always erroneously regarded as wasteland believed to be infested with snakes and other vicious creatures, and newspapers have propagated curious stories about mangrove swamps. One told of three hundred homes blackened and two men killed by mangrove root gas (Lugo and Snedaker, 1974). Some regarded mangroves as 'freaks' and even government authorities in developed countries regarded mangrove land as wasteland.

2.2 Timber Products

Mangrove forests have many good uses. The wood is good fuel as charcoal or firewood and charcoal production is carried out extensively in South-East Asia. In peninsular Malaysia, the Matang mangrove forests are harvested in rotation once every 30 years since 1900, so that a continuous supply of timber is assured. Mangrove timber is extensively used in house construction, particularly in coastal towns and villages. In the Philippines, Rhizophora is used in the manufacture of synthetic fabrics and, more recently, extensive areas of mangrove forests in Sabah, Malaysia, have been harvested for wood chips which are exported to Japan (Liew et al., 1975). The annual exploitation of between 2 000 - 4 000 hectares of mangrove forests is viewed with concern because of the limited availability of the resource and the 30-year period necessary for regeneration.

Apart from these major uses, mangrove leaves are used as livestock feed and for various medicinal purposes while mangrove bark is a commercial source of tannin used in the tanning of leather and preservation of fish nets.

2.3 Exploitation of Mangrove Land

In many parts of South-East Asia mangrove land has been reclaimed for agriculture, especially in the major deltas of continental Asia (Moormann and Pons, 1974). The pioneer crop in these areas is rice which, being an aquatic crop, requires temporary waterlogged conditions. Rice cultivation is successful, provided salinity can be suppressed during the growing season by adequate drainage. In peninsular Malaysia rice cultivation on reclaimed mangrove land has been unsuccessful due to the development of acid sulphate soils. Pyrites (FeS_2) are formed in the soil where the amount of carbonates ($CaCO_3$) is too little to neutralize the acidity that is released upon oxidation of pyrites during reclamation. Mangrove soils in peninsular Malaysia contain more than 2 percent pyrites and no carbonates; thus, acidity occurs after reclamation as exemplified in the Merbok estuary and Batu Pahat (Diemont and van Wijngaarden, 1975).

One crop which has been successful in reclaimed mangrove land is coconut. Here, sea water is prevented from flowing in by bunds or dykes. Coconut is planted after the land has been left fallow for a number of years so rendering the soil less acidic.

The major constraints in the development of mangrove soils for agriculture are salinity, acidity, toxicity and other limiting factors. Thus, from a technical and financial point of view, large-scale reclamation of mangrove land for agriculture is not recommended (Moormann and Pons, 1974).

2.4 Aquaculture

In many parts of South-East Asia, particularly in Java, southern Sumatra, the Philippines, Taiwan and Singapore, the culture of fish and prawns is practised in ponds dug out of cleared mangrove forests (Macnae, 1968). Fish fry and prawn larvae are introduced or allowed to enter the ponds at high tide through sluice gates. The annual production of milkfish (Chanos chanos) may be as high as 338 kg/hectare. Prawn ponds in Singapore have recorded maximum annual yields of 1 200 kg/ha. Usually, yields are much lower.

2.5 Mangrove-dependent Fisheries

A most important function of the mangrove ecosystem is to provide food and shelter for an infinite variety of coastal fishes and shellfish. The pathways by which energy derived from the mangrove ecosystem supports coastal and estuarine fisheries has been worked out in detail by Heald and Odum (1969) for the Florida coast. They showed that 95% of the leaf material from the mangrove Rhizophora mangle enters the coastal waters. Leaves fall or get washed into the shallow waters at an annual rate of 9 metric tons per hectare (or 2.5 grams per m^2 per day). This leaf detritus becomes dispersed by tidal and coastal currents over large areas of estuaries and shallow coastal regions.

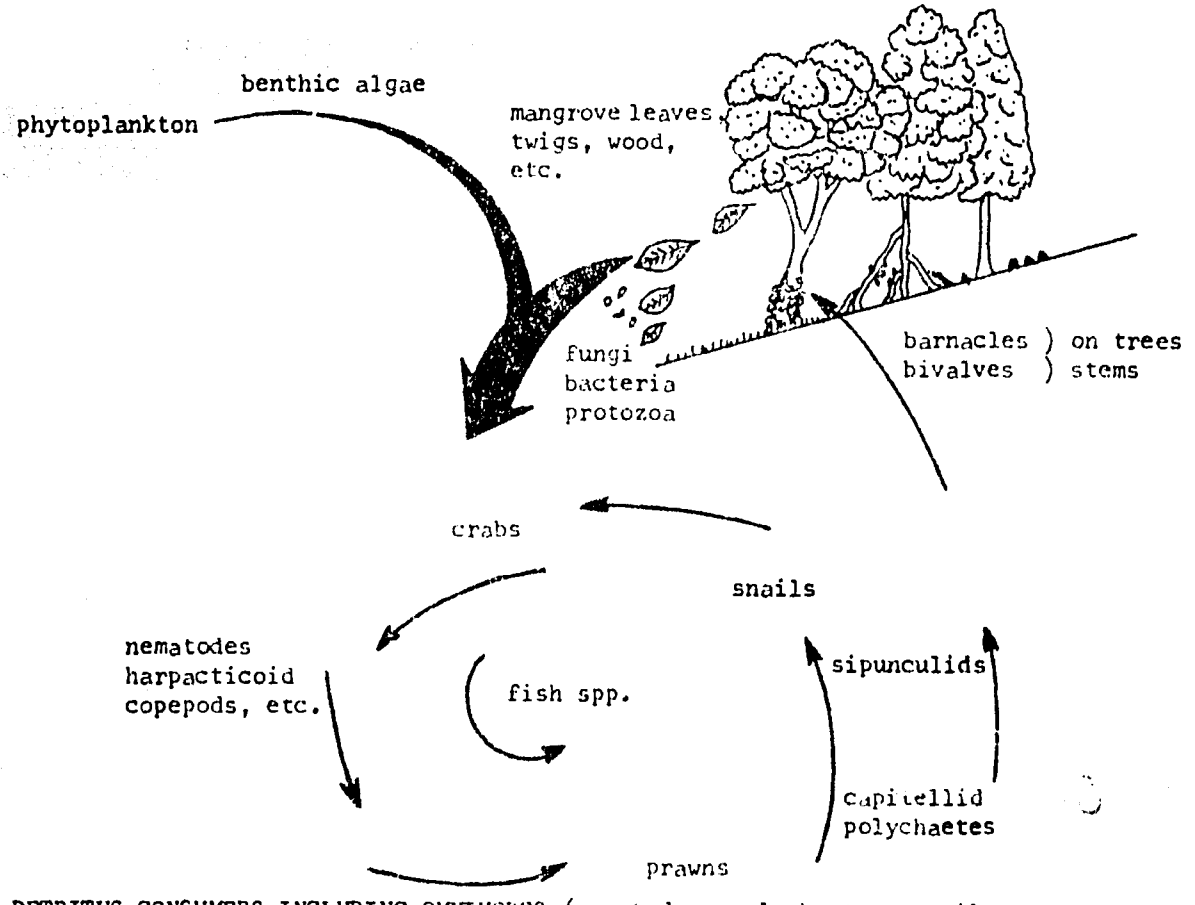
The first link in the food web is provided by bacteria and fungi which convert the indigestible lignin and cellulose of mangrove plant tissue into a protein source which can be digested by the organisms of the second link in the food web. This link is composed of omnivorous crustaceans such as amphipods, mysids, harpacticoid copepods, caridean and penaeid prawns and few omnivorous and detritivorous fishes. All these animals ingest varying quantities of detritus particles which are covered by digestible micro-organisms. While passing through the digestive tract, these particles are mechanically broken down into smaller fragments and partially removed of the absorbed micro-organisms. Once the particle is excreted as faecal material, the entire process commences again and may be repeated a number of times so that a particle may be ingested by several different detritus feeders before it is completely broken down. The detritus consumers also ingest other materials which include benthic animals, fine inorganic particles and live microalgae.

In the mangrove forest and adjacent waters of the west coast of peninsular Malaysia the food web is more complex than that of Florida waters due to the presence of more species of crustaceans, gastropods and fishes. In the small rivers and creeks which drain the mangrove shore north of Port Klang, preliminary studies have shown that there are some 30 species of fishes and several species of prawns (Table 1). Examination of the gut contents of these fishes, several of which are important economically, show their dependence on mangrove-derived detritus and mangrove-dwelling invertebrates. The gut contents of some mangrove water fishes is given in Table II. In the mullet, Liza melinoptera, over 40% of the diet consisted of mangrove leaf detritus (Chong, 1977), while in Haplochilus melastigma it was over 80%. Carnivorous fish, such as the barbel eel (Plotosus canius), were solely dependent on mangrove invertebrates such as snail, Cerithida obtusa. The diet of many other fish included barnacles, fiddler crabs or their planktonic larvae. Occasionally, mangrove vertebrates such as mud skippers were found in the diet of fish. The food web in the mangrove forest and adjacent shallow waters may be represented as in figure 1. It shows that shallow water fishes are dependent on mangrove invertebrates for their food and firmly demonstrates that the mangrove shore makes a significant contribution to the coastal shallow water food web of the west coast of peninsular Malaysia.

Table 1

A list of fish and prawn spp. collected from the mangrove estuary/river (Sungei Sementa Besar), Kapar, Malaysia. Samples were collected using a cast net

Arius sp.
Chorinemus sp.
Pellona kampeni Web. & de Beauf.
Haplochilus melastigma McClelland
Anodontostoma chacunda (Ham.Buch.)
Stolephorus commersonii Lacepède
Thryssa mystax (Schneider)
Eleotris butis Cantor
Gerres lucidus Cuv. & Val.
Gobius koku Rus.
Gobius sadanundio Ham.Buch.
Gobius viridipunctatus Cuv. & Val.
Boleophthalmus boddaerti Cuv. & Val.
Periophthalmodon schlosseri
Equula sp.
Leiognathus equulus (Forsskal)
Lutjanus johni (Bloch)
Vatamugil cunnesius (Valenciennes)
Liza melinoptera (Cuv. & Val.)
Liza subviridis (Valenciennes)
Ambassis gymnocephalus Bleeker
Ambassis urotaenia Bleeker
Pomadasys hasta (Bloch)
Plotosus canius Ham.
Scatophagus argus Linnaeus
Sillago sihama (Forsskal)
Spinephelus amblycephalus Bleeker
Siganus javus (Linnaeus)
Sphyraena jello Cuvier
Tetrodon fluviatilis Ham.
Therapon jarbua Forsskal
Toxotes jaculator Pallas
Penaeus merguiensis de Man
Penaeus indicus H. Milne-Edwards
Metapenaeus brevicornis (H. Milne-Edw.)
Palaemon sp.
Parapeneopsis maxillipedo Alcock



DETRITUS CONSUMERS INCLUDING OMNIVORES (nematodes, polychaetes, snails, bivalves, prawns, crabs, sipunculids, fish, etc.)

↓

SMALL CARNIVORES (small fish, etc.)

Periophthalmodon schlosseri (mudskipper),
Periophthalmus vulgaris (mudskipper),
Stolephorus commersonii (anchovy),
Plotosus canius (barbel eel),
Pomadasys hasta (silver grunter), etc.

↓

LARGE CARNIVORES (game fish, fish eating birds, otters, etc.)

Sphyraena jello (barracuda)
Therapon jarbua (crescent perch)

Figure 1. The detritus food web based on mangrove plant material in the mangrove shore and adjacent waters of the west coast of peninsular Malaysia (modified after Odum, 1970)

Table II

The principal components of the diet of some fish and a shrimp inhabiting a mangrove river/estuary (Sungei Sementa Besar), Kapar, Malaysia. Values indicate percentage volume of diet in stomach or whole gut

Species \ Components of diets	Mangrove detritus	Inorganic particles	Microalgae	Benthic meiofauna and zooplankton	Diatoms and crustacean remains	Crabs - *Sesarma* spp. and snails	Sipunculid	Barnacles and others	Others
*Liza melinoptera**	44.0	38.6	17.4						
Gerres lucidus	47.0			53.0					
Anodontostoma chacunda	41.6	37.3	17.8						3.3
Haplochilus melastigma	82.5				17.5				
Plotosus canius						77.5	12.5	10.0	
Acetes erythraeus	38.5	11.4	22.4	25.2					2.5

*Chong (1977)

Another important function of the mangrove ecosystem, including the shallow and calm rivers and creeks, is to provide shelter for the juvenile stages of many commercially valuable prawns. Studies in progress on the west coast of peninsular Malaysia (Chong, personal communication) have shown that the post-larvae and juvenile stages of the banana prawn (*Penaeus merguiensis*) shelter in the calm mangrove waters. It is possible that the detritus-rich benthos and the flora of microalgae contributes substantially to the diet of the young prawns. Figure 2 illustrates the life cycle of the prawn which on maturity migrates to offshore waters to spawn.

A significant part of the diet of juveniles and sub-adults of *Penaeus merguiensis*, *P. indicus* and other prawns that frequent mangrove waters, consists of mangrove plant detritus. This observation confirms that the mangrove ecosystem is essential for the survival of the prawn fishery. This view is reinforced by comparing the fishery statistics of the west with those of the east coast of peninsular Malaysia (Pathansari, 1976). Prawn catches in 1971 totalled 45 954 t for the west coast and only 3 500 t for the east coast. It is at once obvious that the mangroves which colonize almost the entire sheltered west coast of peninsular Malaysia is the contributory factor to the thriving prawn fishery. Demersal fishery resource surveys of 1974 also confirm the meagre prawn resource of the east coast of the peninsular (Lamp and Latiff, 1976). The removal of mangroves from a locality can therefore bring about the depletion of offshore marine fisheries through loss of food and shelter for the juveniles of prawns and fish.

An attempt to establish a relationship between commercial prawn production and the total acreage of mangrove forest was carried out in Indonesia (Martosubroto and Naamin, 1976). They found a significant linear relationship where prawn production increased with the size

of the mangrove forest acreage. The implication is that any reduction in mangrove forest acreage will cause a decrease in prawn yield.

The recent war in Vietnam where about 36% of the nation's mangrove forests were defoliated and destroyed provided an opportunity to study the consequences of such destruction on coastal fisheries. The absence of such comparative baseline data precluded De Sylva and Michel (1974) from giving any good reasons for the decline in the marine fishery off Vietnam, but the authors postulated that the decrease in marine fish catch since 1964 may be attributed to general pollution, effect of DDT, malathion and herbicides, or to some war-related sociological reason.

2.6 Other Values

Mangroves can afford protection to coasts from tidal waves. Foresberg (1971) and Chapman (1971) suggest that the devastating effects of the 1970 tidal wave which struck Bangladesh would have been less severe if the coastal belt of mangrove forests had not been converted into paddy fields.

Mangroves can stabilize areas of high accretion and growth rates of mangrove shores may be substantial in regions of high sedimentation. In the central parts of the west coast of peninsular Malaysia rates of accretion have been greatly accelerated due to tin mining activity inland. Substantial amounts of fine sediments derived from tin mining and deforested areas are carried out to the sea by the many rivers. These sediments subsequently settle on the shore through tidal and wave action. Dixon (1969) noted changes along a stretch of the coast over a period of thirty years and found a net gain of new land. Accretion resulted in the formation of 3 660 acres of new forest, while erosion resulted in loss of 1 620 acres of *Bruguiera* forest during the same period.

3. POLLUTION PROBLEMS IN THE MANGROVE ECOSYSTEM

3.1 Effluent Pollution

An important source of pollution in the mangroves in an agricultural country like Malaysia is waste from agricultural products such as natural rubber, palm oil, copra and pineapple. Of these, palm oil is important since copious amounts of it are produced. At present Malaysia has about 80 factories producing more than one million metric tons of palm oil per year and an estimated effluent waste of 3.4 million metric tons is discharged each year with no pre-treatment into rivers and estuaries. Palm oil effluent is mainly inorganic and has a high Biochemical Oxygen Demand (BOD) load of 20 500 mg/l (at 20°C for 5 days). Although the effluent is biodegradable, its high BOD load and suspended solids usually cause pollution when discharged into mangrove estuaries.

An example is the effect of palm oil effluents have had on a mangrove estuary (Sungei Puloh), which has a salinity of 15 parts per thousand and 31 ‰ at the upper and lower reaches respectively. Seow (1976) in a study of the water chemistry of the estuary for a distance of 5 km showed that various water conditions changed with the condition of the tide. The Biochemical Oxygen Demand at the outfall was in excess of 50 mg/l at all times. The maximum value of 146 mg/l was obtained during a neap tide when effluent discharge was high. BOD values taken during this neap tide showed that the river was polluted for a distance of 5 km where a BOD of 84 mg/l was recorded. At all times the estuary was polluted for a distance of 2 to 3 km downstream.

There was no sign of pelagic fauna at the outfall, but at a distance of 2 km downstream, three species of fish (*Liza melinoptera*, *Anodontostoma chacunda*, *Haplochilus melastigma*) and a prawn (*Penaeus* sp.) occurred in greater abundance. However, the pelagic fauna here was less diverse than in the unpolluted regions of the mangrove river (Seow, 1976). Preliminary observations along the banks of the river (or estuary) indicated the complete elimination of the burrowing and surface-dwelling fauna. The mangrove trees within the immediate vicinity of the outfall appeared normal, but the mangrove fauna had been depleted or eliminated.

It is interesting to note the ability of the mangrove plants to tolerate palm oil effluent, which had a BOD load several times higher than sewage. This concurs with the suggestion of Odum and Johannes (1975) that the mangrove ecosystem may possess characteristics which facilitate its use for tertiary sewage treatment in the tropics where good sewage treatment facilities are often beyond economic reach. This suggestion stems from the concept that the mangrove plants require a steady supply of nutrients in order to maintain their characteristic rates of growth (Lugo et al., 1974). Fine sediments, which are typical of mangrove shores, are known to have a high absorption capacity for nutrients. This was confirmed by Walsh (1967) who reported that large amounts of nitrates and phosphates were removed from waters flowing through a mangrove shore.

Inherent in any suggestion to dump sewage in a mangrove shore is the danger of pesticide contamination. Sewage effluents normally have high concentrations of organochlorine pesticides (Portmann, 1975). Therefore, use of mangrove shores as sites for sewage treatment could lead to measurable increases in pesticide residue levels, not only in the mangrove fauna but also in the coastal fish and shellfish.

3.2 Herbicidal Effect on Mangrove Forests

Mangrove plants are very susceptible to herbicides. As mentioned earlier, military operations during the recent Vietnam war destroyed over 100 000 hectares (36%) of mangrove forests (Ross, 1974). Defoliated mangrove areas showed increased soil erosion. Earlier observations by Westing (1971) indicated that herbicide sprayed areas were resistant to recolonization. More recent reports indicate regeneration proceeding naturally in some areas while areas further inland or at high shore levels are being recolonized more slowly (Ross, 1974). Delay in recolonization is attributed to large quantities of wood debris which restrict seedling implantation. Undoubtedly, the most important factor may be the absence of mature plants to supply seedlings for the vast denuded areas in the upper reaches of the shore.

3.3 Oil Pollution

Oil pollution is a constant threat to the mangrove communities, particularly in shipping lanes such as the narrow Straits of Malacca. There were two oil spills by tankers in the Straits during the last three years. The two tankers spilled a total of 10 300 tons of crude oil which was dispersed by toxic detergents. No information is available on the damage to the mangrove environment though there were press reports that fish resources were affected.

Rutzler and Sterrer (1970) reported that the mangrove communities were more seriously damaged by an oil spill on the Panama coast than adjacent sand beach or rocky shore communities. Rhizophora seedlings were killed along with a variety of intertidal invertebrates and algal mats in the mangrove shore. Mathias (1976) carried out experiments on seedlings of the pioneer mangrove Avicennia intermedia using diesel oil mixed with sea water in various ratios and found that concentrations of 10 000 ppm and above killed seedlings.

3.4 Ability of Mangrove Forests to Regenerate

Mangrove forests possess the remarkable ability to regenerate when clear felled for timber or for some other purpose but recovery from herbicide destruction may be slow for the reasons discussed earlier.

From the silvicultural point of view, the mangrove forests are the easiest to manage since seed planting is easy if natural regeneration is delayed (Dixon, 1959). Stands of the preferred Rhizophora spp. are planted by sticking foot-long fruits into the mud. These take root rapidly. White and White (1976) reported the almost complete natural regeneration in 10 years of several sites in Papua New Guinea cleared for oil drilling operations. Small areas still bare within the mangrove forest are believed to be oil polluted or roaded.

4. CONCLUSIONS

The destruction of mangrove forests by reclamation for industrial or agricultural uses is proceeding at an unprecedented rate in South-East Asia. For example, in the most developed state of Selangor in Malaysia more than 50% of the total mangrove land has been reclaimed for industrial and agricultural purposes over the last decade. Of this, about 50 km^2 were filled with soil transported on a conveyor belt system from a now flattened hill 10 km inland. The land reclaimed was used for low cost flats (four storey high), godowns, industrial estates, etc. In Singapore, the main industrial estate of Jurong stands on reclaimed mangrove land.

Very often thousands of hectares of mangrove forests have been reclaimed without any feasibility studies on the viability of the planned projects. For example, at Kuala Selangor of Malaysia, a 16 km^2 area was cleared of mangroves for construction of ponds for production of salt from sea water. A modern factory was built for purifying the impure salt, and foreign expertise was sought at considerable expense to a state corporation. The industry collapsed after functioning intermittently for a year when the authorities realized that the locality had a mean rainfall of 2000 mm (it rained too often) with no distinct dry climatic period to facilitate continuous or even periodic salt production.

There is considerable misuse and mismanagement of mangrove forests throughout the tropics and sub-tropics. In order to make rational use of the remaining mangrove forests in the world, Odum and Johannes (1975) called for a monetary evaluation of the mangrove ecosystem just as was visualized for the temperate salt marshes (Gosselink et al., 1974). Such an evaluation will have to take into consideration the timber production, the coastal fisheries, including shellfish and mangrove crab (Scylla serrata) production, the potential of the shallow water oyster and mussel production and the potential of the mangrove shore as a land builder. Unless mangrove biologists and concerned authorities take immediate action to provide government authorities with good evidence of the true value of the mangrove ecosystem, the existing mangrove forests will vanish in the next few decades.

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