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THE SOUTH CHINA SEA: AN IMPACT TO INDONESIA MANGROVE AT THE HUMAN PERSPECTIVE ON ECOSYSTEM, FUNCTION, SERVICES AND BENEFIT

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ABSTRACT With respect to the sustainability, utilization, conservation and protection, the mangrove ecology in Indonesia are described briefly along with their roles and function for the human being. Apart from their ecological value, the mangrove forests provide numerous commercial products, generating much needed economic opportunities in most of the islands in the country. These products represent a primary resource for coastal people and they have a direct impact on the forest ecology. Aspects of utilization both by traditional and modern methods presented as a consequent of human civilization.

Keywords: Indonesia, Ecology, Mangroves, Function, Biodiversity, Utilization.

INTRODUCTION

As an archipelagic country, Indonesia (6^oN – 10^oS & $95^o E$ – 142^oE) is home to some of the world's most valuable natural resources. Its natural resources are vital to Indonesian's government, its citizens and to the international community. Indonesia is one of the most bio-diverse countries in the world (Mittermeier & Mittermeier 1997), and one of the nine most economically and environmentally important countries (Flavin 2001). The islands are endowed with a unique scenic beauty as well as marine life and are of diverse ecological characteristics.

In recent years, as the human population in Indonesia has increased to 210 million in 2005 (BPS 2004), environmental problems have become of vital interest and importance to the public. The United Nations Conference on Environment and Development (UNCED) added momentum to the growing consensus on the need for environmentally sustainable development. As a follow-up to UNCED, the Agenda 21-Indonesia has been considered the legal basis for sustainable development. Consequently, ecology becomes an urgent key word for the success of any development of natural resources in the country (**Tables 1, 2, Figures 1**). Ecology always has been a source of fascination to professional ecologists, biologists, naturalists and conservationists (**Table 3**).

Table 1. Guidelines for the selection of mangrove areas for preservation, conservation, declaration as forest reserves and released for fishpond development in Indonesia (Source: Umali 1987).

Location	Proposed Action	Reason for Proposed Action
1. Adjoining river systems	Conserve, not released for fishpond	Maintenance of ecological balance
2. Adjoining to productive fry and fishing grounds	Conserve, not released for fishpond	Insure breeding, spawning, and nursery grounds of fishes and shellfish
3. Adjoining to populated areas or urban water	Conserve, not released for fishpond	Insure continuous use for minor products
4. Places with significant hazards if developed	Preserve	Protection against storms, erosion, flood, etc.
5. Primary and dense forest growth regardless of location	Preserve	Maintenance of ecological balance, protection against riverbank erosion, uses as wildlife sanctuaries and for education and research
6. Ground small	Preserve	Maintenance of ecological balance
7. Others, (exclusive or Nos. 1-6)	Release for development	Fish production and other land uses, whichever is most compatible

Table 2. Examples of uses and environmental functions of mangroves in Indonesia: a source of ecological issues and human conflicts.

Uses	Functions
A. Sustainable Production Uses	**A. Regulatory or Carrier Function**
1. Wood products:	1. Erosion prevention (shoreline and riverbanks)
1.1. Timber	2. Storage and recycling of human waste and pollutants
1.2. Firewood/fuel-wood	3. Maintenance of biodiversity
1.3. Charcoal	4. Provision of migration habitat
1.4. Wood chips	5. Provision of nursery, breeding, spawning, feeding, shelter grounds
1.5. Industrial wood	6. Provision of nesting and resting sites
1.6. Others: tannin, medicine, feed, honey, dyes	7.Nutrient supply and nutrient regeneration (organic matter sources)
2. Fishery products (Traditional hunting, fishing, gathering):	8. Coral reef and seagrass maintenance and protections
2.1. Fish	9. Habitat for indigenous people
2.2. Crustaceans	10. Recreation sites
2.3. Shellfish	11. Landscape, Tide break and Sea breeze protections
3. Genetic resources	12. Land establishment
B. Conversion Uses	**B. Information Functions**
1. Industrial/urban land-use	1. Spiritual and religious information
2. Aquaculture	2. Cultural and artistic inspiration
3. Salt-ponds	3. Educational, historical and scientific information
4. Rice field and plantation	4. Potential information
5. Mining	
6. Dam site	

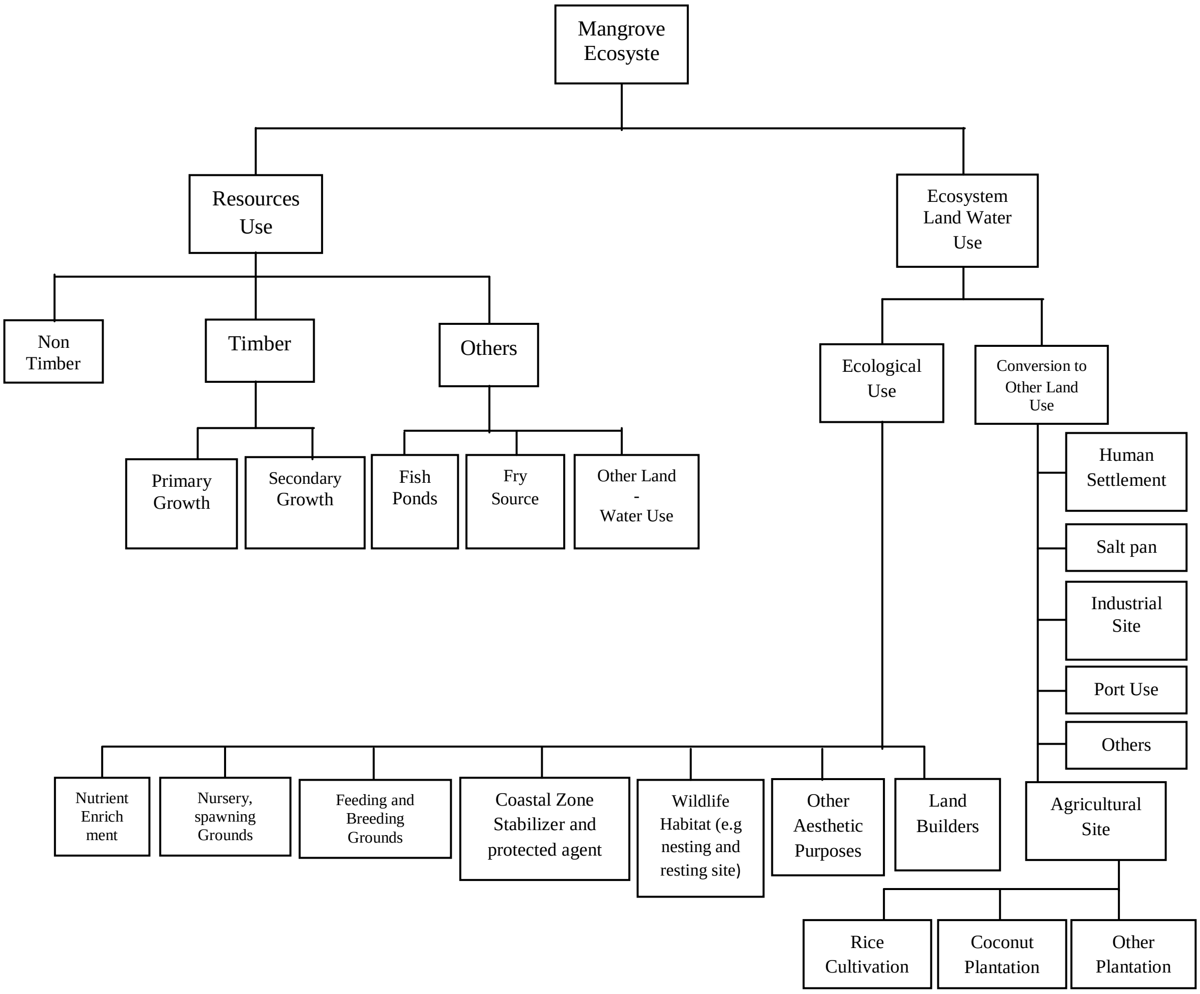

Figure 1. Taxonomy of Uses in a Mangrove Ecosystem in Indonesia: A South China Seas Mangrove (Source:Sukardjo 2003)

Table 3. Problems and/or issues faced by coastal zone in Indonesia as seen by a mangrove ecologist (Source: summarized from Sukardjo *et al*. 1997).

Major issue	Problems/issues	Management strategies
Coastal zone degradation	1. Mangrove deterioration: Hyper-salinity, Over-exploitation, Pollution and Soil erosion.	1. Increase river flow. 2. Reforestation. 3. Introduce resistant taxa. 4. Assessment of annual loss.
	2. Pollution: Industrial, Sewage, Oil, Agriculture, Toxic wastes, Thermal, etc.	1. Pre-treatment of effluents. 2. Monitoring. 3. Clean-up operations. 4. Ship waste be processed or eliminated. 5. Multi-purpose numerical modeling. 6. Reduction of harmful compounds.
	3. Decrease flow of rivers: Soil erosion, Hyper-salinity.	1. Restore the flow.
	4. Threat to biodiversity: Disappearance of species, Loss of sanctuaries.	1. Improve the habitat. 2. Reintroduce species. 3. Marine parks. 4. Ecotourisms.
	5. Urbanization: Dredging, Channelisation, Destruction of flora and fauna, Solid waste.	1. Regulate coastal development. 2. Dump dredged material far away. 3. Reforestation.
	6. Sea level rise (SLR): Loss of land and biota, Great economic loss.	1. Estimation of accretion and SLR. 2. Conservation of mangroves.
	7. Socio economic: Poverty, Illiteracy, Lack of municipal facility.	1. Socio-economic uplift of fishermen. 2. Education. 3. Alternate jobs. 4. Marine Park.5. Apiculture, Mariculture, Silvofisheries.
	8. Lack of public awareness and people participation.	1. Local people participation in all coastal matters. 2. Education through mass media.
	9. Lack of harmonization and enforcements of legislation.	1. Central, provincial and local governments cooperate. 2. Penalties.

Indonesian islands (17,504 islands) stretch over 5,700 km from the Indian oceans to the Pacific oceans, and the area is a typical humid tropical region. Under these tropical environmental constraints, mangroves occur on all coastlines and in all estuaries and embayments in Indonesia with suitable conditions (**Table 4**). In particular, they are present along a large part of the more than 108,000 km Indonesian coastline. The biotic components – plants, animals and microbes – interact with mangroves and are energy dependent system. The abiotic physical chemical environment and the biotic association of the plants, animals and microbes comprise an ecological system or ecosystem. The ecosystem is defined as a system composed of physical - chemical and chemical biological processes active within a space time unit of any magnitude.

Table 4. Environmental factors controlling the growth and development of mangrove in Indonesia: a summary for understanding their ecology (Source: Sukardjo 1999).

Jennings and Birds (1976): Control the establishment of mangrove ecotone	**Walsh (1974): Basic requirements for extensive mangal development**	**Chapman (1976): Basic requirements for mangrove establishment**	**Percival and Womersley (1975): Environmental conditions influencing mangrove**
1. Aridity	Tropical temperatures	Air temperature	-
2. Mineralogy	Fine grained alluvium	Mud substrate	Mangrove soil
3. Neotectonic effects	-	-	-
4. Sedimentation	-	-	Accretion
5. Tidal conditions	Large tidal range	Tidal range	Saline conditions and tidal inundation
6. Wave energy	Shore free of strong wave and tidal action	Ocean current	Physiographical structure of the area
7. -	Salt water	Salt water	-
8. -	-	Protection	-
9. -	-	Shallow shores	-
10. -	-	-	Artificial conditions brought about by exploitation

Indonesia has the richest some mangroves in the world (Spalding *et al*. 1997). Mangrove ecosystems are complex, intensely dynamic and sensitive to storms and hurricanes, and among the natural assets for national development and human welfare. Excessive interactions of human beings with their modern tools and greed in natural habitats and/or ecosystems, is identified as the major threat to the existence, to a large extent, of natural habitats in Indonesia. Mangrove stands designated for conservation – with biodiversity and fish habitat values as well as public value as reducers of salt-water intrusions and flooding – have been completely destroyed in many locales. In the decade, mangroves degraded vastly, both structurally and ecologically, with 5.3 million ha being denuded areas (Santoso 2005). The quantitative analysis of interconnections between mangrove species and their abiotic environment has therefore been a central issue in Indonesia (**Tables 2, 3, 4 and 5, Figures 1)**

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Table 5. Causes of loss of mangrove forests in Indonesia (Source: summarized from Sukardjo *et al.* 1997 and Anonym 1997).

Direct Human Action	Indirect Human Action	Natural Causes
1. Conversion to shrimp and fish ponds	1. Sediment diversion from dams and flooding	1. Sea level rise
2. Construction of sea walls and dykes	2. Change in waterways by construction of canals and roads	2. Drought
3. Construction of tourism facilities	3. Increased soil salinity by changes to freshwater runoff	3. Typhoons and other tropical storms
4. Drainage for agriculture and mosquito control		4. Soil erosion
5. Dredging and flood protection		
6. Discharge and spraying of pesticides		
7. Industrial and road development		
8. Mining activities		
9. Maintenance of saltpans		
10. Oil pollution		
11. Wood chipping		

The amount of literature on mangroves and mangrove ecosystems is impressive. A number of recent texts give an overview of mangrove distribution, mangrove research, and mangrove ecology and mangrove management, e.g. Tomlinson (1986), Field (1988), Robertson and Alongi (1992), Aksornkoae (1993), Hong & San (1993), FAO (1994), Stafford-Deitsch (1996), Spalding *et al*. (1997, 2010), Hogarth (1999), Kathiresan and Bingham (2001), Lacerda (2002), Saenger (2002), Duke (2006) and Alongi (2009). All are very useful for an understanding the mangrove ecosystem in Indonesia.

This paper provides an essay of mangrove ecology in Indonesia for better understanding to their sustainability, utilization, and conservation and protection. Also the paper represents an introductory part of philosophical discussion on the resilience and restoration of soft bottom near shore ecosystems in Indonesia after tsunami catastrophe.

MANGROVE ECOSYSTEM IN INDONESIA

Distribution and characterization

In the Indonesian archipelago, mangroves occur around the coasts. Characteristically, they occupy the tidal wetlands of the islands and the coming and going of sea and freshwater alternatively are the fundamental condition of their establishment. Here, mangroves to be found growing vigorously under such condition, and in the estuaries they form extensive forests. Also, where fresh and sea – water meet and mix there is sedimentation of the water's silt content and flocculated material. The anoxic sediments store large amount of elements, especially potassium, magnesium and calcium (Sukardjo & Kartawinata 1979), most of which are probably sequestered from seawater.

The most extensive areas of mangrove forests occur on sedimentary shorelines, where large rivers discharge onto low gradient coasts. But rapid rates of sedimentation within the forest may account for massive tree mortality in mangroves, e.g. mortality of *Bruguiera* trees in Segara Anakan, Cilacap (Soerianagara 1968). Deltas and estuaries which are subject to variable rates and types of geomorphological change create a variety of habitats which are colonized by mangroves. Moreover, the nature of the sediments, relief, first colonizers, salinity, currents and tides, rainfall, temperature and their variations, solar radiation with their concomitants of light and heat, humidity/moisture, physical and chemical changes, depth of the water table and nature of the areas from where sediments are brought in, are all factors that control the character of mangrove ecosystem and their productivity locally, even for *Rhizophora mucronata* plantations in Tritih, Cilacap (Sukardjo 1996). It is therefore, not only the soil plant interaction that controls the mangrove ecosystem (Sukardjo 1994a), but a number of other factors as well (**Table 4**). My field observations suggest that the best development of mangrove ecosystems occurs in sites where the upper tidal areas are exposed to a continuous supply of fresh water, as is found in areas with high rainfall (>1500 mm/year), freshwater seepage and river deltas.

Mangrove roots are effective sediment binders and stabilize sediments as peat (a combination of silt, sand, and decomposing forest detritus), which prevents fine particles in coastal rivers from reaching offshore seagrass beds and coral reefs and, therefore, they are often planted for erosion control. Thom (1967, 1982) pointed out that local geomorphology and tidal energy control the relative amount of sediment trapping by mangroves. Field data indicate that sediment is accreting beneath mangrove trees (DBH>10 cm) at 4-8 mm/year and saplings (diameter 2-10 cm) at 5-7 mm/year on nine river study areas. Even though mangroves colonize sedimentary environments, excessive sediment deposits can damage them, reduce growth or even kill mangroves (Ellison 1998). Deltaic and estuarine areas, in particular are susceptible to rapid adjustments in patterns of sedimentation in response to sediment supply, and in these areas it appears that the dynamics of mangroves are a response to, and not a cause of, coastal progradation (**van Steenis 1958**). Sediment de-watering and de-oxidation result in the dropping of water level, e.g., the occurrence of *Sonneratia caseolaris* in Sentani Lake, a lagoon that became a lake by tectonic uplift (van Steenis 1963). The fact that, in the absence of erosion, accretion or other disturbance, the mangrove forests on a land – sea interface are close to MSL (Mean Sea Level) undoubtedly suggests that a restricted tolerance to inundation is an important factor determining the topographic height of a mangrove community in Indonesia, e.g., in Banyuasin South Sumatra (Sukardjo & Kartawinata 1979). It's suggested that biological impacts of sediment accretion on mangroves in Indonesia should be studied in any geomorphologic setting.

Naturally, mangrove species show a characteristics zonation within the swamp (Kitamura *et al*. 1997, Bunt 1996, Sukardjo 1995, Smith 1992). Individual mangrove species are consistently associated with particular sections of the tidal range. Thus mangrove species tend to occur in zone according to micro-elevation and frequency of inundation, e.g., in Segara Anakan Cilacap (de Haan 1931) and in Bali Lombok (Kitamura *et al*. 1997, Hayashi & Chaniago 1995). The variation in the degree of inundation of the swamps by sea-water also controls soil salinities, which are important in regulating forest structure (Sukardjo & Kartawinata 1979, Ball 1988a, 2002). In fact, the mangrove forests usually have sharp ecotones (e.g., peat and/or freshwater swamp-forests in Kalimantan with typically by *Combretocarpus rotundatus*) with adjacent ecosystems because the saline condition of the mangrove habitat is tidally and topographically determined. Therefore, coastal geomorphology and hydrology have been used to classify the physiognomy and zonation of mangrove forests (Lugo & Snedaker 1974). The Indonesian mangroves would be categorized as fringe, riverine, basin, or dwarf forests in the typology of either Lugo & Snedaker (1974) or Cintron *et al*. (1985), and they described the micro-topographic effects of hydrology on the formation of forest type locally (e.g., Sukardjo & Kartawinata 1979, Sukardjo 1995).

Indonesia mangrove ecosystems are places where tides and coastal currents bring variations to the forest and where plants and animals adapt to the changing chemical, physical and biological characteristics of their environment (**Table 4**). Environment conditions within mangrove forests make it extremely difficult for non-halophytic and non-wetland plants to grow and reproduce. These include flooding, prolonged hydro-period, salinity, anoxic conditions, and accumulation of toxic substances, such as H_2S, potent inhibitors of cytochrome oxidase in respiratory metabolism. The concentration of H_2S known to cause a 50% inhibition of cytochrome oxidase in plant roots is 13 uM (Allan & Hollis 1972). Sea water provides an ample supply of sulphate for reduction by dissimilatory sulphate reducing bacteria (e.g., *Desulfovibrio*: Postgate 1959, Field 1988), and concentrations of sulphate may exceed 1 mM in mangrove soils (Carlson & Yarbro 1988). Thus, the growth of mangroves may be influenced not only by a species capacity to maintain aerobic metabolism in its roots, but also by its sensitivity to soil phytotoxins, particularly H_2S. Salinity is the major obstacle to species invasion within mangrove forests because in order to survive in a saline environment, plants must possess mechanisms to either exclude salt or mitigate its effects on living cell (Clough 1984). Consequently, mangroves are dominated by halophytic (salt tolerant) woody seed plants that range in size from tall trees (e.g., *Rhizophora*) to small shrubs (e.g., *Aegiceras*) and herbs (e.g., *Acanthus*) that grow in the Indonesian eulittoral zone (**cf. Table 4**). They are circum-tropical on sheltered shores and often grow along the banks of rivers as far inland as the tide penetrates, e.g., in Kalimantan the mangrove extends up to 150 miles for the Kapuas River (van Steenis 1984, 1957). In nature the occurrence of mangrove plants in freshwater is rare. But van Steenis (1963, 1984) recorded the occurrence of two herbaceous mangrove plants, *Acrostichum aureum* and *Acanthus ilicifolius* in the inland in freshwater localities in Java, and mangrove tree, *Sonneratia caseolaris* along the banks of Sentani Lake at c.75 m altitude and in Tami river Kumai some 90 km upstream. In all, nine river studies (Saleh, Musi, Banyuasin, Rokan, Siak, Barito, Kapuas, Mahakam, Kumai rivers), salinity begins by falling approximately linearly with distance from the mouth of the river (significant at $P<0.01$). Their varied tolerance to salinity that has ecological significance. It has been observed in Indonesia that many species of Rhizophoraceae found growing better in polyhaline zone/region. The polyhaline zone is characterized by moderate salinity (18-30%o) and minimum wave action. Substrates are of usually sandy clay to clay loam and/or sandy loam which favors establishment of mangrove seedlings, e.g., in such substrate at the mangrove forests belonging to Watson's inundation class III-IV in Banyuasin South Sumatra, 45,200 seedlings/ha of *R. apiculata* and 6800 seedlings/ha of *B. gymnorrhiza* have been recorded (Sukardjo 1987a). Also, the recognized that shading by *Rhizophora* prevents the establishment of *Avicennia* seedlings under *Rhizophora*.

Mangrove forests are distributed along coastal lines in a variety of habitats and in intertidal areas throughout the archipelago in 28 of the 33 provinces but are concentrated in Irian Jaya, East and South Kalimantan, Riau and South Sumatra. Naturally, mangrove species occur in muddy tidal waters along most island coast of the country (e.g., *Avicennia* spp.), and in some rock platforms (e.g., *Aegialitis annulata*), coral platforms (e.g., *Osbornia octodonta*) and coarse coral sand places (e.g., *Rhizophora stylosa, Pemphis acidula*) of the islands mangroves may still flourish. Little attention has been given to the role of biotic interactions in mangrove distribution in Indonesia. The fauna, such as crabs play an important role (Smith *et al*. 1991, Jones *et al*. 1994, Stafford-Deitsch 1996, Kathiresan & Bingham 2001). Historically, mangrove forests have been viewed as systems dominated by physical factors, in which biological interactions were unimportant (Watson 1928, Macnae 1968, Chapman 1976). Recent evidence suggests that certain biological interactions (e.g., seed predation), play an important role in determining the distribution of some tree species (Smith 1987a, b, Schwamborn & Saint-Paul 1996). Field observations suggest that the mud lobster (*Thalassina anomala*) may influence species distribution as a result of its burrowing activities. However, the mangrove forests or 'mangal' (Macnae 1968) are a typical life community of the tropical shores. They find their best expression both in terms of extent and crop quality (species diversity and growth) along the sheltered coasts in the Malesia (Malesia comprising the political states of Indonesia, Malaysia, Brunei Darussalam, the Philippines, Singapore and PNG) where optimum site conditions for their development exist (Watson 1928, van Steenis 1957, Field 1988, Aksornkoae 1993). The mangroves in the estuaries of the Solomon Islands form the eastern limits of the Malesian mangrove flora (Barth 1982). In general, mangroves are widely distributed along warmer waters (>24^{o}C) coastlines of the world where, with favorable geomorphological, climatic and edaphic conditions, they often form extensive tidal forests. It is therefore, in Indonesia that mangroves occur luxuriantly in most islands as a primary feature of their coastlines.

Structural and functional adaptations

Oceanographical data of inshore waters in the coastal zone of Indonesia indicates that a common situation is for fresh-water to form a layer above salt, the layers rising and falling with the tides. Near the shoreline, flooding by seawater is periodic and based on the rhythm of the tides. Flooding in inland localities is common and by freshwater, typically as a result of high rainfall (>1500 mm per year). Interchange between salt and freshwater is a consequence of spring tides alternating with freshwater runoff. The salinities then fluctuated most widely and irregularly. Each mangrove species occupies that salinity gradient to which it is best adapted. This adaptation to the salinity regime is known as metabolic zonation. According to Ball (1998), salinity is simply a competition eliminator and not the determining factor in zonation. Also, zoning patterns apparently caused by succession governed by the dynamic equilibrium with environmental changes locally (cf. Ellison 2002, Ellison *et al*. 2000).

Mangroves do not require salt water for their survival; some species can grow under freshwater conditions and in areas which do not receive regular tidal inundation (Ball & Pidsley 1995, Hogarth 1999). Individual mangrove trees have been reported at great distances from the coast and elevated well above sea level, e.g., *Sonneratia alba* in Bogor Botanical Garden (van Steenis 1963, 1984, Chapman 1976). But the common characteristic they all possess is tolerance to salt and brackish waters, and most mangrove species grow best in saline waters. Thus mangroves grow in differing salinity regime from marine, brackish (e.g., *Nypa fruticans*, *Sonneratia caseolaris*) to freshwater (e.g., *Amoora cucullata*, *Brownlowia argentata*). Mangroves are never found growing in pure brine. Thus I agreed with the earlier work of Bowman (1917) and Davis (1940**)** who had indicated that mangrove species were facultative saline species in both growth and physiology. Hence mangroves can be identified have three classes of specialized structural adaptations and several reproductive and physiological adaptations and in Indonesia need to be studies in detailed.

Plant structures, such as the pneumatophores (e.g., *Avicennia* and *Sonneratia*), prop roots (e.g., *Rhizophora*), knee roots (e.g., *Ceriops* and *Bruguiera*), plank roots (e.g., *Xylocarpus*) and lenticels (small opening in the bark surface) permit the uptake of oxygen for root respiration in a sediment environment that typically lacks oxygen. These structural attributes provide an effective means of root ventilation (McKee 1993). The studied the size and density of pneumatophores and knee roots in relation to habitat. The height, circumference and number of pneumatophores of *Avicennia officinalis* (height: h= 50.4 cm, circumference: c= 14.5 cm, number: n= 65/m^2), *A. marina* (h=53.4 cm, c=25.4, n= 47/m^2) and *Sonneratia alba* (h=87.5 cm, c=32.4 cm, n=21/m^2) are more in muddy substratum. Also, the height and number of knee roots of *Ceriops tagal* (h=28.7 cm, n=21/m^2) and *Bruguiera gymnorrhiza* (h=24.4 cm, n=14/m^2) are more in muddy substratum than rocky and sandy substratum. Scholander *et al*. (1955) concluded that the heights of pneumatophores depend upon the magnitude of high and low tides. But the data are that dissolved oxygen (DO of stagnant water 0.9 ppm) and salinity (30.5 ‰) are responsible to greater extent for the formation of higher number of pneumatophores and knee roots with better height in the mangroves. Many mangrove species produce propagules that germinate on the tree prior to separation and dispersal. The true biological/ecological significance of viviparous propagules is a matter of speculation. Some mangroves exhibit some degree of vivipary (i.e., germination while attached to the parent tree: *Rhizophora* and *Avicennia*) or precocious germination (i.e., during dispersal: *Lumnitzera racemosa*), and take advantage of tides and ocean currents as energy subsidies. Several authors (e.g., Tomlinson 1986, Tomlinson & Cox 2000) have suggested that vivipary in mangrove may be an adaptive characteristic permitting avoidance of high salinity at germination. The adaptations mentioned above are morphological and characteristics of the above-ground portion of the ecosystem. Other physiological adaptations or below-ground processes, such as allelopathy, may also contribute to the competitiveness of mangroves. Long-term field studies therefore, are urgently needed for mangroves in different environmental setting in Indonesia.

Hogarth (1999) and Kathiresan & Bingham (2001) are recent good review on the biology of mangroves. The fundamental adaptations refer to the variety of physiological strategies that permit mangroves to survive and grow under saline conditions. The three major adaptations developed by the mangrove to deal with salinity include exclusion of salt by the roots, toleration of high tissue salt concentrations and elimination of excess salt by secretion (Hogarth 1999). Thus mangroves functionally have frequently been classified according three strategies of salt tolerance: salt exclusion, salt accumulation and salt secretion (Ball 1988b), although the various mechanisms of dealing with salt are not mutually exclusive. Jennings (1968) reviewed the mechanisms whereby mangroves deal with excess environmental salt. It appears that three are operative: (i) they take up highly saline water and then secrete the salt (extrusion) (e.g., *Avicennia*, *Aegiceras* and *Aegialitis* have salt secreting glands on their leaves), (ii) they take up water but prevent the entry of salt (exclusion), or (iii) they develop tolerance to high salt loads and allow salt to accumulate in the tissues (accumulation) (e.g., *Excoecaria agallocha*, *Lumnitzera*, *Osbornia*, *Rhizophora*, *Sonneratia* and *Xylocarpus*).

The Rhizophoraceae, a true mangrove for example, have root membrane systems that exclude salt from entering the plant; fresh water, required for transpiration, easily passes through the membrane barrier. The Avicenniaceae permit salt to enter the xylem along with the uptake water. The salt, however, passes through the plant and is left as crystallized salt on leaf surfaces when the transpired water has evaporated. Other groups, such as the Combretaceae, are suggested to have an ability to convert starch to sugar when salinities increase and, conversely, convert sugar to starch when salinities drop. The control of the concentration of soluble sugar controls the osmotic pressure of the plant sap and thus the entry of salt. Scholander *et al*. (1962) and Atkinson *et al*. (1967) have shown that the salt-secreting glands of mangrove secrete mainly sodium chlorine. Members of the Rhizophoraceae also have the ability to control the formation and concentration of proline for the same purposes. Clearly further studies are needed on the supposed eco-physiological separation of the mangrove species interactions and responses to different environmental setting and climate regime in the Indonesian archipelago.

Ecosystem productivity and biodiversity

In Indonesia, the mangrove ecosystem is a typical bio-geo-morphological system. Thus mangroves play a significant role in creating the ecosystem, in trapping sediments and in dispersing the energy of storms, tidal borers and winds, e.g., in the coastal plains they trap the river-borne sediments that then become consolidated into islands. Also, the storms further deliver sediments, nutrients (especially phosphorus) and water circulation to the region (Davis *et al*. 2004). There attain their greatest diversity, canopy height and productivity in estuaries with large, high-rainfall catchments (>1500 mm/year) where salinities are about 25-30‰ seawater, meteorological conditions are cloudy and humid and concentrations of phosphorus and nitrogen in the soil are high (Sukardjo 1995, 1994a, Boto & Wellington 1983). Under these favorable conditions (**Table 4**), their trees grow-up to 50 m or more in height and they form an extensive closed-canopy forest. Large mangrove trees (> 50 cm diameter above the prop roots) were once common in rich riverine mangrove forests in many islands of the country e.g., *R. apiculata* trees 50 cm DBH (diameter at breast height) and larger (40-70 m high was recorded by the author) were common in mature forest in Sumatra (Sukardjo & Kartawinata 1979, Sukardjo *et al*. 1984).

Mangrove with greater tidal activity and water turnover generally have higher litterfall than mangrove in areas with stagnant water (Pool *et al*. 1975), as has been observed for East Kalimantan mangrove forests, e.g. 32.06-51.54 kg C/ha/day and litterfall of 20.50-29.35 t dry wt./ha/year (Sukardjo 1995). Sukardjo and Yamada (1992a) reported total biomass production of *R. mucronata* (7 years old) amounted to be 93.726 t dry wt/ha, and for the mangrove forests dominated by *R. apiculata, Bruguiera parviflora* and *B. sexangula* in Riau amounted 40.70, 42.94-89.68 and 75.99-279.03 t dry wt/ha, respectively (Kusmana *et al*. 1992). These higher rates of wood production would place *Rhizophora* and *Bruguiera* among the moderately fast-growing tropical hardwood species. Leaves (7.78-10.82 t dry wt/ha/year) and twigs (5.90-9.53 t dry wt/ha/year) constitute a substantial portion of the annual production of mangroves (Sukardjo 1995) and they form a major source of detritus for the aquatic food chains of adjacent waters. The estimated flux of leaves and twigs components on the floor of mangrove forests in Apar Bay East Kalimantan amounted to be 6.85-12.62 and 4.68-7.99 t dry wt/ha/year, respectively (Sukardjo 1995). The conclusion therefore, in Indonesia, mangroves grow in areas of high solar radiation and have the ability to take up fresh-water from salt, so they are in an excellent position to achieve high primary productivity and are among the most productive of all estuarine ecosystems.

Of all the marine macrophyte systems, the mangroves are the only ones characterized by storage of aerial biomass, so that the individual plants are trees or shrubs and the whole takes on the aspect of a forest. Mangrove forest biomass production and mangrove peat accumulation are components of a cyclical process. This cyclical process varies between geomorphic situations in the islands of Indonesia, and is influenced by sea-level change. The dynamics of mangrove ecosystems and environments should be analyzed and synthesized in terms of forest dynamics, biomass production, mangrove peat accumulation and erosion, material transportation, environmental changes in the surrounding intertidal area, sea-level fluctuation and related human activities (e.g., Sukardjo & Yamada 1992a, Sukardjo 1995). In broader terms, we need data on the biological production of mangrove systems, and changes in standing crop or total biomass that proceed with time. Such an approach will lead to more comprehensive knowledge of the mangrove ecosystem and permit the prediction of its response to future environmental change. Nevertheless the consider that in Indonesia the productivity of mangrove swamps is still really an unexplored field.

Species diversity in equatorial regions is highest (e.g., Malesia), and declines with increasing latitude (Barth 1982, Duke 1992). Species richness of mangroves decreases northwards to just 1 species in southern Japan at 31°31'N (Walter & Breckly 1986, Spalding *et al*. 1997, 2010). In Indonesia, diversity is lowest in Nusa Tenggara (Central Southern Malesia) where a number of the core species are absent, rare or unrecorded and are not completely supplemented by the characteristics south-eastern Malesian taxa. Van Steenis (1958) claim that the low number of mangrove species in the Nusa Tenggara is related to physical factors (heavy surf, rough coastal topography, limited sedimentation). Semeniuk (1983) found that mangrove forests in Western Australia which received ground water from surrounding uplands into the high intertidal zone had higher species richness that forest not receiving such flows of ground water. Sukardjo *et al*. (1984) reported that estuaries for mangrove forests along the Banyuasin coast of South Sumatra with greater freshwater runoff (a function of catchments size and rainfall) often had greater species richness as does mangrove forest along the northern coast of Queensland (Bunt *et al*. 1982, Ball 1998). Consequently mangroves have extensive associations of marine fauna and flora as well as terrestrial and freshwater fauna and flora.

Tomlinson (1986), Kitamura *et al*. (1997) and Primavera *et al*. (2004) describes the basic botany of mangroves. Plants that are confined to the mangrove are called true or strict mangroves; plants that can also occur elsewhere are called mangrove associates (Tomlinson 1986). The term mangrove in a narrow sense refers to erect woody dicotyledonous species, and called as obligate (Johnstone & Frodin 1982), and for their species with tree life form called as principal (Watson 1928), or as core species (Frodin 1986). World-wide, mangrove forests consist of more than 110 plant species, belong to a variety of plant families; not only tree species, but also vines, ferns and algae. However, the actual number of mangrove species has long been a matter for debate; the range of species accepted differs considerably from Schimper (1891) and Watson (1928) through Percival and Womersley (1975) to Duke (1992) and Hogarth (1999).

75 species of mangrove are recorded recently in Indonesia (Sukardjo 1994b) and occur in a range of angiosperm families; And their common species (Rhizophoraceae: *Bruguiera* spp., *Ceriops* spp., *Kandelia candel, Rhizophora* spp.; Avicenniaceae: *Avicennia* spp.; Combretaceae: *Lumnitzera* spp.; Meliaceae: *Xylocarpus* spp. and Sonneratiaceae: *Sonneratia* spp.) can be classified as true or strict (Tomlinson 1986), or obligate (Johnstone & Frodin 1982) or principal (Watson 1928) or core mangrove species (Frodin 1986). Giesen & Wulffraat (1998) listed 204 angiosperm plants and ferns that regularly occur in Indonesia's mangroves. The list consists of more than 50% marginal species, reflecting their diverse terrestrial ancestry. Many species occurring in the mangrove vegetation in Indonesia appear to behave as dry-land plants, tolerant of low water potential but able to tolerate only limited periods of inundation. The conclusion, floristically mangroves is a formation of trees, shrubs and herbs inhabiting tidal wetlands and along coasts, rivers, estuaries or off-shore

accretion in Indonesia islands. Mangroves have no taxonomic significance, and used in different senses: for the individual species, and for the characteristics communities which they form. In order to avoid confusion between these two usages Macnae (1968) proposed the term 'mangal' for the latter. Therefore, mangals are composed of a set of taxonomically heterogeneous group of plants that share convergent adaptations to saline, anoxic habitats, even in islands like Bali and Lombok (Kitamura *et al*. 1997, Hayashi & Chaniago 1995).

Apart from restrictions imposed by ecological factors, there are floristic differences within Indonesia archipelago. Most mangals have genera representatives in tropical closed forests or humid tropical rainforests e.g., only 4 of 9 genera of Rhizophoraceae (*Bruguiera*, *Ceriops*, *Kandelia*, *Rhizophora, Anisophyllea, Combretocarpus, Carallia, Gynotroches, Pallacalyx*,) belongs to mangroves (Ding Hou 1958). It is interesting that *Kandelia candel* does not occur in Java although it is found to the west and north in Sumatra, Malaysia, Thailand, Kalimantan, the Philippines and China (Ding Hou 1958, Aksornkoae 1993). Also, of interest ecologically, *Aegialitis annulata* (Plumbaginaceae), one of a prominent member of the mangrove flora of eastern Indonesia and Australia, does not extent westward into Java and the western Indonesia archipelago (van Steenis 1949). Species such as *Aegialitis annulata*, *Camptostemon schultzii*, *Bruguiera exaristata*, *Osbornea octodonta* and *Ceriops australis* are characteristics Arafura Sea – Coral Sea centered taxa with western limits in Timor and Maluku (Johnstone & Frodin 1982). All mangrove species are not uniformly distributed throughout the archipelago, indicating that the distribution of individual mangrove species is uneven, and need further botanical exploration in the whole country, e.g., *Heritiera globosa*, an endemic mangrove species of Borneo (van Steenis 1984). Moreover, vast stretches of mangrove forests in Indonesia still remain to be studied even on a simple floristic level, while several genera (e.g., *Avicennia*, *Bruguiera*, *Sonneratia*, *Xylocarpus*, and *Lumnitzera* and *Rhizophora* hybrids), still need to be bio-systematically investigated, and also for biogeographically studied (e.g. *R. lamarckii*, *Bruguiera hainesii*, *Camptostemon schultzii*, *Aegiceras floridum*, *Aegialites annulata*, *Kandelia candel*). It is clearly therefore, that Indonesian mangroves flora varies greatly island by island, and is very specialized, consisting of the mangroves proper, which are shrubs or trees belonging to about 15 genera and palms (*Nypa fruticans*, *Phoenix paludosa*, *Oncosperma tigilaria*), and a few associated species such as vines (*Derris trifoliata*), ferns (*Acrostichum aureum*), and rattan palms (*Calamus erinaceus*, synonym: *Daemonorops leptopus*, Watson 1928) that are rarely or never found elsewhere. The general conclusion, it appears that Indonesia was the centre of dispersal of modern-day mangrove flora.

In Indonesia, mangrove forests harbor a relatively small but interesting assemblage of algae (e.g., Ogino & Chihara 1988), diatoms, fungi and lichen (e.g., Hyde 1989) which are well-adapted to colonize and thrive under the unique and dynamic hydrobiological conditions characterizing the intertidal zone of sheltered coastlines of islands. No published work on diatoms exists and data on fungi distribution (both vertical and horizontal) and host specificity were also incomplete, indicating a need for research in these areas. A total of 150 samples examined from Kampong Nelayan mangroves near Belawan North Sumatra (3^o 46' N and 98^o 44' E) yielded 39 species of marine fungi, including 30 ascomycetes, 1 basidiomycetes and 8 deuteromycetes (Hyde 1989). Clearly, the study of marine fungi of mangrove habitats in Indonesia has recently become a focal point of research, since little is known of their ecology.

Associated algae are assumed to be important in biological processes within mangrove forests though direct evidence is not always available, e.g., algal mats can also hinder growth of mangrove seedling (Hogarth 1999). There is a difficulty in defining the ecosystem of the mangal. If the coral reef is a rich association of specific reef dwelling species which evolved and diversified on the high – productivity oases created by the Scleractinian – zooxanthellae symbiosis – the situation of the mangal is different. Perhaps with the exception of the mangrove tree species, there is no species of alga or animal which is specifically bound to the mangal. Mangal species of algae's and animals are littoral quiet-water species, resistant to or requiring suspension – rich waters and silted bottoms; species resistant to considerable fluctuations in salinity and temperature. This is, therefore, a relatively limited diversity of marine species, as compared with the open seashore. The mangal is, however, one of the high productivity environments of the marine shore; and in Indonesia, reported rates of organic matter production as high as 29.35 t dry wt/ha/year (Sukardjo 1995). Mangrove forests are net exporters of particulate organic carbon (POC) (Lugo *et al*. 1976). In an Indonesian mangrove ecosystem, export of particulate organic matter (POM) has been estimated at 45.5 kg C/ha/day (Sukardjo 1995). Also, it has long been recognized that the meiofauna, comprising a variety of taxonomic groups, occupy a position of considerable significance in the biodegradative processes occurring in estuaries mangroves. Reduced freshwater flow through a mangrove forest probably not only reduces the nutrient input from surrounding terrestrial areas, but also results in higher salinity. Therefore, we can define the 'mangal' as an ecosystem based on an accumulation of nutrients produced by the mangrove trees (e.g., Litterfall POM, DOM, FOM) upon which lives a high biomass of a relatively low-diversity community of algal and animals – resistant to extreme environmental conditions. Much has been written about the phytosociology of the mangrove trees, but studies including also algal and animal associates are rare (Tanaka & Chihara 1988, Hogarth 1999, Kathiresan & Bingham 2001). And in Indonesia, the floristic and ecology of algae associated with mangroves are poorly known (Ogino & Chihara 1988, Tanaka & Chihara 1988).

The Indonesian mangrove forest provides appropriate breeding, nesting and resting places for many animals, birds, amphibious, etc. e.g., in Cimanuk delta complex (Sukardjo 1987b). These fauna is very rich in species diversity and in number of individuals of each species. The waters of the mangrove forests are breeding and nursery areas for a large number of fish, shrimp, crayfish, clams, oysters, and other living organisms in the water (Sukardjo 2004). For instance, mangrove forests in the marsh in Irian Jaya are host to 5 frog's species, 7 turtle's species and many crab species, and the ocean includes some 1000 species of plants and animals. Mangrove forests are a tough ecosystem to invade because there is a small global species pool that can survive the salinity, water-logged, and anaerobic soil conditions of mangrove habitats, e.g., in the Cimanuk delta complex, in addition to having an advantage over-fresh water species that are salinity – stressed, mangroves also compete successfully with salt-marsh grasses and/or sedges, e.g. *Paspalum vaginatum*, *P. commersonii*, *Panicum repens*, *Cyperus malaccensis* and *Scirpus littoralis* (Sukardjo 1987b). Mangroves are, therefore, not only forests, but also ecosystems. Thus in Indonesia, mangrove ecosystems represent the most diverse combination of floral, faunal and physical elements among coastal habitat.

The mangrove ecosystem, a dominant floral and faunal association on the tropical sheltered and estuarine shores, covers 25% of the World's tropical and subtropical coastline (FAO 1994). Indonesian mangroves contribute 23% of the world's mangroves areas (Spalding *et al*. 1997) and are extremely productive (Sukardjo 1995), providing the source for timber, charcoal, tannin, dyes and medicines, fibers as forestry resources (Becking *et al*. 1922), and fish, shellfish, mollusks and others as fishery resources (Schuster 1949, Sukardjo 2004). They increase species richness or biodiversity in estuarine areas. Also, they are both systems of high organic production and nutrient traps. Mangroves reduce nutrient loads into the sea and thus encourage the growth of seagrasses and corals (Ogden & Gladfeller 1983). Mangrove ecosystems contribute to the enrichment of the coastal marine waters by providing convenient nursery areas for shrimp, crabs and fish (Toro & Sukardjo 1990, Primavera 1998). Crab, prawn and oyster are other fisheries intimately associated with mangroves (Sukardjo 2004). Although equal in importance to coral reefs, as far as frequency is concerned, mangrove forests have been little studied as integral ecosystems (Sukardjo 2002). Irrespective of the wide range in variation among the mangrove species and mangrove forest types, this ecosystem is widely valued for its role in the perpetuation of near-shore fisheries, the protection of coastlines, and as a renewable resource of economic value, e.g., the Bintuni Bay mangroves in Province of Irian Jaya Barat (Ruitenbeek 1991). My conclusion therefore, Indonesian mangrove ecosystems reflect the dynamics between climatic variations of coastal processes and biological interactions as well as interventions by human activities.

ECOSYSTEM SERVICES – A GENERAL VIEW OF UTILIZATIONS

Mangrove ecosystems in Indonesia are very varied and their structure and function depend heavily on the nature of the prevailing environment. The combination of trees along with their root systems, wave energies together with the coastal geomorphology, explain the function of mangrove ecosystems. Those provide a dynamic interface between the sea and the land, and are also very important as storm barriers between land and ocean, e.g., mangrove root systems can mitigate damaging tropical storm impact by slowing wave and win speed (Saenger 2002). Despite their significance, the function of the Indonesian mangrove ecosystem as climate, soil and ground-water stabilizer system remains poorly understood, with research up to the present having been concerned mostly with the study of the individual components within the system. The two main functions of an ecosystem are the exchange of nutrients between different trophic levels (nutrient cycle) and energy flow, e.g., consumption of litterfall by detritivores (crabs). In connection with the utilization of mangrove ecosystem in Indonesia and sustainable mangroves management program of Mangrove Information Center – Japan International Coorperation Agency (MIC-JICA) project, thus two functions are not presented. Instead, for practical terms, the **Figures 1 and Table 2** provide a general over-view mangrove functions.

The total estimated area of mangroves in Indonesia is about 9.6 million ha (Santoso 2005) and includes degraded and non-degraded mangroves in both state and non-state forest areas. It is acknowledged that the figures vary in accuracy from province to province, but they do provide a general indication of the resource base within the country. Thus, mangrove ecosystems are advisable places for non-destructive aquaculture (Sukardjo 2000), and provide territory for land and aerial fauna e.g., intertidal mudflats of mangrove ecosystems along the coast of Jambi to South Sumatra are important feeding areas for shorebirds and some wildfowl during the low water period when they are exposed and for diving ducks and fish during high water when they are submerged (Silvius 1986).

There are permanent human habitations in the country with millions of people who are directly or indirectly dependent on the mangrove environment for their daily life and livelihood, e.g., in Sinjai, South Sulawesi, up to 100% of the households have been reported as mangrove dependent, and in Batu Ampar West Kalimantan, the traditional charcoal trading recorded since 1906 (Wind 1924). The economic importance of mangrove forests as a direct source of timber, fuel-wood and charcoal is well known since the colonial era (e.g., Becking *et al*. 1922, Wind 1924, Bodegom 1929, Sukardjo 1987a). However, other intrinsic benefits are often not recognized and consequently the true value of mangrove forests to the national wellbeing, socially and economically, is not considered in decisions affecting these forests (cf. Sukardjo 1991). Essentially, it appears evident that immediate short term economic gains take precedence over long term benefits, be they direct or indirect. Historically mangroves are an item of trade and they are a source of employment and income for the coastal communities in the islands (Wind 1924). Over-exploitation by traditional uses exists as a result of population pressures and economic needs, e.g., in Bengkalis Riau (Bodegom 1929, unpublished data 2004). Often times, however, other considerations such as unique human social-cultural environments and political associations, take precedence over economic and environmental considerations. In the face of increasing population pressures, urban expansion, greater needs for fuel, food and other necessities of life under the general umbrella of socio-economic development, mangrove forests become open and generally easy prey to pressures for utilization, harvesting and often conversion. These pressures or threats take various forms as the major cause of mangroves loss for the country, but data and statistics at provincial level are lacking (Sukardjo 2002). For instance, my recent field observations post-tsunami in Aceh suggest that destruction was far worse where protective mangrove swamps had been replaced by tambak (fish ponds) and settlements.

Mangrove forests reach their maximum development in South-east Asia and Indo-Western Pacific region (Macnae 1968, Chapman 1976, Tomlinson 1986, Field 1988, Aksornkoae 1993, Hong & San 1993, FAO 1994, Hogarth 1999, Primavera *et al*. 2004). It is rational to assume that a resource with both aquatic and terrestrial biological characteristics would be heavily used for various uses. International Union for Conservation of Nature (IUCN) in its global review of the status of mangrove ecosystems (Saenger *et al*. 1983) identified 22 major uses of the mangrove ecosystem. The major and widespread uses for Asia and the Pacific are identified as firewood, charcoal, construction purposes, stock grazing (India), honey (Bangladesh), fish, crustaceans, shellfish (India), recreation (Australia and New Zealand), preservation (Bangladesh), shoreline protective (New Zealand) and protective planting (New Zealand and Bangladesh). Localized major uses include many of the widespread major uses, as well as for paper (Bangladesh), woodchip (Malaysia and Indonesia), shellfish (Malaysia), riverbank protection (Taiwan and New Zealand) and riverbank protective planting (New Zealand).

The people of South-east Asia have been deriving multiple benefits from such forests (Hamilton and Snedaker 1984, Hong & San 1993, Lacerda 2002, Primavera *et al*. 2004). Fortunately, trans-boundary diagnostic analysis (TDA) for the South-east Asia countries indicated that their mangrove forests are in the similar rate of degradation (Talaue-McManus 2000). People will continue to need fish from reefs, wood and charcoal from mangrove forests, and waste disposal in nearby waters. Conservation aims to satisfy these short-term needs in a way that ensures the survival of the resources in the long term. Protected areas help channel development to avoid sacrificing one resource by harvesting another or by modifying habitats. Clearly this role is one of living resource conservation for sustainable development as defined in the World Conservation Strategy. As temporary custodians of the world's resources we are privileged to use them. We do not have the freedom to use them carelessly; we are obligated to maintain them and pass them on undamaged to later generation. The point, therefore, is that the benefits from mangroves in Indonesia can be classified into 3 categories (**Table6**), and the general view of the products of mangrove ecosystems are presented in **Table 7**. However, mangroves are different things to different people in Indonesia (**Table 8**). To many, they remain an accessible wilderness area, and a habitat for waterfowl: to others such unoccupied space presents a great opportunity for development.

Table 6. Benefits from mangroves in Indonesia: a general considerations for global friendly approaches (Source: summarized from Sukardjo *et al*. 1997)

Local Communities	**National Interest**	**Global Interest**
1. Shelter	1. Timber production	1. Conservation
2. Construction timber	2. Charcoal production	2. Education
3. Firewood	3. Fishing industry	3. Effect of climate change
4. Food	4. Mixed shrimp farms	4. Preservation of biodiversity
5. Income from fishing, shrimp culture and wood gathering	5. Recreation	
6. Income through cottage industries	6. Tourism	
7. Medicine	7. Education	
8. Fodder for animals	8. Coastal and estuary protection	
9. Protection from storm damage and riverbank erosion		

Table 7. Products of mangrove ecosystem commonly used by coastal inhabitants in Indonesia (Source: Becking et al. 1922, Burkill 1923, Ding Hou 1958, Heyne 1950, My field notes 1979-2004).

1. **Mangrove forest products**

    1.1. Fuel: Firewood for cooking and heating, Charcoal, Alcohol
    1.2. Construction materials: Timber and scaffolds, Heavy construction timbers, Rain-road ties, mining pit props, Boatbuilding materials, Dock pilings, Beams and poles for buildings, Flooring, paneling and clapboard, Thatch or matting, Fence posts, water pipes, chipboards and glues
    1.3. Textiles and leather: Synthetic fibers (e.g., rayon), Dye for cloth, Tannins for leather preservation
    1.4. Food, drugs and beverages: Sugar, Alcohol, Cooking oil, Vinegar, Tea substitute, Fermented drinks, Dessert topping, Condiments from bark, Sweetmeats from propagules, fruits or leaves, Cigar substitute
    1.5. Household items: Furniture, Glue, Hairdressing oil, Tool handles, Mortars and pestles, Toys, Matchsticks, Incense
    1.6. Agriculture: Fodder, Green manure
    1.7. Paper products: Paper of various kinds
    1.8. Others products: Packing boxes, Wood for smoking sheet rubber, Wood for firing bricks, Medicines from bark, leaves and fruits
    1.9. Fishing equipment: Poles for fish traps, Fishing floats, Fuel for smoking fish, Fish poison, Tannins for net and line preservation, Wood for fish drying or smoking racks

2. **Other natural products:** Fish, Crustaceans, Shellfish, Honey, Wax, Birds, Mammals, Reptiles and reptile skins, Other fauna (amphibians, insects)

Table 8. Sustainable Mangroves Management in Indonesia: A case study - Problems, causes and solutions to mangrove degradation at the Sulawesi project sites in 1996 (Source: Anonym 1997).

Problems (Locations)	**Causes**	**Solutions**
Uncontrolled conversion of mangrove forests (Lariang, Muna, Luwu, current enforcement at Kwandang is adequate but may be temporary).	1. Mangrove forests have a low value to individual. 2. External values unknown. 3. Land-use plans do not include mangroves. 4. Regulations not enforced.	1. Incentives for conservation taking account of external values. 2. Assess total value of mangroves. 3. Comprehensive land-use plans. 4. Enforcement of agreed regulations.
Non-sustainable wood cutting (Muna especially).	1. Lack of employment. 2. Good demand for wood.	1. Create other employment. 2. Create new uses for mangroves. 3. Forest management. 4. Reforestation of denuded areas.
Conversion to tambak (All sites, especially Luwu).	1. Perceived profitability. 2. Source of livelihood. 3. Desire to own land.	1. Identify inappropriate areas. 2. Trade-off tambak improvement for mangrove conservation. 3. Reforest tambak in green belt. 4. Reforest abandoned tambak.
Loss of mangroves on some foreshore (Luwu, Muna, Lariang).	1. Timber/firewood cutting. 2. Foreshore erosion.	1. Reforestation of foreshore. 2. Agree on mangrove conservation policy with local people, MOF and PEMDA.

Mangroves are a renewable resource. It is possible to apply the concept of sustained yield management (Hamilton & Snedaker 1984). Three factors are of prime importance when discussing this concept is (i) The productivity, (ii) Renewability and (iii) Sustenance of the resource. In the past, various workers have described the utilization trends in many ways, for example (1) Direct uses (fish production) and indirect uses (as silt retainer and land builder), (2) Use of mangroves at ecosystem level (as nursery, spawning, breeding and feeding grounds, nesting and resting sites or as dumping grounds for waste materials) and at component level (thatching material from nipa palm or tannin production), (3) Single-use system (aquaculture and rice production in mangrove areas) and multiple-use system (recreation areas and fishing); and lastly (4) Commercial products (woodchip production and marine products) and traditional uses (food and medicinal plants).

In Indonesia, various alternatives uses of mangrove ecosystems are of relevance to the present status of utilization of mangrove resources in the province and/or in the districts of village level. For instance, a range of sustainable alternatives arose from the friendly discussion with the local community (e.g., with Suku Apit in Bengkalis, Riau and with local peoples in Sinjai, South Sulawesi). Thus sustainability does not mean that the resources should be preserved in its original state because then the system is not being utilized. Two broad sub-heads of utilization trends in Indonesia can be identified as follows:

1. Sustainable uses (traditional uses, minor products: alcohol and sugar, tannin and dyes, and honey, recreation and wildlife resource, marine products). The concept involves either a sustainable harvest or sustainable economic returns, though the latter are governed by many factors beyond the control of the producer besides the site productivity and yield. Ideally this type of uses should not destroy the

equilibrium and endanger any component of the ecosystem. The product should be renewable in perpetuity by following conservation policies and proper management practices. Any use if not based on proper management practices would result in decreased yield and degradation of quality of the product.

2. Exploitative uses (agriculture, mariculture, salt production, settlements, mining and oil exploration). Exploitative uses of mangrove forests involve conversion of mangrove areas to other uses resulting in irreversible changes in land-use pattern. Such uses, depending upon their nature and intensity, may endanger wildlife, destroy gene-pool reservoirs, reduce species diversity, eliminate the protective role of mangrove forests and cause changes in soil and water chemistry. Most of those result from the excessive use of one component of the ecosystem.

People will continue to need fish from mangroves, reefs and seagrass bed, wood and charcoal from mangrove forests, and waste disposal in near by waters. On the other-hand the destruction of the mangrove forests and/or habitat for other purposes growing vastly. For instance, reclamation of land for agriculture destroyed the habitat of mangrove fauna, e.g., *Nasalis larvatus*, *Presbytis cristata*, *Rana cancrivora*, *Crocodylus porosus*, *Leptoptilus javanicus*, *Ardea sumatrana* (Low *et al*. 1994). Moreover, using resources in the coastal zone and ocean requires that some areas be retained in their natural states. The following are some of the important broad guidelines for future use of mangrove ecosystem in Indonesia (See: Sukardjo & Toro 1988 for the detail):

1. Drastic reduction in the scale of exploitative trend, such as agriculture and aquaculture development. Follow proper management techniques on an intensive scale rather than on extensive areas.
2. Highly selective logging to ensure regeneration for the next cycle with minimum detrimental effect on site. As an ecologist and forester, It would not suggested a complete moratorium on the utilization of renewable products.
3. Development of new and refinement of the present management techniques with vigorously defined silvicultural and harvesting prescriptions.
4. Preservation of typical areas/stands for gene-pool conservation, education and research.
5. Basic research in: (i) Quantitative relationship between plant communities and marine faunal productivity, and (ii) Effect of increased utilization of mangrove environment on the protective role of the ecosystem.
6. Study of socio-economic conflict between traditional uses and large-scale commercial operations – direct or alternative – in a comprehensive economic analysis framework that includes all benefits and cost – direct, indirect and intangible.

Ecosystem benefits – The points for protection

Undeniably, Indonesia today is plagued by a host of environmental problems, the bulk of which are, in some way or other, triggered by the dire consequences of ill conceived strategies for achieving progress and development. One such malady is the wanton interference, modification, reclamation, pollution and destruction of shallow-water coastal ecosystems, particularly of mangrove forests and coral reefs.

Generally in Indonesia, mangroves are considered by many politicians and administrators as waste-lands or at best as idle-lands waiting to be developed for other more economically profitable purposes, and, on the other hand, being regarded as unique habitats harboring peculiar types of fauna and flora (by naturalists and conservationists) or as a protective belt against coastal erosion and thus having an important role in land-building and coastal stabilization processes (by naturalists, conservationists, geomorphologists), and therefore should be protected and left untouched at all costs. Between these two extremes of views of the value of mangrove resources, there are the **ecologists** and **foresters** who are of the opinion that mangroves are valuable and renewable resources provided that they are managed according to ecological principles. Also, due to their geographic locations, the waters of mangroves are able to receive enrichment from land and sea. As a result, the waters are usually rich in nutrients and other organic debris which are exported from the forest ecosystem through tidal flushing. They, in turn, support the micro-organisms which form an important food source for fisheries. And mangroves act as breeding, feeding, nursery and spawning grounds for some important coastal fishery species (Singh *et al*. 1994, Vance *et al*. 1996, Primavera 1998, Pauly & Ingles 1999, Crona & Ronnback 2005). It is therefore, to conserve areas of the mangrove forest, keeps the mangroves as a mangrove ecosystem in our mind, e.g., the mangroves in the Solo-Brantas deltas region (Davie & Sumardja 1997). Thus understanding to the impacts of the various human activities which cause the destruction and/or loss of the mangroves are key words for protection (**Table 5**). In general, the scales of impact are classified according to area affected as shown in **Table 9**. Thus protected mangrove areas in Indonesia are designated to preserve some natural aspects of the environment that society values. Also, protected areas may, hypothetically, be said to play a role in the conservation of biological diversity (biodiversity) of coastal – marine system (**Table 10**).

Table 9. Scales of impact commonly encountered with destructive uses of the mangrove ecosystems (Source: Saenger *et al*. 1983).

Activity	**Scale of impact (ha)**
1. Clear felling	10,000 – 500,000
2. Diversion of freshwater	1,000 – 500,000
3. Conversion to agriculture	100 – 100,000
4. Conversion to aquaculture	100 – 10,000
5. Conversion to salt ponds	100 – 1,000
6. Conversion to urban development	100 – 1,000
7. Construction of harbors and channels	100 – 1,000
8. Mining/mineral extraction	10 – 100
9. Liquid waste disposal	1 – 10
10. Solid waste/garbage disposal	1 – 10
11. Oil spillage and other chemicals	1 – 10
12. Exploitive traditional uses	1

Table 10. Status of wetlands and associated biodiversity in the South China Sea project site in Indonesia: a summary (Source: Talaue-McManus 2000).

Site description	Area (ha)	Economic and Social values	Disturbances and Threats	Biodiversity	Conservation measures taken
1. Pulau Betet, South Sumatra: Large island with mangrove forests, intertidal mudflats and peat swamp forest (as ecotone)	10, 000	Important as nursery ground for fish and shellfish	Illegal logging. Collection of eggs of water-birds for food	Mangrove forest dominated by *Rhizophora* and *Bruguiera*. Important area for resident and migratory waterfowl; at least 30 species. Estuarine crocodile *Crocodylus porosus*	None
2. Banyuasin Musi river delta, South Sumatra: Large delta system of the Banyuasin and Musi rivers with extensive mangrove systems, intertidal mudflat	150,000-200,000	Fisheries especially shrimps, prawns and cockles. Timber	Reclamation, Logging, Disturbance of breeding colonies of water-birds, Hunting, Forest fire	Over 30 species of mangrove, freshwater swamp forests, peat swamp forests and grassy marshes.	None
3. Sungai Lalan, South Sumatra: Extensive mangrove swamps and intertidal mudflat	586,417 including 80,000 of swamp forest	Fisheries	Logging. Forest clearance for transmigration scheme. Crocodile hunting. Pollution and disturbance from boat traffic	Mangrove, freshwater swamp and peat swamp forest species. At least 12 fish species; unknown number of waterfowl species; about 5 mammal species; 5 reptile species	None
4. Bakau selat Dumai, Riau: Large area of rich and undisturbed mangrove forest and peat swamp forest	60,000	Fisheries	Settlements. Logging	Mangrove and peat swamp tree species. Rich in waterbirds and wildlife; no species inventory	None
5. Pleihari Tanah Laut, South Kalimantan: Low-lying coastal area with 40% grassland and shrub land and 50% swamp	35,000	Fisheries. Water supply	Wood cutting. Hunting of deer. Shifting cultivation. Grazing of domestic livestock	Mangrove forests, grasslands and swamp forest, heath forest. Waterfowl and migratory shorebirds. Mammals. Marine turtles, estuarine crocodile and monitor lizard	Protected as a wildlife reserve since 1974
6. Kelompok Hutan Kahayan, Central Kalimantan: Large area of swamp forests (peat, freshwater, mangrove)	150,000	Marine fisheries	Timber cutting. Forest clearance for agriculture	Mangrove forest, freshwater and peat swamp forests. No information on fauna	None
7. Tanjung Putting National Park, Central Kalimantan: Vast low-lying area of mangrove, peat and freshwater swamp forests and kerangas forest	Area of wetlands unkown; 296,800 ha out of official area of 300,040 ha has been mapped	Important genetic resource	Illegal cutting. Illegal hunting and fishing. Poaching of waterfowl eggs	Mangrove, peat and freshwater swamp species, kerangas forest. Very rich fauna	Protected as a Biosphere Reserve in January 1977 and a National Park in October 1982
8. Tanjung Penghujan, Central Kalimantan: Swampy coastal area bordered by a fringe of mangrove forest and backed by freshwater swamp forest	40,000	High potential for outdoor creation	Tree felling for wood	Mangrove and freshwater swamp forests. Rich wildlife but little information; *Nasalis larvatus* present	None
9. Muara Kendawangan, West Kalimantan: Complete seral succession of lowland habitats from coastal sand bars, mudflats and mangrove forest through swamp forest to dry lowland forest	c.150,000: 75,000 ha of freshwater swamps; 65,000 ha of peat swamps; 10,000 ha of mangroves	No information	None known; uninhabited	Mangrove, peat and freshwater swamp forests. Rich in wildlife including mammals and birds	None; proposal for establishing a Nature Reserve approved but not implemented
10. Gunung Palung and	C.130,000: 7,000 ha	High	Logging. Shifting	Mangroves, fresh	A Nature

surrounding swamps, West Kalimantan: Relatively undisturbed hill and lowland forest including mangroves, freshwater swamp forest, peat swamp forest and wet lowland forest on alluvium	mangrove forest; 20,000 ha freshwater swamp forest; 30,000 ha peat swamp forest; 5,000 ha wet lowland forest; 62,000 ha moist lowland dipterocarp forest; 1,000 ha montane forest; 5,000 ha wet hill forest	potential for outdoor. Conservation education	cultivation	water and peat swamp forests, wet lowland forest. 192 species of birds. Mamals: 2 insectivore; 4 chiropteran; 7 primate; 7 rodent; 2 carnivore; 5 ungulate species. 3 reptiles	Monument 30,000 ha in area was established in 1930's; upgraded to Nature Reserve and renotified in 1981; proposal to extend to a total area of 100,000 ha made
11. Hutan Sambas, West Kalimantan: Lowland forest including mangrove forest, 100 ha of beach forest; peat swamps and moist lowland diptercarp forest	120,000: 43,000 ha of mangrove forest; 100 ha beach forest; rest are peat swamps and moist lowland dipterocarp forest	Potential for an international reserve linking up with Samunsam Reserve in Sarawak	Uncontrolled logging. Hunting. Poaching of sea turtle eggs. Shifting cultivation	Mangrove, peat swamp, freshwater swamp forests, moist lowland dipterocarp forest. Rich in wildlife; large and important sea turtle nesting beach	None

In Indonesia, mangroves are non-homogeneous open ecosystems that are extremely dynamic, interacting with the atmosphere above as well as the processes of the adjacent land and sea. The conservation of mangroves should thus include not only the various vegetation and tidal inundation zones but also the adjacent marine and terrestrial areas (including the water catchments areas).

The pressure from environmental activists for more conservation sustainable use of ecosystems and the protection of biodiversity has been unremitting and its influence on governments around the world profound. The principal goals of area protection are conservation. IUCN in its authoritative statement on resources conservation, the World Conservation Strategy (IUCN 1980), defines conservation as the management of the biosphere (the thin covering of the planet that contains and sustains life) so that it may yield the greatest benefit to present generations without losing its potential to meet the needs and ambitions of future generations. Such sustainable development cannot occur without conserving living resources, in the sea as well as on land. The three major goals of the World Conservation Strategy (WCS) are these:

1. To maintain essential ecological processes and life support systems (such as soil regeneration and protection, the recycling of nutrients, and the cleansing of waters), on which human survival and development depend.
2. To preserve genetic diversity (the range of genetic material found in the world's organisms), on which depend the functioning of many of the above processes and life support systems; the breeding program necessary for the protection and improvement of cultivated plants, domesticated animals, and microorganisms; much scientific and medical advance and technical innovation; and the security of many industries that use living resources.
3. To ensure the sustainable utilization of species and ecosystems (notably fish and other wildlife, forests, and grazing lands), which support millions of rural communities as well as major industries.

Article 192 (5) of the treaty says that: States have the obligation to protect and preserve the marine environment. This article not only provides a legal framework for preserving marine and coastal ecosystems, but also suggests that nations will be giving increasing attention to conserving coastal and marine living resources. In Indonesia, a major obstacle to attaining the major goals of WCS is the destruction of natural areas, so protecting habitats by establishing protected areas is essential. Also a major role of marine and coastal protected areas, in fulfilling the objectives of the WCS, has been considered the preservation of genetic resources in Indonesia.

Moreover, marine and coastal protected areas help maintain ecosystem productivity, safeguarding essential ecological processes by controlling activities that disrupt them or that physically damage the environment. Ethnically, Indonesia is complex and in the coastal zone is mixed (Sukardjo 2002). Thus marine and coastal protected areas in each island can address several goals simultaneously. Multiple objectives can allow simultaneous conservation and non-conservation activities. Creating marine and coastal protected areas can help achieve development goals and enhance the benefits of current use. Thus, conservation and management of mangroves and/or coastal – marine system are dependent upon a scientific base for direction, credibility, and understanding (Sukardjo 1990).

Understanding must be placed within the context of the physical, chemical, biological, and ecological patterns that define coastal and marine regions and to the need to place biodiversity in a dynamic, functional framework. This also must relate directly to the changes brought about by evolving human societies and their resource uses, perceptions, and values in each of the islands of Indonesia. Reactive management alone is insufficient to safeguard the values of coastal and marine habitats and species, e.g., Mahakam delta in East Kalimantan. In Mahakam delta, management must be planned to meet both the immediate needs of people and their future needs through conservation. Safeguarding critical habitat for fish production, preserving genetic resources, protecting scenic and coastal areas, and enjoying our natural heritage all may sometimes require the strict protection of natural areas.

In some areas, e.g., Batu Ampar, West Kalimantan, limited uses (such as fishing, rotational tree felling for poles and charcoal production, and use by tourists) may be permitted on a sustainable basis. While careful design and implementation of management can ensure continued benefits from natural areas, some types of benefits inevitably conflict, e.g., silvofishery (Sukardjo 2000).

Biodiversity and biogeography have been proposed as the contextual basis for representation. These approaches are part of the same paradigm; biodiversity describes the what and biogeography describes the where and the when. The how is implied by the functional relationships among the biota and ecosystems. These relationships must become the objectives for long-term, sustainable conservation management (Sukardjo 1991). Biodiversity is the vast number of organisms that under-pin the functioning of a biological system. In the coastal wetlands in Indonesia, it includes the variability among living organisms from all sources, including terrestrial and marine ecosystems (**Table 10**). It also includes diversity within species and between species. Thus, in Indonesia mangrove vegetation distribution pattern is frequently used as the only biotic component in conservation evaluation program, and the inclusion of many more taxa undoubtedly improves the resolution power of any subsequent site value rankings, e.g. in Java (Sukardjo 1990).

Farnsworth & Ellison (1997) discuss various conservation issues concerning mangrove ecosystems and they conclude that more information and education needs to be disseminated at the local level. It’s that mangroves conservation is everybody’s business (Sukardjo 1987b, 1990, 1991, 1994b). Three principal categories of issues relating to use and conservation of mangroves in Indonesia can be identified:

1. Legislative and administrative issues (e.g., planning co-ordination, coastal development control, etc.).

2. Social and economic issues (dredging, extractive industries, educational uses, etc.), and

3. Ecological and bio-physical issues (exotic species, vegetation clearing, migratory birds, greenhouse effects, etc.).

It is therefore, sustainable uses and/or sustainable production of the mangrove ecosystem should be the key word for decision makers at the central government, provincial up to district levels (**Tables 11, 12**). One of the major constraints on development of a mangrove conservation plan for improving the quality of life of mangrove dwellers is lack of basic knowledge about community structure, resource utilization, and economic conditions of people living in and around mangrove forest communities.

Table 11. National responsibilities for sustainable uses of mangrove ecosystems in Indonesia (Source: summarized from Sukardjo *et al*. 1997)

Task	Outcome
1. Compile a national mangrove inventory	1. Extent of mangroves, economic, social and ecological importance of mangrove areas
2. Devise a national policy for use of mangrove areas	2. Acts, statutes, regulations covering mangrove areas
3. Categorize the use of mangroves throughout the country	3. Forest, fisheries and conservation areas, traditional users, alienable land.
4. Establishment of a permanent mangrove estate	4. Designate national forests, fisheries and conservation reserves
5. Encourage sustainable use of mangrove areas	5. Increase community involvement, educational and recreational activities, awareness of importance of mangroves and value of mangrove products

Table 12. Tasks at site level for sustainable production of mangrove ecosystems in Indonesia (Source: summarized from Sukardjo *et al*. 1997).

1. Preparation of management goals and objective
2. Full inventory of site
3. Analysis of economics of the operation
4. Development of rational working goals
5. Enforcement of laws against unauthorized use of the site
6. Consultation with local communities
7. Training of workforce
8. Environmental impact assessment before commencement of operation
9. Strict pollution controls
10. Creation of buffer zones between the site and any adjacent developments
11. Research on growth and productivity of the site
12. Use of sound harvesting and extraction techniques which promote natural regeneration
13. Implementation of restocking program, and 14. Conservation and protection of critical habitat within the site

Mangrove ecosystem – an appeal for sustainability

Mangroves in most islands of Indonesia are renewable resources which can be put to many uses. These have been the traditional source of timber for the production of charcoal, firewood and poles, they are also the source of nipa leaves for thatching and cigarette roles and sap for sugar and alcohol production, barks for tannin and a source of medicinal plants and others forest minor products (e.g., Becking *et al*. 1922, Burkill 1935, Heyne 1950, Sukardjo & Yamada 1992b, Sukardjo *et al*. 1997, Bandaranayake 1998). Sustainable production of natural products seeks to avoid environmental disasters in the short and long term and to encourage preservation of the natural system as much as possible. Despite a recent better understanding and awareness of the role of mangroves, these coastal forest communities continue to be destroyed or degraded (or euphemistically 'reclaimed') at an alarming rate.

Although the mangrove forests represent an important part of the marine ecosystem, very little is known about the mangrove ecosystem in the SE Asia and Indo-Western Pacific areas (e.g., Clough 1982, Bardsley *et al*. 1985, Field & Dartnall 1987, Hong & San 1993, Miyagi 1999, Primavera *et al*. 2004). Some work has been done on descriptive floral and faunal surveys but not an integrated floral and faunal functional analysis. In Indonesia, ecological questions in mangrove ecosystems are directed at an array of processes occurring at different temporal and spatial scales. Therefore, the mangrove ecosystem, which encompasses the coastal tidal swamps and the numerous streams that flow through it, has been widely acknowledged to play a significant role in the sustenance of coastal marine fisheries in the tropical world, especially in the South China sea regions (Talaue-McManus 2000). However, the aquatic faunal associations with the mangroves in Indonesia have not been fully understood owing to the paucity of studies carried out in this field. Nevertheless, the fact that the mangrove ecosystem is a highly productive one makes it an invaluable habitat for fish, crustaceans and mollusks to generate their life habits of propagation, larval development and growth. For example, fish and crustaceans are frequently associated with structurally complex habitats that provide a refuge from predators (William & Bell 2004).

Several ecological and economic characteristics of mangroves in Indonesia are now relatively well understood:

1. Mangrove forests perform multiple ecological function (e.g., production of woody trees, provision of habitat, food and spawning, breeding and feeding grounds for fish and shellfish, provision of habitat for birds and other valuable fauna, protection of coastlines and accretion of sediment to form new land), and some of these functions have benefits far beyond the geographical limits of the mangrove zone itself.

2. Mangrove areas have high biological productivity associated with heavy leaf production and litterfall, and rapid decomposition of the detritus.

3. The mangrove ecosystem is dynamic, changing in both location and composition, and has great resilience with the ability to restore itself after heavy damage, as long as seed sources and water flow are maintained.

4. There are many direct economic benefits from mangrove resources (mangroves may be, e.g., a source of firewood and charcoal, self-renewing sites for collecting fish and shellfish, sites for collection honey, an attraction for tourism).

5. In cooperation with irrigated farms and upland forests, the relatively undisturbed mangrove forests in Indonesia and in Southeast Asia provide a salubrious environment for people, associated with the absence of vectors for important diseases. In the relatively undisturbed state, mangrove forests do not support the reproduction of the local brackish-water malaria mosquito *Anopheles sundaicus*. This is in contrast with New Guinea (includes Irian Jaya), where highly effective malaria vectors (*A. farauti*) breed in undisturbed mangrove areas, so that malaria inhibits human settlements in these zones (**Table 13**). Others are the most common diseases caused by *Vibrio cholerae* and *V. parahaemoliticus*. Health therefore, is to minimize the sources of disease by maintaining the ecological balance of the mangrove ecosystem, and not merely the absence of disease and infirmity.

6. Mangrove zones are useful for a great variety of human settlements, ranging from villages for near-subsistence fisher-

folk to housing and industrial developments.

Table 13. Malaria vectors associated with mangroves modification (Source: Sukardjo *et al*. 1997).

Country	Mangroves Modification	Brackish Water Malaria Vector	Malaria
Indonesia	Fish ponds (Tambak)	Anopheles sundaicus	+
Burma/Myamar	Charcoal production	A. sundaicus	+
Malaysia	Nypa fruticans plantation	A. hackeri	+
PNG	n.a	A. farauti, A. punctulatus	++
Philippines	Fish ponds, Export Wood, Agriculture, Urbanization, Coconut plantation	A. sundaicus, A. litoralis	-, +
Thailands	Urbanization	A. subpictus	n.a
VietNam	Military defoliation, Construction of irrigated fields	A. sinensis	+

In Indonesia, sustainability of the mangrove ecosystem should be based on the cultural perception, economical consideration and ecological basis (Sukardjo & Toro 1988, Sukardjo 1991). It is therefore, the criteria used to identify priority areas for the establishment and improved mangrove protected areas are outlined in **Table 14**, and the tasks for the ecologists are summarized in **Tables 15** and **12**. Sustainability means the commitment of the country to use all the mangrove resources based on the ecological principles (**Tables 1, 3**). Thus the management of the protected areas and/or forest areas is not under the control of administrative boundary of the provinces (**Tables 10, 12**). Cooperation among the provinces in the country is necessary step and important principle.

Table 14. Categories of protected areas and corresponding conservation objectives (Source IUCN In-press).

Primary Conservation Objectives	I	II	III	IV	V	VI	VII	VIII	IX	X
1. Maintain sample ecosystems in natural state	1	1	1	1	2	3	1	2	1	1
2. Maintain ecological diversity and environmental regulation	3	1	1	2	2	2	1	2	1	1
3. Maintain open options; manage flexibly; permit multiple use					3			3	2	1
4. Conserve genetic resources	1	1	1	1	2	3	1	3	1	1
5. Conserve watershed condition	3	3	3	3	2	3	3	3	3	3
6. Control erosion, sediment; protect downstream investments	3	3	3	3	3	3	3	3	3	3
7. Produce protein and animal products from wildlife; permit sport hunting and fishing			2		3	3	3	1	3	
8. Produce timber, forage or marine products on sustained yield basis				3	2		3	1	3	
9. Provide educational, research and environmental monitoring	1	2	1	1	2	3	2	2	1	1
10. Provide recreation and tourism services		1	2	3	1		3	1	3	1
11. Protect sites and objects of cultural, historical and archaeological heritage		1	3		1	3	1	3	2	1
12. Protect scenic beauty and open space	3	1	2	2	1			3	2	1
13. Stimulate rational, sustainable use of marginal areas and rural development	2	1	2	2	1	3	2	1	2	2

Note: 1= Primary objective for management of area and resources, 2= Not necessarily primary, but always included as an important objective, 3= Included as an objective where applicable and whenever resources and other management objectives permit. I= Strict Reserve, II= National Park, III= Monument/Landmark, IV= Managed Reserve, V= Protected Landscape/Seascape, VI= Resources Reserve, VII= Anthropological Reserve, VIII= Multiple Use Area, IX= Biosphere Reserve, X= World Heritage Site.

Table 15. Summarized of tasks for ecologists in the implementation of a sound conservation policy in the mangrove ecosystem in Indonesia (Source: Sukardjo 1990).

1.	Promoting an active and sound use of the country's natural resources, including (a). Cooperation in town planning and development, (b). Cooperation in the planning of green belts, rehabilitation/restoration and the conservation of historical parks, (c). Nature conservation in general, i.e., of fauna, flora, water, air and soil.
2.	Research: (a). Of areas in need of conservation, (b). Biological studies of animals and plants requiring conservation, (c). Studies of natural and man-induced changes, (d). Study and documentation of sectors set aside for the building of 'Masyarakat Adil dan Makmur' (Society Peace and Welfare) and also of future industrial regions as potentially interfering with the conservation of natural resources.
3.	Cultural tasks: (a). Propagation of principles, ideas and aims of nature conservation by means of lectures, exhibitions, films and excursions, (b). Publication of a journal, supported by the government agencies (Pusat, Daerah, KLH, Departemen Penerangan, Departemen Pendidikan), and/or 'swasta' (private), reflecting the efforts of the government in its conservation venture, and of articles on conservation in other media.

CONCLUDING REMARKS

No one opposes the view that the mangroves in Indonesia are valuable and an important resource for human being. There is no objection that mangroves or mangrove ecosystems play a vital role in the income generation of many peoples (**Table 8**). Consequently, the mangroves or mangrove ecosystems are the resources under conflict which need to be guarded for their sustained yield production, e.g., mangrove ecosystem in the Solo-Brantas deltas, East Java (Davie & Sumardja 1997). Moreover, following the general increase in activity around the Indonesian coastline, the public has become more aware of their presence and scientists have become interested in their biology and ecology. The biological information, such as the reproductive biology, recruitment patterns of early stages, and population dynamics of exploited crustacean's species is crucial for profitable and rational fishing strategies, effective coastal management and increased awareness of the need for mangrove conservation and restoration (Sukardjo 2002). Also, as a means of maintaining global bio-diversity, increasing attention is being given to restoration and/or rehabilitating and creating a variety of coastal habitat, e.g., GNRHL (Gerakan Nasional Rehabilitasi Hutan dan Lahan, National Movement for Forest and Land Rehabilitation). This awakening of interest had led to a growing realization that many natural coastal resources may depend on their survival. Thus ecology is the only way to solve many problems in the managing of these valuable resources, since the management approach cannot be restricted by administrative boundaries (e.g., **Table 10**). Ecology, the science that deals with interaction of organisms in their environment, is negatively linked with human interactions in natural habitats, e.g., in coastal zone (**Table 3**). An understanding of mangrove ecosystems and their ecology will provide data to be used in opposing destruction or if necessary to manage their exploitation. It has become imperative now that ecological principles, and the ecology of specific regions (e.g., mangrove forests), be understood by a wide variety of people. Unfortunately, the stakeholders put the mangroves in sectoral egoism/conflict and debates. The debates always far from the scientific merit, often only to shown their un-ability to understand the mangroves and/or mangrove ecosystem properly, even on their basic ecology and taxonomy. Recently, there are many stakeholders of the mangrove ecosystems in Indonesia agreed well that the mangroves are considered as a national resource. Therefore, the participatory of the people and/or inhabitants around the mangrove ecosystem should be considered as an element for the sustainable mangroves management (See: **Figure 2** for the scenario of system, **Tables 8** and **16**). Understanding the mangrove ecology become necessary step for all parties concerns with the mangroves and/or mangrove ecosystems. Without such information, any program for the rehabilitation, conservation and management of mangrove systems in Indonesia rests largely upon speculative interferences. Moreover, a significant component of the economic potential of mangrove swamps is the exploitation of their macro-benthic species, particularly crustaceans and mollusks. Fortunately, the problems faced by fishery development in Indonesia constraint the used of the fishery potential and it should be first carefully solved (**Table 16**). The mangroves of Indonesia's coast are of outstanding scientific interest because of their many structural and physiological peculiarities, and therefore exhilarating to view and exciting to explore.

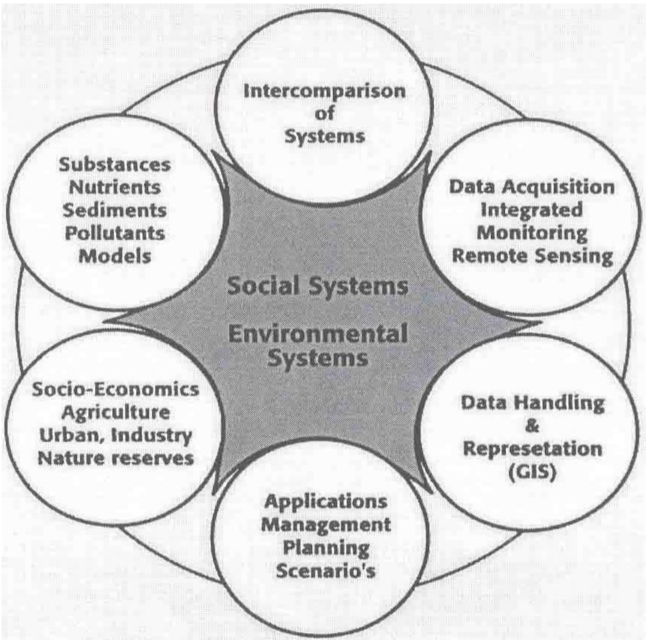

Figure 2. Mangrove Ecosystem in Indonesia: *Changing System and Associated System*

Table 16. Sustainable Mangroves Management: A case study - Problems faced by fishery development projects in general in Indonesia as view by a mangrove ecologist.

Problem Category	Problem Type
1. Conceptual	(a). Too many or unbalanced components, (b). Too big, (c). Schedule too tight, (d). Non-sustainable, (e). Inflexible.
2. Technical	(a). Production technology, (b). Poor engineering.
3. Financial/Economic	(a). Under-estimated costs, (b). Counterpart and recurrent budget shortage, (c). Low output prices or market problems.
4. Social	(a). Inequitable benefit distribution, (b). Slow adoption.
5. Institutional	(a). Bad management or staffing, (b). Unsuitable organizational structure, (c). Ineffective technical assistance, (d). Procurement difficulties, (e). Land acquisition difficulties, (f). Poor monitoring and evaluation.
6. Environmental	(a). Natural disaster, (b). Resource degradation.
7. Political	(a). Turmoil or war/conflict, (b). Insufficient government commitment.

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