Cuscus *(Ailurops ursinus)*, a rare nocturnal mammal, is a timid animal and hides among the trees of Indonesia's tropical forests.

Pimeleodendron amboinicum can reach a height of 20 m, with diameter of 130 cm. Locally known as Daso-daso, it grows on the slopes at 150 m above sea level, and is found in Southeast Sulawesi and Maluku. Its straight and strong trunk is often used for building material, board and pillars.

3 THE STATE OF BIODIVERSITY IN INDONESIA

The previous chapter described the value and significance of biodiversity, particularly for sustaining development in Indonesia. In order to utilise this asset(s) wisely, we need to know the potential and condition of national biodiversity at present.

Indonesia has an important position in terms of global biodiversity, since it is one of the ten countries with the richest biodiversity, often known as *megadiversity country* (Primack et al. 1998). Table 3.1 presents the characteristics of megadiversity countries. The figures in the table have not included the diversity of coral reef species Indonesia, or the soil and cave biota as well as their associated organisms, although Indonesia is reported to have the highest cave fauna diversity in the world (Bedos et al. 2001). If all these components are taken into account, Indonesia could well be on the top of the list in terms of biodiversity richness.

Indonesia's geological history and topography supports its biological diversity and uniqueness. For instance, Indonesia is an archipelagic country located in the biodiversity distribution path of the Asian continent (Java, Sumatra and Kalimantan islands) and Australia (Papua), and in the transitional zone of the Wallace line (Sulawesi, Maluku and Nusa Tenggara islands), and therefore harbors the biological richness of Asia, Australia and the transitional zone of the two continents. The geological history of each island in Indonesia gave rise to the climate variations, which is wet in the western part and drier in the eastern part, thus influencing the ecosystem formations and flora and fauna distribution.

(Doc. BirdLife-Indonesia)

Figure 3.1. Cave ecosystems are relatively little studied in Indonesia.

Table 3.1. Countries with highest diversity and endemism.

Country	Diversity value	Endemism value	Total value
Brazil	30	18	48
Indonesia	18	22	40
Colombia	26	10	36
Australia	5	16	21
Mexico	8	7	15
Madagascar	2	12	14
Peru	9	3	12
China	7	2	9
Philippine	0	8	8
India	4	4	8
Ecuador	5	0	5
Venezuela	3	0	3

Source: Mittermeier et al. 1997.

Note: Diversity value is calculated based on the diversity in five vertebrate groups (birds, mammals, reptiles, amphibians, and freshwater fishes), two invertabrate taxa (butterfly and tiger bettle), and higher plants. Endemisme is calculated based on four vertebrate groups (birds, mammals, reptiles, amphibians), two invertabrate taxa (butterfly and tiger bettle) and higher plants.

POTENTIALS

Indonesia is estimated to have 90 ecosystem types, from snow peaks at Jayawijaya, alpine, sub-alpine, montane to lowland rainforests, coastal forest, grasslands, savannah, wetlands, estuaries, mangrove and marine and coastal ecosystems, including sea grass and coral reefs to deep sea ecosystems. Although it covers only 1.3% of the total landmass in the world, Indonesia harbors a very high fauna species diversity, as outlined below (Dephut 1994; Mittermeier et al. 1997):

- About 12% (515 species, 39% endemic) of the total mammal species, second in the world.
- 7.3% (511 species, 150 endemic) of the total reptile species, fourth in the world.
- 17% (1531 species, 397 endemic) of the total bird species burung, fifth in the world.
- 270 species amphibians, 100 of which are endemic, sixth in the world.
- 2827 invertebrate species.

Furthermore, Indonesia has 35 primate species (ranking fourth in the world, 18% of which are endemic) and 121 butterfly species (44% endemic). Perhaps Indonesia is the only country after Brazil and maybe Colombia that has the highest freshwater fish diversity, about 1400 species (Dephut 1994; Mittermier et al. 1997).

(Doc. Payne et al. 2000)

Figure 3.2. The proboscis monkey (*Nasalis larvatus*) is an endemic primate in Kalimantan.

(Doc. Bogor Botanic Garden)

Figure 3.3. Palms are one of the multi purposes plant species spread widely in the Indonesian forests.

In terms of plant diversity, Indonesia ranks fifth in the world, with more than 38,000 species (55% endemic). Palm diversity in Indonesia ranks first in the world, with 477 species (225 of which are endemic). More than half of the total timber producing tree species (350) with economic value (members of the Dipterocarps family) are found in this country, 155 of which are endemic to Kalimantan (Dephut 1994; Newman 1999).

These figures will certainly be higher as the on-going field studies all over the country are completed. But, they may be reduced since the existence and condition of biodiversity is influenced by the practices and behavior of community and cultures, which in Indonesia have a high diversity as well.

This chapter will briefly describe the state of biodiversity agriculture, forest, wetlands, and marine and coastal ecosystems. Each of these four sections consists of a description on the state of the resource, significant value, and threats or problems causing its degradation. Data is largely obtained from literature and interviews with relevant resource persons. However, it should be noted that comprehensive data to illustrate the state of biodiversity in Indonesia, especially time series data, is often not complete, scattered, outdated, and different sources often provide different data. This fact has a bearing on the accuracy of the description provided in this document; but such limited information are still useful to provide an indication of the destruction level of biodiversity in Indonesia.

In addition, this chapter will touch on the state of species and genetic diversity, particularly in terms of their degradation. Finally, this chapter discusses cultural diversity as an integral part of biodiversity management, especially in the context of traditional wisdom systems.

FOREST ECOSYSTEM

In Indonesia there are about 15 natural forest formations, covering an area of about 119 million hectares (RePPProT, *in* Zuhud and Putro 2000). Main forest types range from lowland evergreen forests in Kalimantan and Sumatra, monsoon forests and savannah in Nusa Tenggara, to alpine forests in Papua. Indonesia's forests are very important for the international community since it covers approximately four percent of the world's *frontier forest* (vast areas of natural forests, with complete ecosystem compositions and relatively undisturbed, thus natural ecological and succession processes can continue) (Bryant et al. 1997).

In Indonesia there are also community forests (tree gardens), that is forests managed by communities through agroforestry systems. Some examples are the *damar* (resin tree) gardens in Lampung, mixed rubber gardens in Jambi and South Sumatra, *tengkawang* (ellips nuts) and fruit, and mixed durian gardens in West Kalimantan, cinnamon gardens in West Sumatra and Jambi, and mixed tree gardens (*kebun talun*) in West Java. The rich plant and animal diversity in these many forms of community and secondary forests have not been much studied.

Forests are the main natural habitat for so many plant and animal species such as fungi, moss, ferns, flowering plants, orchids, insects, amphibians, reptiles, birds and mammals. The potential and endemism level of plant and animal biodiversity in each bioregion is different, based on the different forest ecosystems. Table 3.2 provides the potentials and endemism level of mammals, birds, reptiles and plant in each bioregion.

Indonesia's forests are also valuable sources of internationally traded timber; there are about 120 families (267 species) of high quality timber that dominates the international timber trade (Dephut 1991). In addition, Indonesia's forests contain about 1300 plants known to have medicinal properties (Sangat et al. 2000).

Benefits and value of forest ecosystem

Forests have various economic, social and environmental benefits and value. Indonesia's forest biological resources provide economic benefits through the production of commercial timber, non-timber forest products, fruits, medicine, game and food materials. Forest areas also provide tourism services that are important for Indonesia's tourism development. In 1998/1999, some 3.5 million domestic and international tourists visit conservation areas (Ditjen PHKA 1999). Forests provide ecological benefits by functioning as provider of environmental services, such as hydrological functions, microclimate regulation, providing habitat for wildlife and valuable genetic resources. Forests also have social cultural functions for many indigenous and local community groups.

The monetary value of all these benefits has been partially calculated and a summary is

Table 3.2. Species diversity and endemism in each bioregion.

Island	Bird	Endemic (%)	Mammal	Endemic (%)	Reptile	Endemic (%)	Plant	Endemic (%)
Sumatra	465	2	194	10	217	11	820	11
Java-Bali	362	7	133	12	173	8	630	5
Kalimantan	420	6	201	18	254	24	900	33
Sulawesi	289	32	114	60	117	26	520	7
Nusa Tenggara	242	30	41	12	77	22	150	3
Maluku	210	33	69	17	98	18	380	6
Papua	602	52	125	58	223	35	1030	55

Source: BAPPENAS 1993, WCMC 1994.

provided in Table 3.3. Another example is the value hydrological services provided by the Gede-Pangrango National Park (NP) as provided in Table 3.4. Due to differences in the valuation approach, sometimes the monetary values may also be different.

Resource degradation and depletion

Forest ecosystems are facing threats such as deforestation, fragmentation and conversion into other uses. The World Bank estimates that by 2005 lowland forests in Sumatra will disappear, a similar fate will be faced by Kalimantan in 2010, while in Sulawesi only 11% of the forest ecosystem will be left in 1997 (see Figure 3.4). Forest Watch Indonesia, a forum of 20 NGOs, that conduct studies on the state of the forest in Indonesia, reported in 2002 that since 1996 deforestation rate is about two million hectares per year.

Although different, formal data also indicates an alarming forest degradation rate. Based on the 1993 Forestry Statistics, forest area was estimated to be about 141.8 million hectares, while in 2001 this was reduced to about 108.6 million hectares. In eight years forest area was depleted by 32.2 million hectares.

Table 1 in Appendix 1 presents a comparison of forest areas in 1993, 2001 and 2002 based on their functions, i.e.: 1) production forest, consisting of permanent production forest (HP), limited production forest (HPT) and production forest that can be converted (HPK); 2) conservation forest (HSAW), and 3) protected forest (HL).

The data shows that the Kalimantan bioregion experiences the highest rate of forest reduction, 12.8 million hectares within a period of eight years or an average of 1.6 million hectares/year. Degradation occurs in all forest types, but the highest is in production forest (HP and HPT). The second highest rate of forest depletion is experienced by Sumatra, 11.8 million hectares in the same period or an average of 1.5 million hectares/year. Depletion occurs in all forest functions, except conservation forest (HSAW) which actually increased slightly in area. Forest depletion in Sulawesi is about 1 million hectares/year. In other bioregions, there is a slight increase in forest areas, mostly due to addition in protected and conservation forests.

Depletion in production forest areas, particularly in Kalimantan, Sumatra and Sulawesi together with changes in land cover indicates a significant reduction in forest cover. Recalculation of production forest by MoF based on Landsat images in 1997 to 1999 showed that out of the 46.7 million hectares production forest, actual primary forest was only 41%; logged over areas in good to moderate condition was about 2%; and the remaining 30% was degraded forest areas. Another calculation on forest cover all over Indonesia by FWI is presented in Tables 2 and 3 in Appendix 1.

The recent official data shows that degraded forest area in Indonesia amount to 43 million hectares, with an average deforestation rate of 1.6-2.4 million hectares/year. Deforestation is 0.20% per year in Sumatra, 0.42% in Java, 0.94% in Kalimantan, 1% in Sulawesi and 0.70% in Papua (Dephut nd).

One clear example on the cause of the depletion and degradation of forest ecosystem is forest and land fires in 1997-1998, which burnt no less than 9.75 million hectares of forest in

Table 3.3. Estimation of selected values of forest biological resources in Indonesia.

Benefit	Value
Timber products	US$ 6.5 billion
Value of non-timber forest products - domestic	Rp. 40,917,911,000
Value of non-timber forest products - export	Rp. 295,196,930,000
Medicinal plants	US$ 14.6 billion
Wildlife	US$ 1,575,817,500
Tourism services	Rp 37.15 billion (only for Leuser NP)
Food sources	Rp. 308,462,376,000 (only for Papua)
Direct and indirect values	Rp. 16.3 billion/year (Alas Purwo NP)
ecological benefits	Rp. 123.11 billion/year (Gede-Pangrango NP)

Sources: Departemen Kehutanan 1995/1996-1999/2000, Zuhud and Putro 1994, Dirjen PHKA/PKA 1997, Ditjen PHKA 1996, BPS 2001, Windarti 1995, Setianingrum 1996.

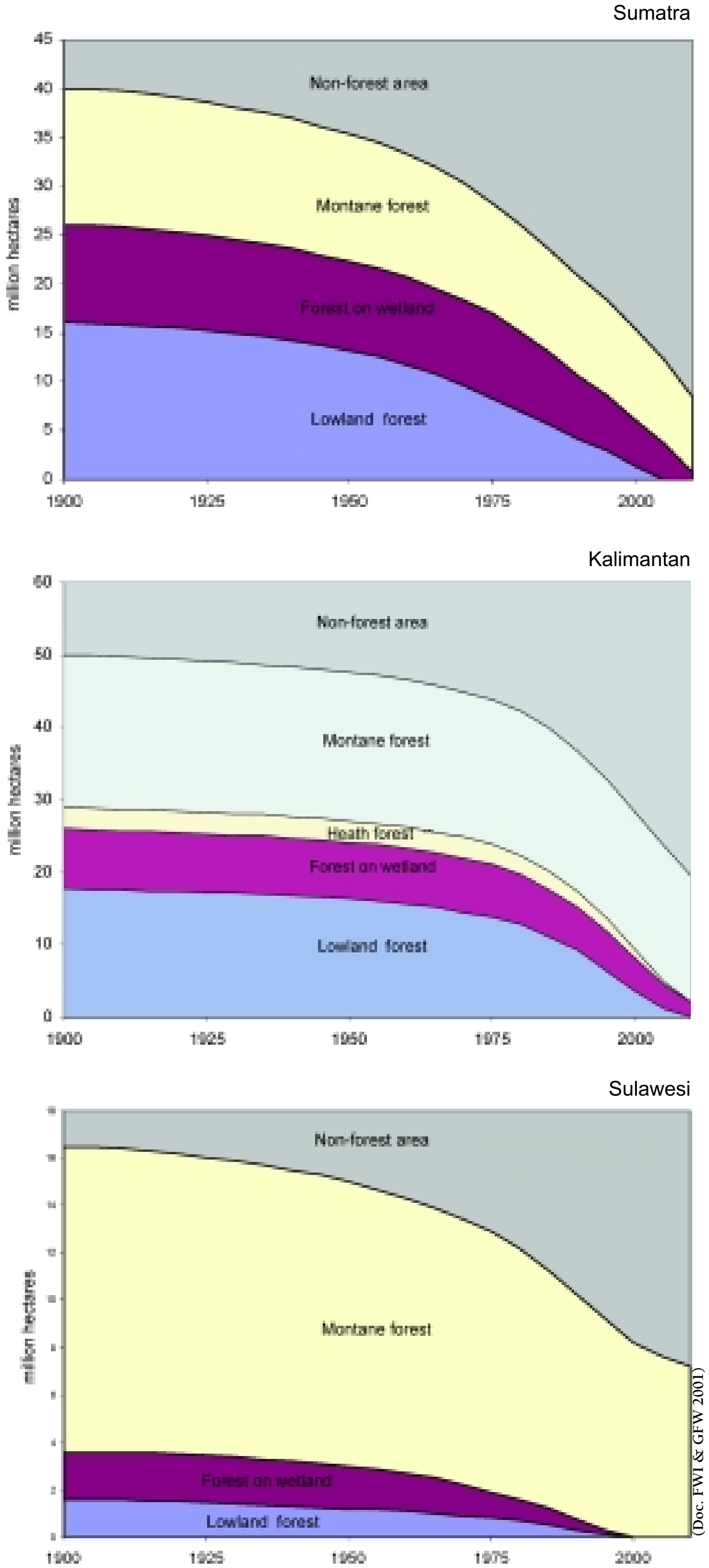


Figure 3.4. Change in forest covers in Sumatra, Kalimantan, and Sulawesi, 1900-2010.

(Doc. Ministry of Forestry)

Figure 3.5. Forest fires often cause economic loss as well ecological damage.

the five major islands of Indonesia. In Kalimantan and Sumatra 3.1 million hectares of lowland forest and 1.45 million hectares of peat swamp forest were damaged by the fire (BAPPENAS *in* Barber and Schweithelm 2000).

Forest depletion and degradation threatens the integrity of forest ecosystem and the wildlife living in it. The rate of species depletion in Indonesia is discussed in the section of **State of Species and Genetic Diversity**.

MARINE, COASTAL AND SMALL ISLAND ECOSYSTEMS

The marine and coastal ecosystem is a complex resulting from the integration of physical, biogeochemical and biological interactions. The official classification of marine ecosystem has only been recently developed but for a limited level and scope. It is possible that important marine ecosystems may not yet be identified and thoroughly studies, because of limited reference as well as constraints in supporting technologies.

Many different classification systems exist for coastal areas, depending on the objectives. However, in general two types of data are used in classifying coastal areas, i.e.:

- Detailed research of a closed area based on influencing factors at the local level, such as substrate, habitat, current patterns, waves and climate; and,
- Global approach based on one or two types of data, such as ecosystem type (Wilkinson and Buddemeier 1994) or geomorphology (Jelgersma et al. 1993).

Given the limited availability of knowledge, the ecological perspective is most often used to study coastal and marine areas. There are many studies from the geological and geomorphologic perspective but their results have not contributed significantly to the knowledge

Table 3.4. Total value of hydrological services in Gunung Gede-Pangrango NP.

Household Sector	Value (per year)
a. Tap-Water (PAM) consumers in:	
• DAS Cimandiri Hulu	Rp. 2.09 billion
• DAS Ciliwung Hulu	Rp. 0.65 billion
• Sub DAS Cisokan Tengah Hilir	Rp. 2.2 billion
b. Non-tap water consumers in:	
• DAS Cimandiri Hulu	Rp. 18.95 billion
• DAS Ciliwung Hulu	Rp. 6.76 billion
• Sub DAS Cisokan Tengah Hilir	Rp. 25.59 billion
Agriculture	
• DAS Cimandiri Hulu	Rp. 20.65 billion
• DAS Ciliwung Hulu	Rp. 4.13 billion
• Sub DAS Cisokan Tengah Hilir	Rp. 42.17 billion

Source: Windarti 1995.
Note: PAM is the state water company (Perusahaan Air Minum); DAS is the watershed areas (Daerah Aliran Sungai).

of ecosystem classification in marine, coastal and small island areas. In marine, coastal and small island zones, there are several unique but interrelated ecosystems, which are also dynamic and very productive. Bengen (2001) listed several marine and coastal ecosystems from the ecological perspective, consisting of estuaries; mangrove; sea grass; coral reef; rocky and sandy beaches; and small islands.

In addition to ecosystem diversity, Indonesia's seas also contain fish and other biotic resources with a Maximum Sustainable Yield (MSY) amounting to 6.4 million tons/year. Marine resources consist of large and small pelagic fish, demersal, and reef fishes, penaeid shrimps, lobster and squids. MSY of various waters in Indonesia is presented in Table 1 of Appendix 2.

This document contains more description on coral reef and mangrove since data on other ecosystems are not sufficient. According to the Ramsar Convention (see the section **Wetlands Ecosystem**), both coral reef and mangrove are included in the wetlands ecosystem. However, given the importance of these ecosystems, particularly in the light of Indonesia as an archipelagic country, discussion on the two ecosystems are provided separately in this section.

The various marine and coastal ecosystems are described below.

Estuaries

Estuaries are rather closed coastal areas that have connections to the open sea, and receive freshwater supply from inland. This ecosystem is dominated by loam substrate that is deposited from the lands by the hydrological systems and flooding of seawater. Examples of the estuary ecosystem are the river mouths, bays and tidal swamps.

In the tropics there are three types of estuaries based on the geomorphology characteristics: terrestrial coastal estuary, lagoon or semi-closed bay, and tectonic estuary. The last type is not found in Indonesia and other tropical areas, because it is formed through the activities of glaciers that cause the flooding of ice valleys by seawater.

a. Coastal estuaries are the most common, formed by the rise in seawater that floods rivers in flat beaches.
b. Lagoon or semiclosed bays are formed by the prevention of open and direct interaction between marine waters and the land due to dunes or sand hills that are parallel to the coastline.
c. Tectonic estuaries are formed by tectonic activities (earthquake or volcanic eruption) which lower the land surface, which in turn will be flooded by sea water during high tide.

Estuaries have ecological functions and benefits as suppliers of nutrition and biological resources for life forms in this ecosystem and the surrounding habitat, through the natural exchange that occur during tidal changes. This ecosystem is the habitat for several animals, mainly providing protection and feeding areas. For certain fish and shrimp species, estuaries are important nursery and spawning grounds.

There are three main fauna components in this ecosystem, i.e. marine, freshwater and brackish water fauna. The marine fauna dominates in this ecosystem, i.e. animals that have low capacity to adjust to changes in salinity (*stenohalin*), generally at below 30 ppm and those that can adapt to reduction in salinity up to 30 ppm (*eurihalin*). The brackish water fauna are made up of those that can adapt to salinity of 2-30 ppm.

The number of species living in estuaries is far less compared to those living in fresh and seawater. This is due to the highly fluctuative environment, thus only species that have special capability in this environment can survive. Estuaries also have less flora diversity.

(Doc. State Electricity Comapny)

Figure 3.6 Fishing is an important economic activity for communities living near and around estuaries.

The turbid water means that only emergent plants can survive, such as the nypah (*Nypa fruticans*).

The water column in estuaries are habitats for plankton (phytoplankton and zooplankton), neustons (organisms similar to plankton that live on the surface of the water), and nektons (active macro organisms such as fish and insects). At the bottom of estuaries there are various macro and micro benthic organisms. Phytoplanktons are microscopic plants which float at or stay near the water surface. They are the main agents of photosynthesis that are dependent on bacteria whose function is to break down biological materials into nutrition that can be used by communities living in the water.

The unique characteristic of organisms living in estuaries is their ability to adapt to their environment. Morphological adaptation is indicated by the presence of fine hair (*setae*) in estuary organisms whose function is to prevent blockage of respiratory tract by mud. Physiological adaptation is shown by maintaining the ionic balance of their body fluids in order to adapt to the fluctuation in salinity. Behavioral adaptation is done by making holes in the mud to survive harsh environments, especially among invertebrates.

This ecosystem is often considered as having no economic benefits and is therefore considered dispensable when developing infrastructure in coastal areas. Conversion of estuary ecosystem is generally done in the process of building settlements, ports, industrial areas and transportation routes. However, fishing and fish culture are important economic activities in estuaries.

Mangroves

Mangrove is the collective term for tree vegetation that grow in muddy coasts in tidal areas, from the highest water level to the lowest tidal level. Mangrove forests occur only in coastal areas where the waves are broken by barriers such as sand, coral reef or islands. They can be classified into three main types: coastal/delta, river estuary/lagoon and island types (MacKinnon et al. 2000).

Mangroves cover an area of about 2.5 million hectares in Indonesia, during the early 1990s, with 89 plant species (Nontji *in* Dahuri et al. 2001). Table 3.5 presents the distribution of mangroves in Indonesia, while the plant species found in them can be seen in Table 3.6.

Table 3.5. Mangrove distribution in Indonesia (hectares).

Island	Mangroves		
	Original area	Current area	In Protected area
Sumatra	857,000	485,025	61.900
Java & Bali	171,500	19,577	2,600
Nusa Tenggara	38,600	25,300	2,500
Kalimantan	1,092,000	353,450	78,000
Sulawesi	272,500	84,833	6,300
Maluku & Papua	4,129,000	2,450,185	680,900

Source: Wetland-IP 1998.

Mangroves have diverse functions and benefits. The litter and other parts of mangroves which are carried by water provides important nutrition for coastal ecosystem and other ecosystem in the surrounding estuaries, without always being connected directly with the mangrove area and its productivity. Mangroves also serve as nursery grounds for young fishes, shrimps and other organisms such as crabs, clams and snails. Thus it is clear that mangroves have an important function in supporting coastal fishery. In addition, mangroves also protect certain coastal areas from abrasion. Mangroves also produce timber, of which *Rhizophora* is most preferred for building materials and rayon production. But such timber has not been harvested in a sustainable manner, and now not many places are left where *Rhizophora* timber can be harvested sustainably. Other mangrove products include fuelwood, timber for other uses, chemicals for tanning and dyes, oils, green manure, and nypah (*Nypa fruticans*), with potentials to produce alcohol (Mercer and Hamilton 1984 *in* Whitten et al. 1999). Mangrove vegetation is relatively well researched in Indonesia (Kartawinata 1990).

This ecosystem serves as habitat of various animals. Among others, mammals: javan lutung (*Semnopithecus auratus*), long-tailed macaque (*Macaca fascicularis*), small-clawed otter (*Aonyx cinerea*), fishing cat (*Felis viverrinus*), proboscis monkey (*Nasalis larvatus*), mangrove blue flycatcher (*Cyornis rufigastra*), mangrove whistler (*Pachycephala cinerea*), milky stork (*Mycteria cinerea*), rare lesser adjutants (*Leptoptilos javanicus*); reptiles: monitor lizard (*Varanus salvator*), common skink (*Mabuya multifasciata*), common cat snake (*Boiga dendrophila*), python (*Python

Table 3.6. List of plant species reported in Indonesia's mangrove forests.

		Distribution				
Family	**Species**	**1**	**2**	**3**	**4**	**5**
Species occuring only in mangrove						
Avicenniaceae	*Avicennia alba*	x	x	x	x	x
	A. marina	x	x	x	x	x
	A. officinalis	x	x	x	x	x
Bombacaceae	*Camptostemon schultzii*				x	x
Combretaceae	*Lumnitzera littorea*	x	x	x	x	x
	L. racemosa	x	x	x	x	x
Euphorbiaceae	*Excoecaria agallocha*	x	x	x	x	x
Flacourtiaceae	*Scolopia macrophylla*	x	x			
Leguminosae	*Cynometra ramiflora*			x	x	
Meliaceae	*Xylocarpus granatum*	x	x	x	x	x
	X. moluccensis	x	x	x	x	x
Myrsinaceae	*Aegiceras corniculatum*	x	x	x		x
Myrtaceae	*Osbornia octodonta*	x		x		x
Palmae	*Nypa fruticans*	x	x	x		x
Plumbaginaceae	*Aegialitis annulata*	?	?			
	A. rotundifolia				x	x
Rhizophoraceae	*Bruguiera cylindrica*	x	x	x		x
	B. exaristata					x
	B. gymnorrhiza	x	x	x	x	x
	B. hainesii					x
	B. parviflora		x	x	x	x
	B. sexangula	x	x	x	x	x
	Ceriops decandra	x	x	x		x
	C. tagal	x	x	x	x	x
	Kandelia candel		x			
	Rhizophora apiculata	x	x	x	x	x
	R. mucronata	x	x	x		x
	R. stylosa			x		x
Rubiaceae	*Scyphiphora hydrophyllacea*	x	x	x		x
Rutaceae	*Paramignya angulata*		x	x		
Sonnerataceae	*Sonneratia alba*	x	x	x	x	x
	S. caseolaris	x	x	x	x	x
	S. ovata	x	x	x	x	x
Sterculiaceae	*Heritiera littoralis*	x	x	x	x	x
Species occuring in association with mangroves						
Apocynaceae	*Cerbera manghas*	x	x	x	x	x
Bignoniaceae	*Dolichandrone spathacea*			x	x	
Lecythidaceae	*Barringtonia acutangula*	x	x	x		x
	B. racemosa	x	x	x		x
Malvaceae	*Thespesia populnea*	x	x	x	x	x
	Hibiscus tiliaceus	x	x	x	x	x
Palmae	*Oncosperma tigillarium*	x	x	x		
Tiliaceae	*Brownlowia argentata*	x		x	x	x

Source: (Chai 1975a, 1975b; Soegiarto and Polunin 1980; Saenger et al. 1983) *in* MacKinnon et al. 2000.
Note: 1. Kalimantan; 2. Sumatra, Java; 3. Sulawesi; 4. Maluku, Nusa Tenggara; 5. Papua.

reticulatus) and estuarine crocodile (*Crocodylus porosus*) are found in some mangrove areas; amphibians: mangrove frog (*Rana cancrivora*), insects (*Anopheles sundaicus* and *Aedes* mosquitoes) (Whitten et al. 1999).

Seagrass

Seagrass is the only flowering plant (Angiospermae) that has *rhizomes*, leaves and real roots which survive under seawater. Substrate colonisation in shallow waters is done through the dispersal propagules (Man 2000 *in* Bengen 2001). This colony forms a large carpet of seagrass in shallow seas, at the depth of 2-12 m, which still receive sunlight, and needs good water flow and exchange to transport nutrition and oxygen, as well as transport metabolites of seagrass outside the colony. Seagrass can grow in virtually all types of substrate, from loamy to rocky substrates. However, seagrass growing on sandy-loam substrate is the most common in Indonesia, located between mangroves and coral reef.

Seagrass perform many ecological functions and benefits to coastal and marine areas, among others, by producing detritus and nutrient, binding sediment and stabilising soft substrate through dense and interconnected root system, providing protection, feeding, spawning and nursery ground for several marine species, such as green turtle (*Chelonia mydas*) and dugong (*Dugong dugon*).

Human activities pose threats to seagrass due to the strong economic bias in considering the role of and benefits provided by seagrass. Like the estuary ecosystem, seagrass is often sacrificed for the development of coastal areas.

Seagrass ecosystem is not a separate entity, but interacts with other surrounding ecosystems, most importantly with mangrove and coral reef. There are five types of interaction between the seagrass, mangrove and coral reef ecosystems: physical, dissolved organic materials, particulate organic materials, fauna migration and human impacts (Ogden and Gladfelter 1983 *in* Bengen 2001).

Coral reef

The latest data on coral reef, obtained from satellite images, indicates that Indonesia's coral reef area is 21,000 km^2 (Mahdi Kartasasmita, Kompas 5 March 2003). Prior to this, coral reef was measured through projections and yielded different figures, ranging from 50,020 km^2 (Moosa et al. 1996 *in* KLH 2002) to 85,000 km^2 (Dahuri 2002). Another source, Reefbase (1997) reported that Indonesia harbors at least 14,000 units of coral reef in its islands, with an estimated total area of 85,700 km^2 or 14% of the world's coral reef. It should be noted that data on the state of coral reef in Indonesia is limited (only 40 locations have been studied in Indonesia), and therefore it is not possible to obtain a general picture, in contrast with the information on forests which is obtained through satellite images.

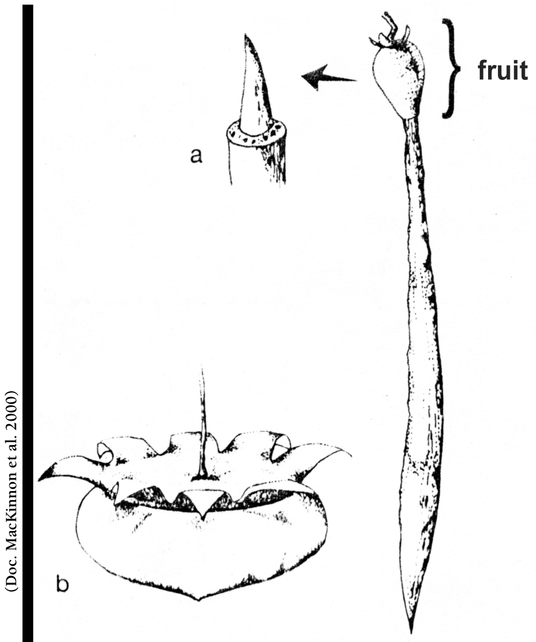


Figure 3.7. Propagules: (a) *Rhizophora mucronata,* showing the root and top of the seedling after it is detached from the parent tree, and (b) Fruit of *Sonneratia alba.*

Indonesia has one of the most biologically diverse coral reefs in the world. More than 480 hard coral species have been recorded in the eastern part of the country, covering about 60% of identified coral species in the world (Dahuri and Dutton, *in* Burke et al. 2002). Indonesia has the highest coral fish diversity in the world; more than 1650 species are found only in the eastern part (Suharsono and Purnomohadi, *in* Burke et al. 2002). Given that the survey on coral reef has yet to be completed, the knowledge on its biodiversity is still limited in Indonesia.

Beach/coastal ecosystem

According to Bengen (2001), coastal ecosystem is located between the lowest water line and the highest water level. This ecosystem varies from areas with rock and pebble substrate (supporting limited flora and fauna) up to active sandy areas (where bacteria, protozoa, metazoas are found), and areas with loam and mud substrate (where most infauna - animals that seldom emerge to the surface - are found). Coastal ecosystem consists of rocky and sandy beaches.

Rocky beaches are fertile coastal and marine areas. The combination of hard substrate for attachment, high wave frequency and clear waters provide a favorable habitat for marine biota. Rocky beach is the habitat of various marine molluscs, starfish, crabs, anemones, and algae.

Sandy beaches do not provide permanent substrate for organisms to attach themselves and survive, because the currents continuously shift the substrate particles. Two groups of organisms that can adapt to sandy substrate are macro infauna (1-10 cm in size) which can dig holes in the sand, and micro organisms (0.1-1 mm) that live in between sand particles in spaces influenced by tidal waves.

Small islands

Small island ecosystem is an insular terrestrial unit (separated from the mainland or main island), having an area of less or equal to 10,000 km^2 and less than 10 km wide (Bengen 2001; DKP 2001). Small islands have special physical and biological characteristics such as limited freshwater supply because of relatively small water catchment areas, sensitive and vulnerable to outside influences whether natural or human made, and, in some cases, have high flora and fauna endemism.

Fresh water in small islands mostly come from rainwater, only a small part comes from surface water (small rivers or groundwater). Fresh water sources in small islands are very much influenced by physiography, climate and hydrology, geology and hydrogeology, soil and vegetation, and impact of human activities (Falkland 1991 *in* Bengen 2001).

Benefits and value of marine and coastal ecosystem

Like forests, coastal and marine ecosystems also provide economic, social and environmental benefits. Plants in mangrove forests, for example, are used for medicine, food, building and industrial materials. In addition, mangrove timber is a source of material for charcoal and chipwood industry. A list of benefits provided by mangroves is given in Table 3.8. Mangroves also yield microorganisms that have various uses such as bacteria, fungi, protozoa, and other microorganisms.

(Doc. Payne et al. 2000)

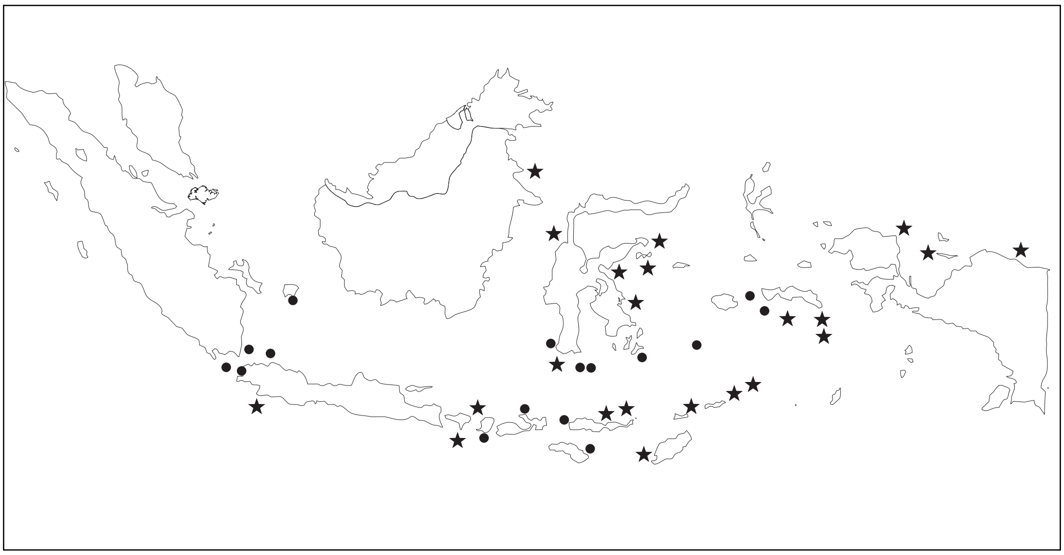
Figure 3.8. Irrawaddy dolphin, an endemic freshwater mammal in Kalimantan.

Table 3.7. Seagrass species in Indonesia.

Species	Description
Cymodocea rotundata *C. serrulata*	Found in tidal areas, generally around mangroves.
Enhalus acoroides	Grow on loamy substrate and turbid waters. Occurs as a single species, or dominant among the seagrass community.
Halodule pinifoli *H. decipens* *H. minor* *H. ovalis*	Fast growing and pioneer species, generally found on loam substrate. Dominant species in tidal areas, can grow in a depth of up to 25 m.
Halodue uninervis *H. spinulosa*	Forms a single seagrass species on flat areas of damaged coral reef.
Syringodinium isoetifolium	Generally found in shallow and loamy subtidal areas.
Thalasia hemprichii	The most common species, usually grows with other species lain, and can survive in depth of up to 25 m. Generally thrives on sandy substrate.
Thalassodendron ciliatum	Generally dominates subtidal areas and associates with coral reef.

Source: Bengen 2001.

Mangroves are the habitat of marine such as milkfish, shrimps and crabs.



(Doc. Tomascik et al. 1997)

Figure 3.9. Location of seagrass researches in Indonesia.

Note: Stars indicate locations where seagrass beds were observed by T. Tomascik and A. Mah.

Fishery is a source of protein for most of Indonesia's coastal population, as well as a source of foreign exchange. Some 280 ornamental fish species associated with coral reef and 170 coral species are traded commercially. Seagrass provide materials for food industry (*agar*), animal feed and traditional as well as modern medicine. The beauty of coastal and marine ecosystem also attracts domestic and international tourists, thus providing alternative source of foreign exchange.

The following list provides estimated value of some coastal and marine ecosystem benefits:

1. Use and non-use value of mangroves in Indonesia is US$ 2.3 billion (calculated by GEF/UNDP/IMO 1999).
2. Economic value of Indonesia's coral reef is estimated at US$ 567 million (GEF/UNDP/IMO 1999).
3. Value of seagrass is US$ 3,858.91/ha/year (Bapedal and PKSPL – IPB 1999).
4. Ecological and economic value seaweed in Indonesia is about US$ 16 million (GEF/UNDP/IMO 1999).
5. Economic value marine fish potentials in Indonesia is US$ 15.1 billion (Dahuri 2002).

Coastal and marine ecosystem also provides sources of livelihood and employment for about one million coastal population, thus having a significant social benefits as well. The marine ecosystem links the many islands and small island groups in Indonesia, thus it also has a socio-political function of "bridging the archipelago".

The coastal and marine area provides environmental services, among others, as carbon sinks (the function of seaweed) and in protecting the coastline from erosion (the function of mangroves). The value of carbon sequestration of seaweed is estimated at US$ 180/ha/year (GEF/UNDP/IMO 1999). Table 2 of Appendix 2 presents economic, social and ecological values of the Malacca Straits, as an illustration of the value of coastal and marine areas.

Resource depletion and degradation

Given that data on the biological richness of coastal, marine and small island ecosystems are limited, information on resource depletion and degradation is also not comprehensive. Therefore, the following description represents only those components on which data is available.

Coral reef in Indonesia is increasingly depleted due to destructive fishing practices, excessive fishing, pollution, and development in coastal areas and sedimentation. During the last 50 years, damaged coral reef increased from 10% to 50%. Between 1989 and 2000, reefs with 50% live corals has gone down from 36% to 29%. (Hopley and Suharsono, Wilkinson et al. *in* Burke et al. 2002).

P3O-LIPI in 1995 and COREMAP in 2000 obtain a more detailed data from observation

Table 3.8. Some products from mangroves in Indonesia.

A. Plant Products		
Category	**Products**	**Examples of species used**
Fuel	fuel wood charcoal alcohol	most tree species most tree species *Nypa fruticans*
Building materials	timber, poles heavy construction (bridge) railway track base mining ship building dock foundation building pole floor roof floor mat fence, pipe board glue	*Bruguiera, Rhizophora* spp. *Bruguiera, Rhizophora* spp. *Rhizophora, Ceriops* spp. *Bruguiera, Rhizophora* spp. *Livistona saribus, Lumnitzera* *Lumnitzera* spp. *Rhizophora, Bruguiera* spp. *Oncosperma tigillaria* *Nypa fruticans, Acrostichum speciosum* *Cyperus malaccensis, Eleocharis dulcis* *Scolopia macrophylla* particularly Rhizophoraceae *Cycas rumphii*
Fishery	fishing pole buoyant fish poison net glue rope anchor ship-building material	*Ceriops* spp. *Dolichandrone spathacea, S. alba* *Derris trifoliata, Cerbera floribunda* Rhizophoraceae *Stenochlaena palustris, H. tiliaceus* *Pemphis acidula, Rhizophora apiculata* *Atuna racemosa, Osbornia octodonta*
Textile and leather	synthetic (e.g. rayon) cloth dye leather preservative/ tanning cloth	particularly Rhizophoraceae *E. indica, Peltophorum pterocarpum* particularly *Rhizophora, Lumnitzera* spp. *Eleocharis dulcis*
Agriculture	fertiliser	*Paspalum vaginatum, Colocasia esculenta*
Paper products	various types of paper	*Avicennia marina, Camptostemon schultzii*
Household items	furniture ornaments hair oil perfume tools pillow filling basket toys poison ornamental plants candle	many woody plants *Xylocarpus granatum, Scaevola taccada, Nypa fruticans* *X. mekongensis* *Phymatodes scolopendria* *Dolichandrone spathacea, X. granatum* *Typha angustifolia* *Cyperus malaccensis, Scirpus grossus* *Dolichandrone spathacea* (mask), *Excoecaria indica* (seeds) *Cerbera manghas* (insecticide) *Cryptocoryne ciliata, Crinum asiaticum Tristellateia australasiae* *Horsfieldia irya*